EIA MODEL DOCUMENTATION:

PETROLEUM MARKET MODEL

OF THE

NATIONAL ENERGY MODELING SYSTEM

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Oil and Gas Analysis Branch

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Acronyms and Abbreviations

AEO	EIA Annual Energy Outlook
API	American Petroleum Institute
ASTM	American Society of Testing Materials
BAU	Business As Usual
bbl	Barrel
bbl/cd	Barrels Per Calendar Day
Btu	British Thermal Unit
BTX	Benzene, Toluene, and Xylene Aromatics
BPSD	Barrels Per Stream Day
CAAA	Clean Air Act Amendments
CARB	California Air Resources Board
CG	Conventional Gasoline
Cn	Represents a hydrocarbon stream containing n atoms of Carbon, i.e. C1 is Methane, C2 is Ethane, C3 is Propane, C4 is Butane, etc.
DOE	Department of Energy
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
ETBE	Ethyl Tertiary Butyl Ether
IEA	International Energy Agency
IEO	EIA International Energy Outlook
LP	Linear Program
LPG	Liquefied Petroleum Gas
Mbbl/cd	Thousand Barrels Per Calendar Day
MMbbl/cd	Million Barrels Per Calendar Day
MTBE	Methyl Tertiary Butyl Ether
NACOD	North American Crude Oil Distribution
NEMS	National Energy Modeling System
NES	National Energy Strategy
NGL	Natural Gas Liquid
NIPER	National Institute for Petroleum and Energy Research
NOx	Nitrogen Oxide
NPC	National Petroleum Council
NPRA	National Petroleum Refiners Association
OB1	Optimization with Barriers 1
OSL	Optimization Subroutine Library
ORNL	Oak Ridge National Laboratory
PADD	Petroleum Administration for Defense District
PCF	Petrochemical Feed
PMM	Petroleum Market Module
RFG	Reformulated Gasoline
Rvp	Reid Vapor Pressure
RYM	Refinery Yield Model (EIA)
SCF	Standard Cubic Feet
SIC	Standard Industrial Classification
SPR	Strategic Petroleum Reserve
TAP	Toxic Air Pollutant
VOC	Volatile Organic Compound
WOP	World Oil Price
WORLD	World Oil Refining Logistics Demand (model)

1. Introduction

1.1 Purpose of this Report

The purpose of this report is to define the objectives of the Petroleum Market Model (PMM), describe its basic approach, and provide detail on how it works. This report is intended as a reference document for model analysts, users, and the public. Documentation of the model is in accordance with EIA's legal obligation to provide adequate documentation in support of its models (Public Law 94-385, section 57.b.2).

1.2 Model Summary

The PMM models petroleum refining activities, the marketing of petroleum products to consumption regions, the production of natural gas liquids in gas processing plants, and domestic methanol production. The PMM projects petroleum product prices and sources of supply for meeting petroleum product demand. The sources of supply include crude oil, both domestic and imported; other inputs including alcohols and ethers; natural gas plant liquids production; petroleum product imports; and refinery processing gain. In addition, the PMM estimates domestic refinery capacity expansion and fuel consumption. Product prices are estimated at the Census division level and much of the refining activity information is at the Petroleum Administration for Defense (PAD) District level.

1.3 Model Archival Citation

The PMM is archived as part of the National Energy Modeling System. The model contact is:

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1.4 Report Organization

The remainder of this report is organized as follows: Chapter 2, Model Purpose; Chapter 3, Model Overview and Rationale; Chapter 4, Model Structure; Appendix A, Inventory of Input Data, Parameter Estimates, and Model Outputs; Appendix B, Detailed Mathematical Description of the Model; Appendix C, Bibliography; Appendix D, Model Abstract; Appendix E, Data Quality; Appendix F, Estimation Methodologies; Appendix G, Matrix Generator Documentation; and Appendix H, Historical Data Processing.

2. Model Purpose

2.1 Model Objectives

The Petroleum Market Model (PMM) models petroleum refining and marketing. The purpose of the PMM is to project petroleum product prices, refining activities, and movements of petroleum into the United States and among domestic regions. In addition, the PMM estimates capacity expansion and fuel consumption in the refining industry. The PMM is also used to analyze a wide variety of petroleum-related issues and policies, in order to foster better understanding of the petroleum refining and marketing industry and the effects of certain policies and regulations.

The PMM simulates the operation of petroleum refineries in the United States,[1] including the supply and transportation of crude oil to refineries, the regional processing of these raw materials into petroleum products, and the distribution of petroleum products to meet regional demands. The production of natural gas liquids from gas processing plants is also represented. The essential outputs of this model are product prices, a petroleum supply/demand balance, demands for refinery fuel use, and capacity expansion.

PMM inputs include petroleum product demands, parameters for production functions which estimate the amount of domestic crude oil production, and information on the costs and available quantities of imports of crude oil and petroleum products. In addition, the costs of refinery inputs such as natural gas and electricity are needed, as well as the costs and available quantities of blending components such as ethanol, methanol, and methyl tertiary butyl ether (MTBE). Yield coefficients for crude oil distillation and other processing units, processing unit capacities, investment costs for capacity additions, capacities and costs for pipeline and other transportation modes, and product specifications are other essential model inputs.

From these inputs, PMM produces a slate of prices for petroleum products, the quantity of domestic crude oil production, imports of crude oil and petroleum products, estimates of other refinery inputs and processing gain, domestic refinery capacity expansion, and refinery fuel consumption.

The PMM is used to represent the petroleum refining and marketing sector in projections published in the *Annual Energy Outlook*. The model is also used for analysis of a wide variety of petroleum-related issues. The PMM is able to determine the impact on refinery operations and on the marginal costs of refined products of changes in any one or several variables including demands for various kinds of petroleum products; crude oil prices; refinery processing unit capacities; changes in certain petroleum product specifications; energy policies and regulations; and taxes, tariffs, and subsidies.

1The International Energy Model contains representation for foreign refinery operations.

The PMM is comprised of five geographical regions, defined by the Petroleum Administration for Defense (PAD) Districts. Individual refineries are aggregated into one refinery representation for each PAD District. Product demands are input at the Census division level and end-use product prices are produced by Census division. A transportation structure linking the PAD District refining regions to the Census division demand regions is also represented. The PMM produces annual results, currently from 1990 through 2015.

2.2 Relationship to Other Models

The PMM is part of the National Energy Modeling System (NEMS), representing the petroleum refining and marketing sector. The PMM projects prices and sources of supplies of petroleum products. These projections are generated as part of a NEMS supply/demand/price equilibrium solution.

Several other models in NEMS provide inputs to the PMM. These inputs include:

- Demands for petroleum products from the Residential, Commercial, Industrial, Transportation, and Electricity Market Models. The demands include motor gasoline, jet fuel, kerosene, distillate fuel, low- and high-sulfur residual fuel, liquefied petroleum gases (LPG), petrochemical feedstocks, petroleum coke, and other petroleum.

- Import supply curves for crude oil and petroleum products from the International Energy Model (IEM). The crude oil supply curves are provided for each of the PAD Districts for five types of crude defined by sulfur and gravity characteristics. The prices on the crude oil supply curves are based on the world oil price, which is determined in the IEM. Petroleum product import supply curves are provided for traditional and reformulated gasoline, distillate fuel, low-sulfur diesel fuel, jet fuel, low- and high-sulfur residual fuel, LPG, petrochemical feedstocks, and other petroleum. This information is used to evaluate the tradeoff between domestic product production and imports.

- Import supply curves for methanol and MTBE provided by the International Energy Model and ethanol supply curves from the Renewable Fuels Model. The use of methanol and ethanol in the PMM takes into account the consumption of alcohol fuels in the transportation sector (E85 and M85), and the chemical use of methanol.

- Parameters for production functions from the Oil and Gas Supply Model for estimating domestic production of crude oil. The crude oil is categorized into the same five types incorporated into the import supply curves. Natural gas liquids, which are among the non-crude inputs to refineries, are estimated using natural gas production from the Natural Gas Transmission and Distribution Model.

- Prices for natural gas and electricity from the Natural Gas Transmission and Distribution Model and the Electricity Market Model, respectively. The PMM estimates the refinery consumption of these energy sources.

- The market shares of oxygenated, reformulated, conventional, and California specification gasoline. These parameters are estimated offline and input to the PMM. In a similar fashion, the shares of low-sulfur diesel and distillate fuel are provided to the PMM. The shares change over time, based on assumptions about market penetration (see Appendix F for more details). By breaking gasoline and distillate into these categories, the PMM is able to account for additional costs of producing products that meet Clean Air Act (CAA) and Clean Air Act Amendments (CAAA) requirements.

The PMM also provides information to other NEMS models. The output variables include petroleum product prices, petroleum supply sources, refinery fuel consumption, and capacity expansion.

Output variables include:

- Prices of petroleum products, passed to the Residential, Commercial, Industrial, Transportation, Electricity Market, and Natural Gas Transmission and Distribution Models. The prices are used to estimate demands for the various fuels.

- Supply balance quantities, including crude oil production, non-crude refinery inputs, and processing gain, provided for reporting purposes.

- Capacity expansion and utilization rates at refineries.

- Fuel consumption from refineries. This information is passed on to the Industrial Model for inclusion in the industrial sector totals. In addition, refinery cogeneration capacity and generation levels are also sent to the Industrial Model.

- The amount of sulfur allowances earned by small refiners, as described in the CAAA.

- The market prices and consumption of ethanol and methanol.

Figure 2.1 provides a detailed PMM Input/Output flow diagram.

Figure 2.1 PMM Input - Output Flow Diagram

Demand Models

Petroleum Product Demands

Petroleum Product Prices

Macro Model

Refinery Revenue

Integrating Model Model

System Controlling Information

Natural Gas Transportation & Distribution Model

Natural Gas Price

Petroleum Market Model

Renewables Market Model

Ethanol Supply Curves

International Energy Model

Crude and Product Supply Curves

Petroleum Supply Data

Oil & Gas Supply Model

Production Coefficients and EOR Production

Electric Utility Market Model

Electricity Prices & Petroleum Product Demand

Petroleum Product Prices

3. Model Overview and Rationale

3.1 Philosophical or Theoretical Approach

The National Energy Modeling System, as a whole, produces a general equilibrium solution by iterating until convergence to a stable result occurs. For example, the various demand models use the petroleum product prices from PMM to estimate product demands. The PMM then takes the petroleum product demands as given, and estimates petroleum product prices. If the computed prices from PMM converge to within the specified tolerance, the NEMS iteration is complete and the next yearly NEMS cycle begins. If the computed prices have not converged, new demand quantities are computed, passed to PMM, and the cycle is repeated. This process continues until a stable solution is found.

Within the PMM, the refinery sector is modeled by a linear programming representation. A linear programming model is developed for each of the five Petroleum Administration for Defense (PAD) Districts and represents an aggregation of the individual refineries in the PAD District. The PMM linear programming model also contains a transportation structure to move products from the refining regions to the Census division demand regions. Because a single demand region can be supplied by more than one refining region (if the transportation connections exist), changes in one refining region can affect operations in other refining regions. An optimal solution for the five PAD District representation as a whole is found by minimizing the costs of meeting the demands. Revenues are derived from product sales, and costs are incurred from the purchase and processing of raw materials and the transportation of finished products to the market. The model chooses a set of petroleum industry activities (e.g. crude oils, processing units, etc.) to produce a product mix that maximizes the refinery's economic benefits. The activities are constrained by material balance requirements on the crude oil and intermediate streams, product specifications, processing and transportation capacities, and demand. Economic forces also govern the decision to import crude oil or refined products into the regions. See Appendix B for a complete description of the column activities and constraints.

3.2 Comparison with Oil Market Module

The inclusion of a linear programming model directly into the integrated refining and marketing representation is a significant change from predecessor models. The Oil Market Module (OMM), which represents petroleum refining and marketing in the Intermediate Future Forecasting System, uses econometric equations to represent the relationship between refinery production costs (product costs) and product yields. The econometric equations are estimated from pseudodata derived from a refinery linear programming model. Pseudodata were developed by running a refinery LP for hundreds of scenarios where the yield of a reduced set of petroleum products was recorded in response to independently varying product prices over a predefined range. This was done for a base case and three representative world oil prices (WOP). Additionally, a

number of runs ultimately were made where prices of all products were simultaneously increased for each WOP. In total, nearly 400 runs were made to create the pseudodata. An accounting/econometric framework is used to estimate sources of supply to meet demand. Product imports are calculated as the difference between demand and domestic supply.

The decision to change the approach for PMM within NEMS resulted from the identification of several disadvantages for using the OMM approach.[1]

- The econometric equations produce only national level refinery gate (or wholesale) prices for the product slate defined, with regional end-use prices being estimated from predefined regionally specific distribution cost characteristics. Thus, regional differences in input costs or product specifications are not being reflected in the results since regional production levels are not represented.

- Product imports are used as balancing items, thus preventing both a realistic assessment of import dependence and a realistic analysis of import restrictions or tariffs.

- The current OMM cannot model changes in product specifications such as those included in the CAAA.

- The OMM lacks the capability to decide between domestic and foreign capacity expansion efforts. This is an important decision activity directly affecting import levels.

- The OMM cannot be used to analyze the impact of requiring oxygenates in gasoline and the competition between oxygenates.

In addition, any changes to refinery operating scenarios within OMM (whether significant or minor) would involve a three-step process -- (1) modify the linear programming model to reflect the changes, (2) rerun the LP model to generate new pseudodata (involving several hundred runs), and (3) reestimate the econometric equation coefficients. This is a resource-intensive process.

3.3 Fundamental Assumptions

The PMM assumes the petroleum refining and marketing industry is competitive. The market will move toward lower-cost refiners who have access to crude oil and markets. The selection of crude oils, refinery

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[1]Energy Information Administration, *A Critique of the Oil Market Module*, internal study by S. MacIntyre, Energy Supply and Conversion Division, Office of Integrated Analysis and Forecasting (Washington, DC, January 1992).

process utilization, and logistics will adjust to minimize the overall cost of supplying the market with petroleum products. Although the petroleum market responds to pressures, it rarely strays from the underlying refining costs and economics for long periods of time. If demand is unusually high in one region, the price will increase, driving down demand and providing economic incentives for bringing supplies in from other regions, thus restoring the supply/demand balance.

Each PAD District is treated as a single firm. This restricts the ability to deal with issues such as rationalization of small refineries. Rationalization can only be dealt with on a disaggregate basis. Capacity is allowed to expand, with some limitations, but the model does not distinguish between additions to existing refineries or the building of new facilities. Investment criteria are developed exogenously, although the decision to invest is endogenous. The model does not require foresight to be perfect, but uses the best available information concerning future prices, demands, and market conditions as the basis for investment decisions.

Existing regulations concerning product types and specifications, the cost of environmental compliance, and Federal and State taxes are also modeled in the PMM. The PMM reflects recent national and regional legislative and regulatory changes that will affect future petroleum supply and product prices. It incorporates taxes imposed by the 1993 Budget Reconciliation Act as well as costs resulting from the Clean Air Act Amendments of 1990 (CAAA90) and other environmental legislation.

The costs of producing new formulations of gasoline and diesel fuel that will be phased in as a result of the CAAA90 are determined within the linear programming (LP) representation by incorporating specifications and demands for these fuels. The PMM assumes that the specifications for these new fuels will remain the same as specified in current legislation.

Motor Gasoline Specifiations

The PMM models the production and distribution of four different types of gasoline: traditional, oxygenated, reformulated, and reformulated/high-oxygen. The following specifications are included in PMM to differentiate between traditional and reformulated gasoline blends: octane, oxygen content, Reid vapor pressure (Rvp), benzene content, aromatic content, sulfur content, and olefin content.

Starting in 1998 the specifications for traditional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline." These specifications prevent the quality of traditional gasoline from eroding over time, which is the intent of the EPA's "antidumping" requirements.

Oxygenated gasoline, which has been required during winter in many U.S. cities since October of 1992, requires a oxygen content of 2.7 percent by weight. Some areas that require oxygenated gasoline will also require reformulated gasoline. In those overlapping areas, reformulated-high oxygen gasoline containing 2.7

percent oxygen will be required. Oxygenated gasoline is assumed to have specifications identical to traditional gasoline with the exception of a higher oxygen requirement. Similarly, the oxygen requirement is assumed to be the only difference between the reformulated/high oxygen and reformulated gasoline blends.

Beginning in 1995, many areas of the country will require reformulated gasoline. Between 1995 and 1997, the Environmental Protection Agency (EPA) will certify reformulated gasoline according to either the "simple" or "complex" models. The PMM assumes that reformulated gasoline during this time period will meet the EPA's "simple model" definition, which allows no lead content, limits benzene content to 1.0 percent and aromatics content to 25 percent by volume, requires an oxygen content of 2.0 percent by weight, and caps nitrogen oxide emissions at a baseline level. Beginning in 1998, the EPA will only certify reformulated gasoline using the "complex model," which allows refiners to specify reformulated gasoline based on emissions reductions either from their companies' 1990 baseline or from the EPA's 1990 baseline. The PMM uses a set of specifications that meet the "complex model" requirements, but it does not attempt to determine the optimal specifications that meet the "complex model." Specifications such as Rvp, aromatics, sulfur, and olefin content change in the year 2000 reflecting further emissions reductions required by CAAA90.

The CAAA90 provided for special treatment of California that would allow different specifications for oxygenated and reformulated gasoline in that State. In 1992, California requested a waiver from the winter oxygen requirements of 2.7 percent to reduce the requirement to a range of 1.8 to 2.2 percent. The PMM assumes that PAD District V refiners must meet the California specifications. Therefore, for 1993-1994, the specifications for oxygenated gasoline in PAD District V meet a 2.0-percent standard. Starting in 1996, the specifications for reformulated gasoline in PAD District V are the same as California standards.

Rvp limitations are effective during summer months, which are defined differently in different regions. In addition, different Rvp specifications apply within each refining region, or Petroleum Administration for Defense (PAD) district. The PMM assumes that these variations in Rvp are captured in the annual average specifications, which are based on summer Rvp limits, winter Rvp estimates, and seasonal weights.

Motor Gasoline Market Shares

Within the PMM, total gasoline demand is disaggregated into demand for traditional, oxygenated, reformulated, and reformulated/high-oxygen gasolines by applying assumptions about the annual market shares for each type. The shares change over time based on assumptions about the market penetration of new fuels. Annual assumptions for each region account for the seasonal and city-by-city nature of the regulations. The market shares reflect the mandated use of reformulated blends in nonattainment areas as well as assumptions about opt-in and spillover demand from outside these areas. The PMM assumes a 5-percent spillover of oxygenated and reformulated gasoline into attainment areas.

The oxygenated gasoline shares throughout the forecast assume wintertime participation of 39 carbon monoxide nonattainment areas. Year-round consumption of oxygenated gasoline in Minnesota is assumed beginning in 1997 in accordance with State legislation. The PMM also assumes that, starting in 1995, reformulated gasoline will be consumed in the nine required areas plus areas that had petitioned the EPA to opt in.[2] Areas that initially opted-in but opted-out as of June 1995 are not included.

Diesel Fuel Specifications and Market Shares

In order to account for diesel desulfurization regulations, low-sulfur diesel is differentiated from other distillates. Diesel fuel in Census divisions 1 through 9 is assumed to meet Federal specifications.

The PMM contains a sharing methodology to allocate distillate demands between low and high sulfur. Market shares for low-sulfur diesel and distillate fuel are estimated based on data from EIA's annual *Fuel Oil and Kerosene Sales Report 1992* (DOE/EIA-0535(92), October 1993). Since about 20 percent of current demand in the transportation sector is off highway, 80 percent of transportation demand for distillate fuel is assumed to be low sulfur. Consumption of low-sulfur distillate outside of the transportation sector is assumed to be zero.

End-Use Product Prices

End-use petroleum product prices are based on marginal costs of production plus production-related fixed costs plus distribution costs and taxes. The marginal costs of production are determined by the model and represent variable costs of production including additional costs for meeting reformulated fuels provisions of the CAAA90. Fixed refinery costs include fixed operating costs,[3] a 4-percent return on assets, and environmental costs associated with controlling pollution at refineries[4]. Assuming that refinery-related fixed costs are recovered in the prices of light products, fixed costs are allocated among the prices of liquefied petroleum gases, gasoline, distillate, kerosene, and jet fuel. These costs are based on average annual estimates and are assumed to remain constant over the forecast period.

The costs of distributing and marketing petroleum products are represented by adding fixed distribution costs to the marginal and refinery fixed costs of products. The distribution costs are applied at the Census division level and are assumed to be constant throughout the forecast and across scenarios. Distribution costs for each product, sector, and Census division represent average historical differences between end-use and wholesale

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[2]Required areas: Baltimore, Chicago, Hartford, Houston, Los Angeles, Milwaukee, New York City, Philadelphia, and San Diego. Opt-in Areas Within: Texas, District of Columbia, New Jersey, Maryland, Delaware, New York, Connecticut, Virginia, New Hampshire, Massachusetts, Pennsylvania, Maine, and Rhode Island.

[3]Fixed operating costs include payroll, maintenance, labor and materials, depreciation, and other expenses.

[4]Environmental cost estimates are based on National Petroleum Council, *U.S. Petroleum Refining - Meeting Requirements for Cleaner Fuels and Refineries,* Volume I (Washington, DC, August 1993).

prices. The costs for kerosene are the average difference between end-use prices of kerosene and wholesale distillate prices.

State and Federal taxes are also added to transportation fuels to determine final end-use prices. Recent tax trend analysis indicated that State taxes increase at the rate of inflation, while Federal taxes do not. In the PMM, therefore, State taxes are held constant in real terms throughout the forecast while Federal taxes are deflated at the rate of inflation.

Crude Oil Quality

In the PMM, the quality of crude oil is characterized by average gravity and sulfur levels. Both domestic and imported crude oil are divided into five categories as defined by the ranges of gravity and sulfur shown in Table A2 in Appendix A.

A "composite" crude oil with the appropriate yields and qualities is developed for each category by averaging the characteristics of specific crude oil streams that fall into each category. While the domestic and foreign crude types have the same definitions, the composite crudes for each category may differ because different crude streams make up the composites. For domestic crude oil, an estimate of total production is made first, then shared out to each of the five categories based on historical data. For imported crude oil, a separate supply curve is provided for each of the five categories.

Regional Assumptions

PMM refining regions are the five Petroleum Administration for Defense (PAD) districts. Individual refineries are aggregated into one linear programming representation for each PAD district region. In order to interact with other NEMS modules with different regional representations, certain PMM inputs and outputs are converted from a PAD district to a non-PAD district regional structure and vice versa.

Capacity Expansion Assumptions

PMM allows for capacity expansion of all processing units including distillation capacity, vacuum distillation, hydrotreating, coking, fluid catalytic cracking, hydrocracking, alkylation, and methyl tertiary butyl ether (MTBE) manufacture. Capacity expansion occurs by processing unit, starting from base year capacities established by PAD district using historical data.

Expansion is determined when the value received from the additional product sales exceeds the investment and operating costs of the new unit. The investment costs assume a 15-percent rate of return over a 15-year plant life. Expansion through 1995 is determined by adding to the existing capacities of units planned and under construction that are expected to begin operating during this time. Capacity expansion is done in 3-

year increments. For example, after the model has reached a solution for forecast year 1995, the PMM looks ahead and determines the optimal capacities given the demands and prices existing in the 1998 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 1996, 25 percent in 1997, and 25 percent in 1998. At the end of 1998, the cycle begins anew.

Strategic Petroleum Reserve Fill Rate

The PMM assumes no additions for the Strategic Petroleum Reserve during the forecast period. Additions to the Strategic Petroleum Reserve have not been included in recent budgets.

Legislation

The PMM reflects recent national and regional legislative and regulatory changes that will affect future petroleum supply and product prices. It incorporates taxes imposed by the 1993 Budget Reconciliation Act as well as costs resulting from environmental legislation.

The Budget Reconciliation Act imposes a tax increase of 4.3 cents per gallon on transportation fuels including gasoline, diesel, liquefied petroleum gases, and jet fuel. Except for jet fuel, the tax began on October 1, 1993, and takes effect in the PMM in 1994. Jet fuel has been granted a 2-year delay.

With a goal of reducing tailpipe emissions in areas failing to meet Federal air quality standards (nonattainment areas), Title II of the CAAA90 established regulations for gasoline formulation. Starting in November 1992, gasoline sold during the winter in 39 carbon monoxide nonattainment areas was required to be oxygenated.[5] Starting in 1995, gasoline sold in nine major U.S. cities which are the most severe ozone nonattainment areas must be reformulated to reduce volatile organic compounds (which contribute to ozone formation) and toxic air pollutants, as well as meet a number of other new specifications. Additional areas with less severe ozone problems have chosen to "opt in" to the reformulated gasoline requirement. In a few metropolitan areas with both ozone and carbon monoxide problems, the requirements for oxygenated and reformulated gasoline will overlap. In other words, during the winter months a reformulated/high oxygen gasoline will be required.[6]

Title II of the CAAA90 also established regulations on the sulfur and aromatics content of diesel fuel that took effect on October 1, 1993. All diesel fuel sold for use on highways now contains less sulfur and meets new aromatics or cetane level standards.

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[5]Oxygenated gasoline must contain an oxygen content of 2.7 percent by weight.

[6]Gasoline that meets the requirements of reformulated gasoline and has an oxygen content of 2.7 percent by weight.

A number of pieces of legislation are aimed at controlling air, water, and waste emissions from refineries themselves. The PMM incorporates related environmental investments as refinery fixed costs. The estimated expenditures are based on results of the 1993 National Petroleum Council Study.[7] These investments reflect compliance with Titles I, III, and V of CAAA90, the Clean Water Act, the Resource Conservation and Recovery Act, and anticipated regulations including the phase out of hydrofluoric acid and a broad-based requirement for corrective action. No costs for remediation beyond the refinery site are included.

3.4 Alternative Approaches and Reasons for Selection

In any model design a tradeoff must be made between finding an acceptable level of detail and preserving a manageable framework for providing information in a timely fashion. The PMM was developed not only for forecasting purposes, but also to provide a policy analysis tool. These dual objectives were key to deciding the approach taken in the PMM. Various alternatives are discussed below followed by a summary of the reasons for choosing the linear programming approach.

3.5 Pseudodata/Econometric Equation Approach

The OMM, as described above, uses a pseudodata/econometric equation approach. The objective of this approach is to retain the advantages of a large, complex refinery model, with the capability of responding to a wide variety of issues, in an integrated environment. The response surface generated by the large number of model runs represents the output of the LP for given sets of inputs, and the econometric equations provide a means to quickly access the results.

Two primary problems with this approach are inaccuracy and preparation time. The model runs must be devised so that the pseudodata adequately cover the range of each of the inputs. Since the exact combination of inputs cannot usually be anticipated, the pseudodata only provide an approximation of the model response. Moreover, the econometric equations are only an approximation of the shape of the response surface.

Preparation time (i.e., the time required before the model is ready for integrated runs) can be significant for this approach. The design, the generation of pseudodata, and the estimation of the equations all require substantial time and effort. The OMM equations were reestimated only about once every 4 years. However, because NEMS will be used for analytical studies as well as mid-range forecasting, the equations may have to be updated for each particular study.

In addition, the capabilities of the PMM, compared to the OMM, especially the increased regionality, the explicit treatment of imports, and the new products and product specifications, would increase considerably

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[7]National Petroleum Council, *U.S. Petroleum Refining - Meeting Requirements for Cleaner Fuels and Refineries,* Volume I (Washington, DC, August 1993).

the number of runs required to adequately cover the range of each input variable. For these reasons, the pseudodata/econometric equation approach was not considered as a basis for PMM.

3.6 Linear Approximation Approach

Another type of pseudodata approach, called the linear approximation or lookup approach, was considered. Pseudodata would still need to be generated. The output of several hundred model runs would be placed in a database, with each record containing the refinery output quantities and prices associated with a given set of product demand levels and input prices. The runs would cover the expected range of product demands and input prices.

In the integrated environment, the inputs to the PMM (a vector of demands and input prices) would be used to choose a specified number of data records (e.g. 10) from the database. The data records chosen would be those (10) that minimized the Euclidean distance to the input data vector. The output quantities and prices would then be estimated from a linear combination of the chosen set of data records.

Several advantages over the OMM approach are noteworthy. The econometric equations would not need to be reestimated with each new set of pseudodata, considerably reducing model preparation time. Furthermore, the output variables could include more than just product prices. Any variable generated by the use of an LP model could be placed in the database and accessed by the linear approximation method.

However, the same pseudodata criticisms cited above apply to this method as well. Any study or scenario involving unanticipated changes to the refinery operating scheme would require regeneration of several hundred data records using a detailed model. In addition, the number of required runs would rise above the roughly 400 used in the past, due to regionality and the increased interactions between PMM and other models. The number of runs must be sufficient to adequately cover the expected range of each input variable, so it increases substantially with each additional input. Also, the accuracy of this method relative to the other approaches has not been established, but is considered to be less accurate than even the pseudodata/econometric equation approach.[8]

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[8]Energy Information Administration, *Approaches to Estimating PMM*, internal memorandum by J. Kendell, Energy Supply and Conversion Division, Office of Integrated Analysis and Forecasting (Washington, D.C., November 1991).

3.7 Abbreviated Linear Programming Approach

Extreme point modeling is similar to the pseudodata approach in that a detailed model is used to generate output vectors. The results of each run are expressed as column vectors of input/output coefficients derived over a range of cases designed to span the potential solution space.[9]

A linear programming refinery model can be appreciably condensed through the technique of extreme point vectors. The extreme point representation models the refinery as series of operating modes or plans. A slate of products is produced per barrel of processed crude oil. An illustration of two typical extreme point vectors is shown in Table 3.1. Each column of the table represents an operating mode for the refinery, such as maximum production of gasoline or distillate (No. 2 heating oil and diesel fuel). For each solution of the detailed refinery model, the crude oils consumed as inputs are divided by the total crude oil processed to provide a volume fraction of each crude oil, which will sum to 1.0 as shown in the row labeled "Total Crude." Each solution also provides the product volumes produced as outputs, which are also divided by the total crude oil processed. After accounting for fuel burned and losses, not shown in the table, the sum of the outputs will also sum to 1.0. The result is a representation of a feasible and optimal operating plan expressed as inputs and outputs per barrel of total crude oil processed by the refinery model. Extreme point vectors typically have less than 50 equations for each refining region, including crude oil balance equations, refinery unit capacity equations, and product balance equations.

The operating modes, such as maximum gasoline and maximum distillate, are created by successive solutions of the detailed refinery model responding to increased prices for the product to be maximized. Some typical modes to be generated may be:

- maximum/minimum production of each grade of gasoline,
- maximum/minimum production of jet fuel,
- maximum/minimum production of No. 2 heating oil,
- maximum/minimum production of low sulfur highway diesel fuel, or
- maximum/minimum production of residual fuel oil.

The extreme point representations can be expanded to differentiate between various crude oil operating modes, such as incremental volumes of Arab Light or incremental volumes of West Texas Intermediate (WTI).

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[9]Linear Programming, Inc., *PAL/REMS Integration Methodology Study*, final report prepared for the EIA Office of Statistical Standards, Contract No. DE-AC01-84EI-19633 (Washington, D.C., April 1987).

Table 3.1. Example of Extreme Point Vectors
Yields per Barrel of Total Crude Flow

Mode	Max Gasoline	Max Distillate
Crude 1	0.5	0.5
Crude 2	0.2	0.2
Sum Other Crudes	0.3	0.3
Total Crude	1.0	1.0
Gasoline Grade 1	0.14	0.10
Gasoline Grade 2-5	0.35	0.25
No. 2 Heating Oil	0.14	0.30
Resid. <1%S	0.09	0.10
Sum of Other Products	0.28	0.25
Operating Cost ($/bbl)	0.94	1.00

The difference from the pseudodata approach is that these vectors are then placed in a linear programming environment. The extreme points are not just output quantities and prices from the LP model runs, as in the pseudodata approach, but coefficients which break input quantities into outputs of products, taking into account the associated costs. Solutions are derived by maximizing profits or minimizing costs using linear combinations of these extreme point column vectors to represent the refinery LP. A second important difference is that the required amount of extreme points numbers in the tens rather than the hundreds.

The advantage of using extreme point vectors to represent refining operations is that the resulting model is smaller and solves faster than a detailed refinery model. The disadvantage is that the analyst must create enough extreme points to span most of the possible modes and product yields that might be required in an equilibrium pricing model such as NEMS. Moreover, extreme points should probably be regenerated for each new forecast and each particular analytical study. This would be a time-consuming process. Extreme points have also been criticized for inaccurately representing refinery operations,[10] although increasing the range and number of the modes can respond in part to this criticism.

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[10]Ibid., pp. 25-39.

3.8 Detailed Linear Programming Approach

Detailed linear programming models have been very successful at modeling refinery problems. The particular advantage of using linear programming models to represent refinery processes is that they allow refinery managers to calculate the marginal costs of products while simultaneously indicating the required operating conditions for maximum profitability. Furthermore, linear programming process models contain detailed engineering structure directly related to the refinery processes and product quality, and can therefore readily incorporate new technologies and technological change.

A linear programming approach in the PMM allows more flexibility for dealing with analytical issues than the other approaches considered. Changes to product specifications, the addition of new products or refinery inputs, and/or changes in processing unit costs or capacities can be handled directly in the linear programming structure. Many of the shortcomings of the pseudodata and extreme point approaches are not problems for a linear programming approach. The biggest drawbacks to LP models are size and execution time. The linear programming representation currently in the PMM will have to be reduced in size in order to achieve acceptable execution times.

4. Model Structure

During each NEMS iteration, product demand quantities and other variables supplied by NEMS models are used to update the PMM matrix. An optimal solution is obtained from the updated matrix where marginal petroleum product prices and other material balance information are extracted. Post-processing takes place on the petroleum product prices and refinery input and output volumes, system variables are updated, and reports are produced. The modification and optimization of the PMM matrix are both accomplished by executing FORTRAN callable LP subroutines available from an LP subroutine library. Appendix B describes the formulation of the linear programming representation in the PMM.

The linear programming portion of PMM is prepared offline in the form of an MPS[1] file prior to NEMS processing. Offline generation of the PMM matrix is performed using a data-driven mathematical programming language. The control program and optimizer are compatible with the MPS matrix format. FORTRAN and FORTRAN callable subroutines for data table manipulation, matrix generation, and solution retrieval programs for report writing are currently being used. Appendix A describes the input data tables used to develop the input matrix of the PMM.

The REFINE subroutine is the main controlling subroutine for the PMM. The following paragraph describes the REFINE process flow, which is illustrated by Figures 4.1, 4.2, 4.3, and 4.4. The flow diagrams use descriptive text and make reference to PMM FORTRAN subroutine names, which are described in detail in sections 4.1, 4.2, 4.3, and 4.4.

The REFINE subroutine initializes variables and reads fixed data during the first year and first iteration of any NEMS run (Figure 4.1). The subroutine then follows one of five branches during any NEMS iteration.

- If the history switch is on and it is the first year and first iteration,

---

[1]Mathematical Programming System format.

Figure 4.1 PMM Flow Diagram

Figure 4.2 Matrix Preprocessing Subroutines

```
                              │
                              ▼
                        ┌───────────┐
                        │   PMMLP    │
                        └───────────┘
                              │
                              ▼
                        ┌───────────┐
                        │   SETLP    │
                        └───────────┘
                              │
                              ▼
                        ┌───────────┐
                        │  PRTRFLOC  │
                        └───────────┘
                              │
   RFADVBAS=ON                │        CURITR=1 & RFADVBAS=OFF & CURIYR=FIRSYR
        &                     ◇                        OR
     CURITR=1               ╱ If ╲         CURIYR=6 & RFHIST=ON
                           ◇       ◇
              ┌───────────┐                   ┌───────────┐
              │  INSRTLP  │                   │  INSRTLP  │
              └───────────┘                   └───────────┘
                              ▼
```

CHGNGCRV	CHGSPRE	CHGD50FCC	CHGICRD
CHGCESW	CHGMETD	CHGFCCMOD	ADJICRD
ADDCAP	CHGCGCOF	EMISCOST	CHGIPRD
CHGPUBLD	CHGPRDVL	CHGETHN	ADJIPRD
CHGDNGP	CHGETHSUB	CHGUNFO	CHGEXPPRC
CHGELPR	ADJFUVAL	CHGEXPRD	CHGMTBIMP
CHGDMDS	CHGCGCAP	CHGIMTOT	CHGIRAC
CHGDCRD	CHGCATCOK	CHGCKSU	RFROS
CHGGSPC	CHGALKEXP	CHGZ9CST	
	CHGAKNGL	CHGZ9EXP	

```
                        ┌───────────┐
                        │   OPTLP    │
                        └───────────┘
                              │
                              ▼
```

Figure 4.3 Matrix Postprocessing Subroutines

```
              │
              ▼
      ┌───────────────┐
      │   PMMOUT2     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   PRMUPMM     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   DSTCPMM     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   COGNPMM     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   ELPMMRD     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   SULFPMM     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   PMMRFFU     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   RFDMDFU     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   PMMOUTP     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   PMMOUT3     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   DCRDPRC     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   WCNVFCT     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   DOMU        │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   FCCMODOP    │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   ALKMODE     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   GETPMMO     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   RFCAPX      │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   MGSPCDL     │
      └───────────────┘
              │
              ▼
      ┌───────────────┐
      │   RFPRTINF    │
      └───────────────┘
              │
              ▼
```
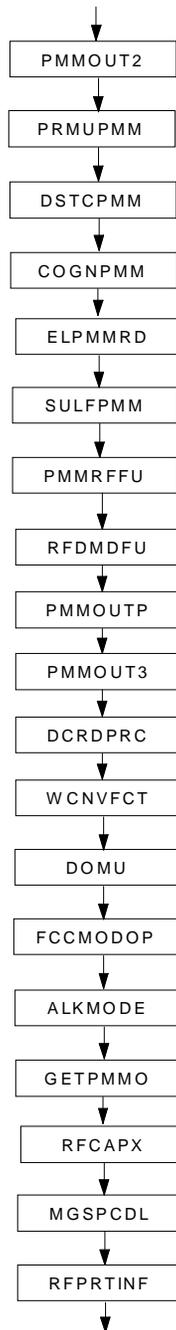
Figure 4.4 Capacity Expansion Subroutines
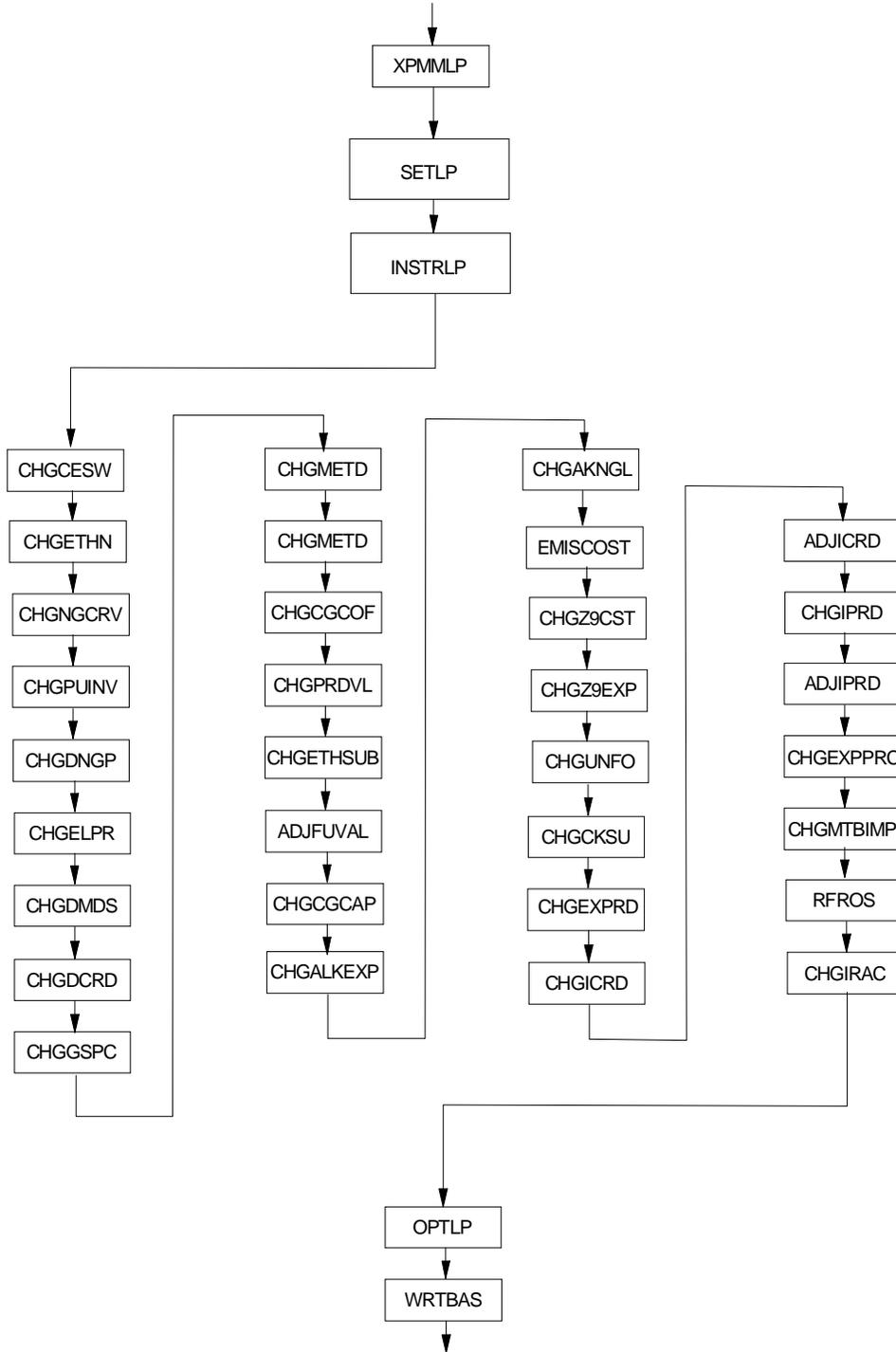
historical values are read from an input file.

- If the history switch is on and it is a historical year after the first year and first iteration, then the PMM performs no operations but simply returns to the NEMS systemoperations. No operations are performed because all historical data were retrieved and variables were updated on the first iteration of the first year.

- If the history switch is on, it is not a historical year, and it is not a reporting iteration; or if the history switch is off and it is not a reporting iteration; then the PMM LP matrix is updated with data from other NEMS models and static PMM input data variables and an optimal solution is calculated (Figures 4.1, 4.2, and 4.3). Petroleum product prices and other PMM output data are retrieved from the LP optimal solutions and output variables are updated.

- If it is a reporting iteration, the history switch is on, and it is not a historical year; or if it is a reporting iteration and the history switch is off; then several internal PMM analyst reports are updated. If it is also a capacity expansion year, then the PMM LP is solved using input data using expectation values for a future year to determine processing unit expansion for the intervening years (Figures 4.1 and 4.4). The capacity expansion methodology is described in more detail below.

- If it is a reporting iteration, the Short Term Energy Outlook (STEO) benchmarking switch is on, and it is NEMS year six; then the PMM LP is solved using input data using expectation values for a future year to determine processing unit expansion for the intervening years (Figures 4.1 and 4.4).

Capacity Expansion Methodology

PMM models capacity expansion for all the refinery processing units which include but are not limited to distillation capacity, vacuum distillation, hydrotreating, coking, fluid catalytic cracking, hydrocracking, alkylation, and MTBE manufacture. Capacity expansion occurs by processing unit, starting from base year capacities established by PAD District using historical data. Expansion is determined by the LP when the value received from the additional product sales exceeds the investment and operating costs of the new unit. The investment costs assume a 15-percent rate of return over a 15-year plant life. For more details on the calculation of the investment costs, refer to the Appendix F section on Refinery Investment Recovery Factors.

Expansion through 1995 is determined by adding to the existing capacities those units planned and under construction that are expected to begin operating during this time. Starting in forecast year 1996, capacity expansion is done in three year increments. For example, after the model has reached a solution for forecast year 1995, the PMM looks ahead and determines the optimal capacities given the estimated demands and prices existing in the 1998 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 1996, 25 percent in 1997 and 25 percent in 1998. At the end of 1998, the cycle begins anew.

4.1 Main Subroutines

Section 4.1 describes the functions of the subroutines in figure 4.1, the main controlling subroutines.

(REFINE) Main controlling subroutine for the PMM.

> Purpose: REFINE is the driver subroutine for the PMM. It uses basic FORTRAN controlling structure, NEMS integrating model common variables, and PMM internal variables to set up and process the PMM LP and to update NEMS variables based on an optimal LP solution.

> Equations: None.

(INITPMM) Initialize variables.

> Purpose: Initializes certain variables.

> Equations:
> $$PUCUM_{pr,pu,yr} = 0.0$$
> $$PUINV_{pr,pu,yr} = 0.0$$
> $$RFQDINPOT_{pr,yr} = 0.0$$
> $$PRDDMD_{pr,yr,prd} = 0.0$$
> $$CRDOTHOT_{pr,yr} = 0.0$$
> $$CRDUNACC_{pr,yr} = 0.0$$
> $$CRDSTWDR_{pr,yr} = 0.0$$
> $$CRDPRDSUP_{pr,yr} = 0.0$$
> $$PRDSTKWDR_{pr,yr} = 0.0$$
> $$BLDIMP_{pr,yr} = 0.0$$
> $$PUBASE_{pr,yr,pu} = 0.0$$
> $$PUBASEUT_{pr,yr,pu} = 0.0$$
> where:
> $pr = 1,2,3,4,5$: PAD District
> $pu = 1,2,...40$: Processing unit identifier index
> $yr = 1,2,...29$: NEMS year index
> $prd = 1,2,...20$: PMM product identifier index

(FIXDPMM) Read fixed inputs.

> Purpose: FIXDPMM reads in and initializes internal data required for processing the PMM.

> Equations: None.
> Input Files: MU1PRDS   Tax input data
>   MU2PPRDS   Sectoral end-use markups
>   QDCRDCF   Fixed Data input file

(RDPMMXP) Reads in the PMM specific expectation values from a input file.

    <u>Purpose:</u> The RDPMMXP subroutine read the SPRFLRT input file and updates PMM specific expectations values. These values are used for refinery capacity planning.

    <u>Equations:</u> None.

    <u>Input file:</u> SPRFLRT   PMM specific expectations input file.

(LOADPMM) Sets up the PMM LP for proecssing by the OML.

    <u>Purpose:</u> This subroutine defines the OML model space for PMM. Loads the PMM LP matrix into memory and initializes OML model specific variables.

    <u>Equations:</u> None.

(DEFLP) Defines and OML LP matrix model space and initializes common control variables for a given model.

    <u>Purpose:</u> Defines and OML LP matrix model space and initializes common control variables for a given model using the OML function WFDEF.

    <u>Equations:</u> None.

    <u>Data Passed:</u>   MODEL, model name, SIZE, model size

(MPSINLP) Converts a model from and MPS format file and stores it in the model database.

    <u>Purpose:</u> Converts a model from and MPS format file and stores it in the model database using the OML function WFMSPIN.

    <u>Equations:</u> None.

(LOADLP) Loads the LP model from the database into memory.

    <u>Purpose:</u> Loads the LP model from the database into memory and prepares it for optimization using the OML function WFLOAD.

    <u>Equations:</u> None.

(RFHIST1) Read in history data for 1990 through 1994.

    <u>Purpose:</u> RFHIST1 reads in history data from an external file and updates PMM output data for history years 1990 to 1993.

    <u>Equations:</u> None.

Input File: ELCGPUR   PMM historical data input file

(NEXTDATA) Advances file pointer one record.

Purpose: This subroutine is used in to automate reading the historical data file. It advances the file pointer one record until the historical data record is loacted.

Equations: None.

(RFTAX) Aggregates state and federal petroleum product taxes.

Purpose: RFTAX aggregates the states and federal petroleum taxes.

Equations: Total petroleum product tax are set at the state tax plus the nominal dollars federal tax.

(DEMDPMM) Convert system demands.

Purpose: Convert NEMS demands from trillion Btu to thousands of barrels per day for input into the refinery LP. Desegregates gasoline and distillate fuel into types. Calculates U.S. total petroleum product demand by sectors.

Equations: The conversion from Btu to Mbbl/d is as follows:

$$RFQ(PR)_{cd} = (((Q(PR)AS_{cd} - Q(FPR)RF_{cd})/CF(PR)Q)/365)*1000$$
$$PRDDMD_{cd,pd} = RFQ(PR)_{cd}$$

The motor gasoline share of M85 and E85 transportation fuels are also added to the total motor gasoline demands such that:

$$RFQMG_{cd} = (((QMGAS_{cd} + QMETR_{cd}*0.15 + QMETR_{cd}*0.15)/CFMGQ/365)*1000$$

where;

RFQ(PR) = product demand by Census division
PRDDMD = product demand by Census division
Q(PR)AS = product demand in all sectors
Q(FPR)RF = product consumed for refinery fuel
CF(PR)Q = conversion factor from MMBtu/bbl
(PR) = product types
(FPR) = refinery fuel products identifier
cd = Census divisions 1 through 9
pd = PAD Districts 1 through 5
0.15 = Motor gasoline share of the alternate transportation fuel
365 = days per year
1000 = millions to thousands

Refinery fuel consumption, Q(FPR)RF, is subtracted from the product demands since the refinery model is designed to meet demand for saleable products. The variables RFQ(PR), Q(PR)AS, and Q(FPR)RF, and CF(PR)Q are defined explicitly in Appendix A 1.2, Refine Module Variables.

Four types of gasoline are derived from total gasoline demand by applying market share estimates:

$$PRDDMD_{cd,t} = RFQMG_{cd} * MGSHR_{cd,t}$$

where;

PRDDMD = product demand by Census division
t = motor gasoline product designator index, 2,3,4,5
MGSHR = motor gasoline market shares

Refer to Appendix F for more information on the derivation of the gasoline market shares, MGSHR.

Low-sulfur diesel fuel is determined as a share of transportation distillate demand (Refer to Appendix F, Estimation of Low-Sulfur Diesel Market Shares, for more details):

$$PRDDMD_{cd,14} = DSLSPLT*((QDSTR_{cd} /CFDSQ)/365)*1000$$

where;

14 = product index for low sulfur diesel (DSL)
DSLSPLT = 0.8
QDSTR = quantity of transportation distillate
CFDSQ = conversion factor for DSL MMBTU/bbl
365 = days per year
1000 = millions to thousands

Ethanol and methanol consumed in the transportation sector are assumed to be blends of 85 percent alcohol and 15 percent gasoline. Therefore, the demand for transportation ethanol and methanol in the PMM are 85 percent of the transportation demand total, and 15 percent is added to gasoline demand. Finally, U.S. totals are calculated:

$$PRDDMD_{11,pr,yr} = \sum PRDDMD_{cd,pr,yr}$$

where;

11 = total U.S. demand index
pr = product index 1 through 19
cd = Census divisions 1 through 9
yr = NEMS year index 1 through 26

(DPRDPMM) Estimate domestic crude oil production.

Purpose: Estimates domestic crude oil production.

Equations: Conventual domestic crude production are calculated for the nine lower 48 oil gas regions. Alaskan production and Enhanced Oil Recovery (EOR) production are obtained from the Oil Gas Supply Model (OGSM). Conventional lower 48 production is a function of wellhead price, beginning of year reserves, and the draw down rate such that:

$$RFQDCRD_{or,yr} = (OGPRRCO_{or,yr} *$$

$$((DCRWHP_{or,yr} / DCRCWHP_{or,yr-1})^{OGELSCO_{or,yr}}) *$$

$$OGRESCO_{or,yr})/365$$

and

$$DCRDWHP_{or,yr} = OLALP_{or} * (WOP_{yr}-0.50)^{OLBTA_{or}}$$

where;

RFQDCRD = conventional domestic crude production, MMbbl/cd
DCRDWHP = domestic crude well-head price
OGPRRCO = production ratio, supplied by OGSM
OGELSCO = production elasticity, supplied by OGSM
OGRESCO = beginning of year reserves, supplied by OGSM
OLALP = regression constant, supplied by OGSM
WOP = World Oil Price, supplied by International
OLBTA = Wellhead to WOP price elasticity, from OGSM
0.5 = benchmark constant to adjust WOP, supplied by OGSM
or = Oil and gas region index, 1 through 9
yr = NEMS year index, 1 through 26
365 = Day per year

Total domestic production is then calculated by adding conventional production with the EOR production such that;

$$RFQTDCRD_{or,yr} = RFQDCRD_{or,yr} +$$

$$((OGQEORPR_{or,yr}/1000)/365)$$

where;

RFQTDCRD = Total domestic production, MMbbl/cd
OGQEORPR = EOR production, MBCY, supplied by OGSM
1000 = thousands to millions
365 = days per year
or = oil and gas regions, 1 through 6
yr = NEMS year index, 1 through 26

(PMMLP) Solve PMM LP.

    Purpose: PMMLP calls many subroutines that perform updates to the LP bounds, RHS, and input costs and optimizes the matrix.

    Equations: Refer to Appendix B.

(WRTBAS) Write advance basis.

    Purpose: WRTBAS writes the basis for the LP optimal solution to an external file for any given NEMS year by calling the PUNCHLP subroutine.

    Equations: None.
    Output File: BASPMM1   PMM basis output file

(SETLP) Activates a specified OML model memory space for processing.

    Purpose: Sets a given OML model space to be active using the WFSET function, such that any OML routines called will be applied to the given model.

    Equations: None.

(OPTLP) Optimizes the model.

    Purpose: Optimizes the model using the OML function WFOPT.

    Equations: None.

(WRTANLZ) Writes an ANALYZE packed LP matrix and solution file.

    Purpose: WRTANLZ writes an ANALYZE packed LP matrix and solution file the LP matrix and solution specified in memory using the GOMOT subroutine.

    Equations: None.

    Output File: PACKPMM   PMM ANALYZE output file

(XCEPMM) Retrieve and calculate processing unit capacity expansion investment bounds.

    Purpose: XCEPMM retrieves the expected processing investment activity level by using the SCOLP subroutine and calculates the processing unit build and investment bounds.

    Equations: Processing unit cumulative builds and investment bounds are calculated such that:

$$\text{PUINV}_{pd,yr+1,pu} = \text{PUEXP}_{pd,yr+3,pu} / 2$$

$$\text{PUINV}_{pd,yr+2,pu} = \text{PUEXP}_{pd,yr+3,pu} / 4$$
$$\text{PUINV}_{pd,yr+3,pu} = \text{PUEXP}_{pd,yr+3,pu} / 4$$

where;

PUINV = processing unit investment bound, Mbbl/cd
$\text{PUEXP}_{pd,yr+3,pu}$ = processing unit expansion as
           determined in expansion year yr
pu = processing unit index, 1 through 31
pd = PAD District index 1 through 5
yr = NEMS index years 6,9,12,15,18,21,24

The decision to allow half of the expansion to come on line in the first year of each three year period was made because of problems experienced in early testing of the model. This area of the model will be more thoroughly tested and the constraint may be changed.

Processing unit cumulative builds, PUBLD is:

$$\text{PUBLD}_{pd,yr,pu} = 0; \text{ when } yr = 6$$
$$\text{PUBLD}_{pd,yr,pu} = \text{PUBLD}_{pd,yr-1,pu} + \text{PUINV}_{pd,yr-1,pu}$$

where yr > NEMS index year 6
pu = processing unit index, 1 through 31
pd = PAD District index 1 through 5
yr = NEMS index years 6,9,12,15,18,21,24

(RPT1PMM) Write report 1, LP solution.

    Purpose: RPT1PMM writes the LP solution to an external file.

    Equations: None.

    Output File: PMMPRNT   PMM solution output file

(RPT4PMM) Write report 4, PMM iteration reports.

    Purpose: RPT4PMM pulls solution values from the LP using SROWLP, SCOLLP subroutines and writes to an external file PMM analyst reports during each NEMS iteration.

    Equations: Solution values are extracted from solution matrix, reformatted and converted to the proper units.

    Output File: ALPHADN   Iteration reports output file

(RPT6PMM) Write report 6, OMNI formatted tables, supply curves and demands.

    Purpose: RPT6PMM writes OMNI tables used for stand-alone PMM matrix generation.

Equations: None.

Output File: IMPCURV OMNI data table output file

(RPT7PMM) Write report 7, PMM forecast reports.

Purpose: RPT7PMM extracts solution values from the LP using the SCOLLP and SROWLP subroutines and writes to an external file PMM analyst reports at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix reformatted and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(USTOT) Calculates totals by PAD District, Census division, and U.S. for RPT7PMM, RPT8PMM, and RPTA8PMM.

Purpose: Totals various PMM output data.

Equations: Performs units conversions on some of the totals.

(RPT8PMM) Write report 8, continuation of report 7.

Purpose: RPT8PMM pulls solution values from the LP using the SCOLLP and SROWLP subroutines and writes to an external file PMM analyst reports at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix reformatted and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(RPTA8PMM) Write report A8, continuation of report 8.

Purpose: RPTA8PMM pulls solution values from the LP using the SCOLLP and SROWLP subroutines and writes to an external file PMM analyst reports at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix reformatted and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(FCCRPT) Reports the fluid catalytic crackers level of operations.

Purpose: This subroutine reports the levels of operations for the modes of operation of the fluidized catalytic cracker.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(ALKRPT) Prints the alkylation report to the PMM forecast reports.

Purpose: Solution values extracted using the subroutine ALKMODE are reformatted and printed to an output file..

Output File: PMMRPTS PMM reports output file.

(SPECRPT) Prints the motor gasoline specifications report.

Purpose: SPECRPT print the motor gasoline specification report to the detailed PMM reports.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(OBJRPT) Prints the objective function report.

Purpose: OBJRPT print the objective function of the PMM for the NEMS forecast to the PMM detailed reports output file.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(PMMRPTHD) Prints the detailed PMM reports header.

Purpose: PMMRPTHD print the NEMS scenario name, date key, and reporting years as a header to each reporting the detailed PMM reports.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(PMMRPTRW) Rewinds the record pointer during the PMM iterations report.

Purpose: PMMRPTRW rewinds the record pointer for the PMM iterations reports such that only each years final iteration reports are retained.

Equations: None.

Output File: ALPHADN PMM reports output file.

4.2 Matrix Preprocessing Subroutines

Section 4.2 describes the function of the subroutines in figure 4.2, preprocessing of the PMM matrix.

(INSRTLP)   Loads an advance basis into the LP model.

> Purpose: Loads a standard format basis from a file into the LP model using the OML function WFINSRT.
>
> Equations: None.

(PRTRFLOC) Prints the NEMS iteration and year to the OML output file.

> Purpose: Prints the NEMS year and iteration in the OML output file, SYSPRINT, by forcing an OML error message using erroneous calls to the PMM LP matrix. This function facilitates the location of PMM information in SYSPRINT file for debugging purposes.
>
> Equations: None.

(CHGNGCRV) Updates the natural gas supply curve for refinery fuel use.

> Purpose: Updates the bounds on the first point of the eight step natural gas supply curve using the CBNDLP subroutine.
>
> Equations: The lower bound on step one of the supply curve is set at fifty percent of the sum of the upper bounds on the last four steps of the supply curve. The upper bound on step one of the supply curve is set at eighty percent of the sum of the upper bounds on the last four steps of the supply curve during any first iteration of a NEMS year or the capacity planning iteration. During any other NEMS iteration the upper bound on the first point of the supply curve is set at the difference between the sum of the upper bounds of the last four steps on the supply curve and the difference between the sum of the upper bounds on the first four points of the supply curve and the sum of activity levels on all points of the supply curve from the previous NEMS iteration solution. If the upper bound on the first point of the supply curve, just described falls below the lower bound on the first point of the curve, then the upper bound is set at value one percent above the lower bound on the first point of the curve.

(CHGCESW) Update Capacity Expansion Switch.

> Purpose: CHGCESW changes the LP constraint that allows investment in processing units capacities to compete with imported products by using the CRHSLP subroutine.
>
> Equations: None.

(ADDCAP) Update Capacity.

> Purpose: ADDCAP changes the capacity expansion investment and build bounds using the CBNDLP subroutine with values obtained from the XCEPMM subroutine. The upper investment bounds on the aromatics recovery processing unit (ARP) are set at 1000 MBCD during years seven and nine in PAD District five to alleviate the bottleneck on processing unit expansion inherent with the three year look-ahead methodology.

> Equations: None.

(CHGPUBLD) Limit 1995 Capacity Expansion.

> Purpose: Processing unit capacities in the PMM start from a 1994 base, which includes units under construction that are planned to be operational by the end of 1994. Therefore, no capacity expansion is allowed in 1994. This subroutine sets the 1994 expansion limits at zero by using the CBNDLP subroutine.

> Equations: None.

(CHGDNGP) Update Natural Gas Production and Prices.

> Purpose: Natural gas production and prices come from the Natural Gas Transmission and Distribution Model and are inputs to the gas plant portion of the model. This subroutine updates these LP inputs using the CBNDLP and CVALLP subroutines. During the capacity expansion iteration the CHGDNGP subroutine uses the expected natural gas production and prices as inputs into the LP model.

> Equations: The industrial interruptable price of natural gas is used for the prices of gas to refineries in PAD Districts I and V. PAD District III refinery natural gas prices are calculated as the quantity weighted average natural gas well-head price in NGTDM regions two, four, and eight. Natural gas well-head prices in NGTDM regions three and five are used for PAD Districts II and IV respectively. These prices are converted to $/MCF. During the capacity expansion iteration the expected industrial interuptable price of natural gas and expected domestic production of natural gas is used as inputs into the LP matrix.

(CHGELPR) Update electricity costs.

> Purpose: CHGELPR updates the cost of electricity in each of the five PAD Districts using industrial price of electricity using the CVALLP subroutine. During the capacity planning iteration the CHGELPR subroutine uses the expected cost of electricity in each of the five PAD Districts.

> Equations: Industry price of electricity is mapped from Census division to PAD District and units are converted to kWh.

(CHGDMDS) Update product demands for the LP.

Purpose: CHGDMDS sets the upper and lower bounds for product demands. For all products except "other," the upper and lower bounds are equal. The bounds are set at the level of demand for each product in each Census division. For "other," the lower bound is zero and the upper bound is product demand in the Census division and year. This was done to provide more refining production flexibility and minimize infeasibilities. During the capacity expansion iteration the CHGDMDS updates bounds using the expected demands variables.

Equations: None.

(CHGDCRD) Update domestic crude production.

Purpose: CHGDCRD updates the LP domestic crude production variables using the CBNDLP subroutines. During the capacity planning iteration the CHGDCRD subroutine updates the domestic crude production bounds using the expected crude production variables.

Equations: Conventional and Enhanced Oil Recovery (EOR) production are combined for the total U.S. crude production and units are converted to Mbbl/cd.

(CHGGSPC) Updates the motor gasoline specifications.

Purpose: CHGGSPC updates motor gasoline specifications using the CVALLP subroutine..

Equations: None.

(CHGSPRE) Change Strategic Petroleum Reserve (SPR) and Crude Oil Exports for the LP.

Purpose: Sets the upper and lower bounds for SPR additions and crude oil exports. For both items, the upper and lower bounds are equal and are set using the CBNDLP subroutine. They are set as exogenous inputs to the program.

Equations: None.

(CHGMETD) Change methanol demand for the LP.

Purpose: Sets the upper and lower bounds for methanol demand. The upper and lower bounds are equal. During the capacity expansion iteration the expected methanol demand is used to update the bounds.

Equations: None.

(CHGCGCOF) Updates the cogeneration sales to grid coefficients for the cogeneration procsssing unit.

Purpose: Updates the cogeneration sales to grid coefficients using the CVALLP subroutine for the cogeneration procsssing unit.

Equation: $COEF_{cd,yr} = CNST_{cd} * PELAS_{cd,yr}$

where:
COEF = sales to grid coefficient
CNST = Percentage constant, 0.8368, 0.0009, 0.3090, 0.7170, 0.6025 for each PAD District I-V respectively.
PELAS = Prices of electricity to all sectors
cd = census division index
yr = year index

(CHGPRDVL) Update the objective row of the product demands column.

    Purpose: This subroutine updates the objective row value for the product demand columns.

    Equations: The objective row is updated as a function of two times the world oil price.

(CHGETHSUB) Updates LP coefficient that handles the ethanol subsidy.

    Purpose: This subroutine updates the LP coefficient for the ethanol subsidy.

    Equations: The ethanol subsidy remains constant at $18.29/Bbl.

(ADJFUVAL) Adjust refinery fuel use coefficient on all refinery fuels.

    Purpose: This subroutine is used to calibrate refinery fuel consumption with historical estimates. For the AEO 1996 this value was 1.0, thus no calibration was performed.

    Equations: None.

(CHGCGCAP) Updates the refinery cogeneration capacities.

    Purpose: This subroutine updates the base refinery cogeneration capacities with the planned additions.

    Equations: For year 1995 the additions are 2754 and 1468.8 MBCD for the PAD Districts three and five respectively.

(CHGCATCOK) Updates catalytic coke coefficient.

    Purpose: This subroutine updates the catalytic coke LP coefficient.

    Equations: The coefficient is updated once at the beginning of the NEMS forecast and then remains constant throughout the NEMS forecast. The updated coefficient is the current value as from the PMM database minus 0.024.

(CHGALKEXP) Updates the LP Alaskan export crude supply curve.

      Purpose: The LP Alaskan export crude supply curve.

      Equations: The prices steps on the supply curve are set as a function of world oil prices such that the price is the world oil price minus three dollars and eight cents. The volumes are set at sixty six MBCD for the three points on the supply curve. These prices were set bzsed on analyst judgement.

(CHGAKNGL) Updates Alaskan natural gas liquids production.

      Purpose: This subroutine updates the LP Alaskan natural gas liquid bounds using the OGSM variable OGNGLAK.

      Equations: None

(CHGD50FCC) Updates the minimum flow constraint on the D50 mode in the fluid catalytic cracker.

      Purpose: This subroutine updates the minimum percentage flow constraint on the D50 mode in the fluid catalytic cracker.

      Equations: Set the constraint at a minimum of 7.5 percent of through put. This value was made based on analyst judgement to meet the minimum winter mode of operation for the FCC unit.

(CHGFCCMOD) Fluid catalytic cracker (FCC) phase out algorithm.

      Purpose: This subroutine phases out less advanced modes of operation for the FCC processing unit.

      Equations: Phase out for the 70H, 70U, 70M, H70, U70, and M70 FCC modes of operations start in year 2000 by setting an upper bounds of the modes at two thirds of the year 1999 activity, in year 2001 one third of the 1999 activity is applied to the upper bounds, and in year 2001 the bounds are fixed at zero.

(EMISCOST) Updates the refinery emission cost vector.

      Purpose: Update the input cost of the vector of the burning petroleum products in the refinery using the CVALLP subroutine.

      Equations: Emission input costs are set at value determine by the Emission Policy Module.

(CHGETHN) Update ethanol supply curves in LP.

Purpose: CHGETHN updates the LP ethanol supply curve representation with values obtained from the Renewable Fuels Model by using the CBNDLP and CVALLP subroutines. The ethanol supply curves are represented in the LP by a stepwise function comprised of five price, quantity pairs.

Equations: Ethanol supply curve data are only available for Census divisions 3 and 4. In addition, the supply curves for Census divisions 3 and 4 have data for only the last four steps of the supply curve. The ethanol supply curve quantity units are converted to Mbbl/cd and the supply curve steps are converted from absolute quantities to differential step quantities.

(CHGUNFO) Update unfinished oil costs.

Purpose: CHGUNFO updates the cost of unfinished oils using the CVALLP subroutine.

Equations: Unfinished oils costs are set at a value based on typical refinery gate prices for the streams heavy gas oil medium sulfur (HGM), naphtha paraffinic (NPP), and atmospheric residual type B (ARB) as a function of crude oil price where:

$$ARB_{yr} = 1.1 * WOP_{yr}$$
$$NPP_{yr} = 1.2 * WOP_{yr}$$
$$HGM_{yr} = 1.15 * WOP_{yr}$$

where
ARB = Atmospheric residual type B cost
NPP = Naphta parafinic cost
HGM = heavy gas oil medium sulfur cost
WOP = World oil price
yr = NEMS year, 1 through 26

(CHGEXPRD) Update total exported product.

Purpose: CHGEXPRD updates the total product export LP constraint by using the CRHSLP subroutine.

Equations: Total product exports are related to total petroleum product demand and inversely related to total imported petroleum products such that:

$$PRDEXP = (5.21E\text{-}08 / TOTPRDIMP^{1.51}) * ((TOTPRDDMD^{3.51}) * 1E06)$$

where,

PRDEXP = Total product exports
5.21E-08 = Log intercept
TOTPRDIMP = Total petroleum product imports
TOTPRDDMD = Total petroleum product demands
3.51 = Regression coefficient
1E06 = Unit conversion

(CHGIMTOT) Update total product imported constraint.

> Purpose: CHGIMTOT updates the LP constraint for total maximum imported product using the CRHSLP subroutine.

> Equations: Set to 9900 Mbbl/cd. This value is based on analyst judgement and is currently set high enough that the constraint is not expected to be reached.

(CHGCKSU) Update petroleum coke and sulfur costs.

> Purpose: CHGCKSU updates the cost of petroleum coke, export and distress export petroleum coke costs, and the cost of sulfur using the CVALLP subroutine.

> Equations: Petroleum coke costs are based on a 1991 price of $20/ton for low sulfur coke and $15/ton for high sulfur coke. These prices are converted to $/bbl and scaled by the 1991 world oil price (WOP). The results are values of 0.203 and 0.152 which are multiplied by the current year WOP to set the cost of coke. Distress export of petroleum coke cost is set at 10.0 percent of the high sulfur coke costs. A similar approach is used for sulfur, with a cost of $90/ton transformed into value of 5.0 times the WOP.

(CHGZ9CST) Updates the distress product imports supply vectors input cost.

> Purpose: Updates the distress product imports supply vectors input cost using the CVALLP subroutine.

> Equations: The distress product imports input cost a set at five time the WOP.

(CHGZ9EXP) Updates the distress product exports supply vectors input cost.

> Purpose: Updates the distress product exports supply vectors input cost using the CVALLP subroutine.

> Equations: The distress product exports input cost a set at ten percent of the WOP.

(CHGICRD) Update imported crude supply curve in the LP.

> Purpose: CHGICRD updates the LP imported crude supply curves using values obtained from the International Model.

Equations: The International Model provides imported crude supply curves for each PAD District and five crude types to the PMM. These imported crude supply curves represent three price-quantity relationships for each imported crude in each PAD District. The second and third quantity steps for each supply curve are incremental supply volumes. The prices related to these incremental supply volumes are absolute prices. During the capacity expansion look ahead iteration CHGICRD updates imported supply curve bounds with the expected imported crude supply variables.

(ADJICRD) Adjust the international crude supply curves.

Purpose: This subroutine is used to make adjustments to the international crude supply curve prices and/or volumes.

Equations: For all crudes in PAD Districts two and five adjust the costs as follows:
PAD District two imported crude price is the price from the imports supply curves minus one dollar. PAD District five imported crude price is the price from the imports supply curves plus two dollars. These adjustments are estimated based on analyst judgement.

(CHGIPRD) Update imported product supply curves.

Purpose: CHGIPRD updates LP imported product supply curves using values passed from the International Model.

Equations: The International Model provides imported product supply curves to the PMM for each product and each PAD District. These imported product supply curves represent price-quantity relationships for each imported product. The second and third quantity steps on the supply curves are incremental supply volumes. The prices related to these incremental supply volumes are absolute prices.

(ADJIPRD) Adjusts the international product supply curves.

Purpose: This subroutine make adjustments to the international supply curve prices and/or volumes.

Equations: Adjusts the prices on the imported product supply curves for the west coast PAD District five such that the addition amount is added to the import prices for each product:

Imported product	Adjustment Amount
RFG	6.72
TRG	4.41
JTA	3.27
N2H	3.03
N6B	3.03
DSL	5.01
N6I	2.00
PCF	2.00
LPG	2.00
OTH	2.00

In addition the volumes for the east coast, PAD District one, and gulf coast, PAD District three, LPG were change such that each volume point on the supply curve for the east coast and gulf coast are 10 and 25 MBCD respectively.

These adjustments were made based on analysts judgement.

(CHGEXPPRC) Update exported petroleum product prices.

Purpose: This subroutine updates the objective row for each exported petroleum product.

Equations: None.

(CHGMTBIMP) Updates the MTBE and methanol imports supply function.

Purpose: This subroutine updates the MTBE and methanol import supply curve costs and volumes.

Equations: The import supply curves are updated as a function of world oil price. These adjustment were made based on analyst judgement.

(CHGIRAC) Update average refinery acquisition cost parameters.

Purpose: CHGIRAC updates the average refinery acquisition cost constraints using the CVALLP subroutine.

Equations: Cost of crudes in each PAD District are updated and the minimum and maximum tolerance for the average acquisition cost are set $1.99/bbl. This value was chosen based on analyst judgement.

(RFROS) Updates the renewable oxygenates constraint.

Purpose: RFROS update the renewable oxygenates specificaton (ROS) constraints for motor gasoline using the CVALLP subroutine.

Equations: The motor gasoline minimum renewable oxygenates constraints are set at zero, fifteen, and thirty percent for the NEMS years 1994, 1995, 1996 and beyond respectively if the ROS switch is on. If the ROS switch is off the contraint is set to zero. For the AEO 1996 the ROS was off.

4.3 Matrix Postprocessing Subroutines

Section 4.3 describes the function of the subroutines in figure 4.3, postprocessing of PMM optimized matrix.

(PMMOUT2) Update Common Block Variables

> Purpose: Updates the PMM and NEMS system common block values of refinery production volumes by NEMSrefinery product and by PAD District. Also updates the total U.S. production volumes by product. This is done at each iteration for every projection year.

> Equations: Row activity solution values of the PMM LP, representing total refinery production by PAD District by refined product are sequentially read and corresponding common block variables are set to the matrix solution values or to sums of several values as appropriate. For instance, the common block variable to be updated may be LPG production for PAD District I. Then the solution activity for the LP row that controls LPG production volume in PAD District I is accessed from the LP solution area and the corresponding common block variable is set equal to that value.

(PRMUPMM) Add refinery fixed costs.

> Purpose: Retrieves the marginal petroleum product prices from LP using the SROWLP subroutine and adds on the refinery fixed costs to determine the wholesale petroleum product costs. Demands are summed and weighted average prices for each product by Census division and total United States are calculated. The wholesale costs of residual fuel are determined using an econometric equation. Wholesale kerosene prices are set using the wholesale distillate prices.

> Equations: Refinery fixed costs are added to the marginal prices of each product:

$$P_{pr,cd} = VALUE_{pr,cd} + RFPRDFX_{pr,cd} * FXPCT$$

> where:
> P = refinery gate price of petroleum product pr
> $VALUE$ = the marginal value of petroleum product pr
> $RFPRDFX$ =   the refinery fixed costs, including refinery operating costs, return on
>   investment, and environmental control costs (see Appendix F).
> $FXPCT$ = percentage allocated of the fixed cost. Fix cost are allocated only at 80, 80, 90, and 100 percent during the years 1995 to 1998 respectively. This lag in applying total fixed costs takes into account the expected time frame in refinery investment for environmental control costs.
> pr = product
> cd = Census division

Wholesale prices of residual fuel are determined as a function of WOP and residual demand fraction such that:

$$P_{pr,cd} = 42 * (INTCP + SLP * (WOP/42) + (CNSNT * ((QRL + QRH)/QPRD)))$$
where:

P = refinery gate price of low and high sulfur residual fuel
INTCP = -0.57507 or -.117698 for low and high sulfur residual respectively
SLP = 0.979872 OR 1.001313 for low and high sulfur residual respectively
WOP = World oil price
CNSNT = 0.297792 or 0.42297 for low and high sulfur residual respectively
QRL = Demand for low sulfur residual fuel
QRH = Demand for high sulfur residual fuel
QPRD = Total petroleum product demand
pr = product
cd = Census division
42 = gallons per barrel

Demands for all four types of gasoline are summed by Census division:

$$MGDMD_{cd} = \sum_{t=2,3,4,5} PRDDMD_{cd,t}$$

where:
cd = Census division 1 through 9
t = motor gasoline index type 2,3,4,5

A national gasoline total is estimated by summing Census division totals:

$$MGDMD_{us} = \sum_{cd=1,9} MGDMD_{cd}$$

where:
us = U.S. total index 11
cd = Census division 1 through 9

National demand for each type of gasoline is estimated by:

$$MGDMD_{pr} = \sum_{cd=1,9} MGDMD_{pr,cd}$$

where:
pr = motor gasoline index 2,3,4,5
cd = Census division 1 through 9

A weighted average gasoline price is calculated for each Census division based on prices of the various types of gasoline:

$$PALMG_{cd} = \sum_{pr=2,3,4,5} ((PMGDMD_{pr,cd} * PRDDMD_{pr,cd})/MGDMD_{pr})$$

where:
pr = motor gasoline index 2,3,4,5
cd = Census division 1 through 9

National average prices for each product including individual types of gasoline are estimated by:

$$P_{pr,t} = \sum_{cd=1,9} (P_{pr,cd} * PRDDMD_{pr,cd})/PRDDMD_{pr,t}$$

where:

pr = petroleum product index 1 through 19
cd = Census division 1 through 9
t = total product demand index, 11, for product pr

A composite national average gasoline price is estimated by:

$$PALMG_t = \sum_{pr=2,3,4,5} (PMG_{pr} * MGDMD_{pr}/PRDDMD_{pr,t})$$

where:

PMGDMD = motor gasoline price
PRDDMD = product demand
MGDMD = motor gasoline demand
P = price of product
PMG = price of motor gasoline of type pr
pr = product index
cd = Census division
t = national total index

(DSTCPMM) Estimate distillation capacity and refinery utilization.

Purpose: Extracts capacity expansion information from LP. Estimates annual distillation capacity, utilization and annual and cumulative capacity expansion. Totals PAD District estimates to national estimates.

Equations: Refinery distillation capacity is taken at ninety percent total capacity to account for over optimization and in the LP. Units are converted to MMBCD and U.S. total are determined.

(COGNPMM) Estimate refinery cogeneration.

Purpose: Reads refinery capacity, investments, and generation from LP using the SCOLLP subroutine.
Equations: Results are shared out to Census divisions, fuel categories, and self or grid categories. U.S. and PAD District totals are calculated.

Electricity sales to grid are estimated in kWh:

$$RFCGGRIDPD_P = RFCGGENPD_P * PCGRDPD_P$$

Electricity used by refineries is estimated in kWh:

$$RFCGSELFPD_P = RFCGGENPD_P - RFCGGRIDPD_P$$

Estimates are converted to trillion Btu. PAD District level estimates for cogeneration, cogeneration capacity, refinery fuel consumption, generation for self and for the grid are then allocated to the various Census divisions. The estimates for fuel consumption, capacity, generation are desegregated by fuel type and by generation to grid versus to self. Census division estimates are summed to U.S. totals.

(ELPMMRD) Calculate electricity consumption data.

Purpose: ELPMMRD retrieves the electricity consumption activity from the LP using the SCOLLP subroutine.

Equations: Convert units to KWh and desegregates PAD District data to the Census divisions.

(SULFPMM) Estimate sulfur allowances.

Purpose: Estimates sulfur allowances awarded to small diesel refiners for years 1993 through 1999.

Equations: Calculate the possible allowance volumes from small refiners eligible for allowances in million barrels per year:

$$PAV = (QDSAS/CFDSQ) * 0.128 * 0.59$$

where:

QDSAS is the quantity of distillate produced
CFDSQ is distillate conversion factor MMBtu/bbl

The ratio factor 0.128 represents the proportion of distillate produced at small refineries and 0.59 represents the proportion of distillate that is diesel fuel.

Possible allowance volumes (PAV) are converted to possible allowance weight (PAW):

$$PAW = PAV * 302/2000$$

Requested allowances (REQALLOW) are estimated based on the weight of possible allowances:

$$REQALLOW = PAW * 0.00224 * 1000000 * 2$$

Refiner's sulfur allowances (RFSAL) are set equal to the minimum of the estimated amount (REQALLOW) or maximum allowable amount of 35,000.

$$RFSAL = MIN (REQALLOW,35000)$$

Allowances for 1993 are calculated as one-fourth of RFSAL due to the October 1993 start date.

(PMMRFFU) Estimate refinery fuel use.

> Purpose: Estimates refinery consumption of distillate, residual fuel, coal, LPG's, natural gas, still gas, petroleum coke, and other petroleum products by PAD District.

> Equations: Retrieve fuel use values from the LP using the SCOLLP subroutine and converts units to MMBtu. Sums PAD district data to U.S. totals and determines total U.S refinery petroleum fuel use minus natural gas fuel use.

(RFDMDFU) Convert refinery fuel use to Census division demands.

> Purpose: Converts PAD District level estimates for refinery consumption to Census division demands.

> Equations: Calculates refinery fuel consumption in each Census division based on PAD District estimates.

(PMMOUTP) Update the Common Block Variables

> Purpose: Updates a number of NEMS common block price and volume variables whose values are determined by output of the PMM LP. This subroutine is run at each NEMS iteration.

> Equations: Various values are sequentially pulled out of the LP solution area and corresponding common block variables are set to various functions of the solution values.

> The row matrix solution values accessed are activity, slack, lower bound, upper bound, and pi. The column values are for activity, cost, lower bound, upper bound, and DJ. For instance, the common block variable to be updated may be total product imports. Then the activity for the LP row that controls product imports is obtained from the solution and the corresponding common block variable is set equal to that value adjusted for any difference in units of measure.

(PMMOUT3) Update Common Block Variables

> Purpose: Updates the PMM and NEMS system common block values of refinery production volumes by NEMS refinery product and by PAD District. Also updates the total U.S. production volumes by product. This is done at each iteration for every projection year.

> Equations: Row activity solution values of the PMM LP, representing total refinery production by PAD District by refined product are sequentially read and corresponding common block variables are set to the matrix solution values or to sums of several values as appropriate.

(DCRDPRC) Retrieves domestic crude marginal prices from the LP solution.

Purpose: DCRDPRC retrieves the margin values of domestic crude by OGSM region and crude type by using the SROWLP subroutine.

Equations: None.

(WCNVFCT) Calculates the heat rates for petroleum product imports and exports and motor gasoline.

Purpose: WCNFCT calculates the quantity weighted average heat rates for petroleum product imports, exports, and motor gasoline.

Equations: The heat rate of imported petroleum product is calculated using the weighted average of each products heat rate. This calculation is also performed to the exported petroleum products. Each motor gasolines heat rate is used to calculated the quantity weighted average aggregate gasoline heat rate.

(DOMU) Calculate end-use prices by sector .

Purpose: DOMU breaks wholesale petroleum products prices into sectoral end-use product prices.

Equations: Sectoral end-use prices are calculated by adding two sectoral markups, one for taxes the other for transportation costs, to the refinery gate prices for each petroleum product. Units are converted to $/MMBTU and the motor gasoline price is calculated as the quantity weighted average price of the four motor gasoline types.

(FCCMODOP) Retrieves the fluid catalytic crackers modes of operations activity level from the LP solution.

Purpose: This subroutine retrieves the activity level from the FCC modes of operations columns LP solution.

Equations: None.

(ALKMODE) Retrieves the alkylation units mode of operation utilization.

Purpose: This subroutine retrieve the activity amount for each alkylation mode of operation from the LP solution.

Equations: None.

(GETPMMO) Retrieve objective functions value from the LP solution.

Purpose: This subroutine retrieve the objective function value from the LP solutions for reporting in the detailed PMM reports.

Equations: None.

(RFCAPX) Calculate refinery capital expenditure.

Purpose: RFCAPX calculates refinery capital expenditure.

Equations: $RFREV_{yr} = RFREV_{yr-1} * 1.023$

where:

RFREV = refinery revenue
yr = NEMS year
1.023 = growth rate

(MGSPCDL) Retrieves motor gasoline specification information.

Purpose: This subroutine retrieves the motor gasoline specifications LP row status and dual value for reporting.

Equations: None.

(RFPRTINF) Prints "LP infeasible" message and lists infeasible rows and columns.
Purpose: RFPRPTINF prints and error message to the job unit and list row and columns that had infeasibilities.

Equations: None.

Output File: The default system output device, the screen or mainframe job unit

4.4 Capacity Expansion Subroutine

Section 4.4 describes the function of the subroutines in figure 4.4, preprocessing the PMM matrix for capacity expansion expectation.

(XPMMLP) Set up and solve expected PMM LP for capacity expansion loop.

> Purpose: XPMMLP calls subroutines to set up the LP for the capacity expansion look ahead year, solves the LP, and writes the basis for that solution.

> Equations: None.

(CHGPUINV) Update processing unit investment capacities bounds.

> Purpose: CHGPUINV updates the processing unit investment and cumulative build bounds in the LP during the capacity expansion iteration.

> Equations: Processing unit investments are upper bounded by 1000 Mbbl/cd and cumulative builds are fixed bounded based on the processing unit builds to date.

The remainder of the subroutines in figure 4.4 have been presented in section 4.2, the matrix preprocessing subroutine.

4.5 OML Specific Subroutines

Additional subroutines used to perform OML specific matrix operations during the matrix pre and post processing are presented below.

(CBNDLP) Updates LP column bounds.

      <u>Purpose:</u> The LP column bounds are updated with using the OML function WFCBND.

      <u>Equations:</u> None.

      <u>Data Passed:</u> COLNAME, column name, LWBD, lower bound, UPBD, upper bound

(CNAMELP) Retrieves LP column name.

      <u>Purpose:</u> Retrieves LP column name using the OML function WFCNAME.

      <u>Equations:</u> None.

      <u>Data Passed:</u> I, column index, NAME, column name

(CRHSLP) Updates a LP RHS with the specified value.

      <u>Purpose:</u> Updates an LP matrix RHS using the OML function WFCRHS

      <u>Equations:</u> None.

      <u>Data Passed:</u> COLNAME, column name, RHSVAL, right hand value

(CVALLP) Updates coefficient value in the LP matrix.

      <u>Purpose:</u> Updates coefficient value in the LP matrix using the OML function WFCVAL.

      <u>Equations:</u> None.

      <u>Data Passed:</u>   COLNAME, column name, ROWNAME, row name, VAL, coefficient value

(RVALLP) Retrieves coefficient value in the LP matrix.

      <u>Purpose:</u> Retrieves coefficient value in the LP matrix using the OML function WFRVAL.

      <u>Equations:</u> None.

Data Passed: COLNAME, column name, ROWNAME, row name, VAL, coefficient value

(MPSINLP) Loads the PMM LP matrix file into an OML matrix file.

Purpose: This subroutine calls an OML function which reformats an MPS formatted file into an OML LP matrix format.

Equations: None.

(PUNCHLP) Saves the current basis to a file.

Purpose: Saves the current basis to a file using the OML function WFPUNCH.

Equations: None.

(RBNDLP) Retrieves bound values from a column.

Purpose: Retrieves bound values from a column using the OML WFRBND function.

Equations: None.

Data Passed: COLNAME, column name, LWBD, lower bound, UPBD, upper bound

(RNAMELP) Retrieves row names from the matrix LP.

Purpose: Retrieves row names from the matrix LP using the OML function WFRNAME.

Equations: None.

Data Passed: I, row index, NAME, row name

(SCOLLP) Retrieves solution column values from the LP solution.
Purpose: Retrieves solution column values from the LP solution using the OML function WFSCOL.

Equations: None.

Data Passed: COLNAME, column name, SLCT selected range, STATC, status value,VALUE, values

(SROWLP) Retrieve the current solution row from memory.

Purpose: Retrieves the current solution row from memory using the OML function WFSROW, which retrieves the specified solution (activity, slack, lower limit, upper limit, PI value) and status (basic, upper limited, lower limited, equal, free) into a predefined array.

<u>Equations:</u> None.

APPENDIX A

PMM Model Data, Parameters, and Outputs

APPENDIX A PMM Data and Outputs

A.1 PMM Variables and Data Sources

This appendix is divided in two parts; Section A.1 lists the variables and definitions used in the PMM, Section A.2 lists the data tables and their sources used in the creation of the initial PMM matrix that is loaded to the NEMS environment. These data tables constitute the major portion of the PMM data as they represent the refining process unit technology and capacities, quality characteristics and specifications, used in each of the five refining regions.

A.1.1 PMM LP and NEMS Variable Names Cross References

A cross reference listing between the PMM LP matrix names and NEMS variable names is shown in Table A1. The dimensional units are based on the PMM LP variables, the NEMS variable units may vary to conform to NEMS standards.

Table A1. PMM/NEMS Cross References

PMM LP Variable	LP Units	NEMS Variable
D(cd)(prd) N (q(K))	Mbbl/cd,$87/bbl	QN,PN
D(cd)(prd) P (q(k))	Mbbl/cd,$87/bbl	QP,PP
D(cd)(prd) S1	Mbbl/cd	PRDDMD
D@METS1	Mbbl/cd	PRDDMDMD
ZZAMHTOT	Mbbl/cd	??
O@CRDEXP	Mbbl/cd	RFQEXCRD
O@CRDSPR	Mbbl/cd	RFSPRFR
U (pd) KWH	$87/kWh	PELIN
C (cd) ETHR (q(k))	Mbbl/cd,$87/bbl	WQETOH, WPETOH
N (pd) DGP	Bcf/day	PRNG_PADD
U (pd) NGF	$87/MMcf	PGININ, OGWPRNG
P (og) DCRQ1	Mbbl/cd	RFQDCRD, OGQEORPR
A@INVST	MM$87/Yr	Constants 0 or 50000
A@PRDIMP	Mbbl/cd	Constant 9900
P (pd) PFU	MFOED	PRPFU
P (pd) PFF	MFOED	PRPFF
E (pd) (prcunit)INV	Mbbl/cd	PUINV, or Constants of 0, 1000
L (pd) (prcunit)BLD	Mbbl/cd	0.0 PUCUM PUINV
P(pd)F(crdtype)Q(q(k))	Mbbl/cd,$87/bbl	Q_ITIMCRSC, FHLADD, P_ITIMCRSC D (cd)
I(prd) Z9	$87/bbl	ITIM??SC DISTPRC WHERE ?? = LG GS RF LD DS RL RH JF OT PF
I(pd)(iprd)R(q(k))	Mbbl/cd,$87/bbl	ITIM??SC WHERE ?? = LG GS RF LD DS RL RH JF OT PF
A@PRDEXP	Mbbl/cd	PRDEXPTOT

PMM LP Variable	LP Units	NEMS Variable
D (cd)(prd) SX	Mbbl/cd $87/bbl	No change
Q(pd)(prd)(spec)(minmax)	Many	MGSPCS
T (pd) UNFNPP	$87/bbl	IT_WOP, NPPCOEF
T (pd) UNFHGM	$87/bbl	IT_WOP, HGMCOEF
T (pd) UNFARB	$87/bbl	IT_WOP, ARBCOEF
X (pd) CKLCOK	$87/bbl	IT_WOP, PCOKL
X (pd) CKHCOK	$87/bbl	IT_WOP, PCOLH
X (pd) SULSAL	$87/bbl	IT_WOP, SULSAL
D (cd) COKZ9	$87/bbl	IT_WOP, PCOKH, PRCPCNT
D (cd) COKSX	$87/bbl	IT_WOP, PCOKH
Z@IRACX	$87/bbl	IT_WOP
Z@IRACN	$87/bbl	IT_WOP
Z@TOTCRD	$87/bbl	IT_WOP, IRACN, IRACX
D (cd) (prd)	$87/bbl	P(prd) or constant 0.99
K (pd) ACUCAP	Mbbl/cd	DSTCAP, DSTUTL
E (pd) ACUINV	Mbbl/cd	RFDSTCAP, RFDSTUTL
L (pd) ACUBLD	Mbbl/cd	RFDSTCAP, RFDSTUTL, RFDSCUM
A (pd) (prd)	Mbbl/cd	RFDPRD(prd)
A@CRDFCR	Mbbl/cd	RFQICRD
A@PRDIMP	Mbbl/cd	RFPQIPRDT
A@UNFIMP	Mbbl/cd	RFQUFC
A@PRDDEM	Mbbl/cd	RFQPRDT
A@PRDEXP	Mbbl/cd	RFQEXPRDT
A@NGLPRD	Mbbl/cd	RFPQNGL
A@GAIN	Mbbl/cd	RFQPRCG
A@NGLRFN	Mbbl/cd	RFQNGLRF
A@PETCOK	Mbbl/cd	RFQPRCG
A@SULSAL	Mbbl/cd	RFQPRCG
A@FUEL	Mbbl/cd	QCDUUPD
P (pd) COK	Mbbl/cd	QCDUPD
A@INVST	MM$87/Yr	RFCAPEXP
A@ETHPRD	Mbbl/cd	RFQDINPOT RFETHD
A@MTBIMP	Mbbl/cd	RFQDINPOT RFMTBI
A@METIMP	Mbbl/cd	RFQDINPOT RFMETI
G (pd) MOH01	Mbbl/cd	RFQDINPOT RFMETD
A@METDEM	Mbbl/cd	RFQDINPOT RFMETCHM
A@METM85	Mbbl/cd	RFQDINPOT RFMTBM85
A@CRDDCR	Mbbl/cd	RFCRDDCR
A@CRDL48	Mbbl/cd	RFCRDL48
A@CRDAKA	Mbbl/cd	RFCRDAKA
A@CRDTOT	Mbbl/cd	RFCRDTOT
A@NGFTOT	Mbbl/cd	RFNGFTOT
R (pd) ETHMTB	Mbbl/cd	RFMTBD
R (pd) ACUF (crdtype)	Mbbl/cd	RFIPQC(crdtype)
C (pd) F (crdtype)	$87/bbl	RFIPQC(crdtype)
I (pd) (iprd) R (q(k))	$87/bbl,Mbbl/cd	RFIPQ(iprd)
R (pd) FUMN2H	Mbbl/cd	QDISFU
R (pd) FUMN6I	Mbbl/cd	QRESFU
R (pd) FUMN6B	Mbbl/cd	QRESFU
R (pd) FUMCC3	Mbbl/cd	QLPGFU
R (pd) FUMC2E	Mbbl/cd	QLPGFU
R (pd) FUMUC3	Mbbl/cd	QLPGFU
R (pd) FUMIC4	Mbbl/cd	QLPGFU
R (pd) FUMUC4	Mbbl/cd	QLPGFU
R (pd) FUMPGS	Mbbl/cd	QSTGFU
R (pd) FUMNC4	Mbbl/cd	QLPGFU
R (pd) FUMNGS	Mbbl/cd	QNTGFU
R (pd) FUMPGT	Mbbl/cd	QSTGFU
R (pd) FUM (rfothfu)	Mbbl/cd	QOTHFU
P (pd) COK	Mbbl/cd	QCOKFU
K (pd) STGCAP	MMlb/Day	RFSTEAM
D (cd) (prd)	$87/bbl	PVALUE
C (pd) D (crdtype)	$87/bbl	PCRDRF

NAME	LP Units	NEMS Variable
C (pd) F (crdtype)	$87/bbl	PCRDRF
C (pd) ALL	$87/bbl	PCRDRF
C (pd) AMH	$87/bbl	PCRDRF
R (pd) ACUF (crdtype)	Mbbl/cd	QCRDRF
R (pd) ACUD (crdtype)	Mbbl/cd	QCRDRF
R (pd) ACUA (crdtype)	Mbbl/cd	QCRDRF
G (pd) DGR	Bcf	QGPLTRF
G (pd) GPL01	Bcf	QGPLTRF
G (pd) PGSLPG	Mbbl/cd	QGPLTRF
G (pd) SC2CC1	Mbbl/cd	QGPLTRF
G (pd) SC3CC1	Mbbl/cd	QGPLTRF
G (pd) IC4RFN	Mbbl/cd	QGPLTRF
G (pd) NC4RFN	Mbbl/cd	QGPLTRF
G (pd) NATRFN	Mbbl/cd	QGPLTRF
D (cd) (prd) SX	Mbbl/cd	QPRDEX
D (cd) (prd) Z9	Mbbl/cd	QPRDEXD
A@ZZIMP	Mbbl/cd	QPRDIMD
E (pd) (emissn) (emisst)	MMton	RFEMISST
R (pd) FUM (pnfut)	Mbbl/cd	RFFMT

Legend for Codes

Code	Name	Values	No. in Set
(cd)	Census Divisions	1-9	9
(og)	Oil and Gas Divisions	1-6,A	7
(prd)	Products	LPG-M85	20
(q(k))	Quantities	1-9	9
(prcunit)	Process Units	ACU-PFA	37
(crdtype)	Crude Types	LL-HV	5
(iprd)	Imported Products	LPG-DSL	12
(spec)	Product Specificatons	RV-BZ	6
(minmax)	Minimum or Maximum	N,X	
(emissn)	Emissions	VOC-CAR	6
(emisst)	Combustion/Noncombustion	C,N	
(pnfut)	Refinery Fuels	NGS-JNH	30
(rfothfu)	Refinery Fuel for Other	JIH-NPN	19
LG	Imported product	LPG	
GS	Imported product	Traditional mogas	
RF	Imported product	Reformulated mogas	
LD	Imported product	Low sulfur diesel	
DS	Imported product	Distillate	
RL	Imported product	Low sulfur residual	
RH	Imported product	High sulfur residual	
JF	Imported product	Jet Fuel	
OT	Imported product	Other	
PF	Imported product	Petrochemical Feeds	

A.1.2 PMM Output Variables

REFINERY MODULE OUTPUT VARIABLES

NAME	UNITS	DEFINITION
RFREV(MNUMYR)	MM87$87/Day	Refinery revenues
RFQPRDT(MNUMCR, MNUMYR)	MMbbl/cd	Total product supplied
RFQDCRD(MNUMOR+2,MNUMYR)	MMbbl/yr	Domestic conventional crude
RFSPRFR(MNUMYR)	MMbbl/cd	Rf spr fill rate
RFSPRIM(MNUMYR)	MMbbl/cd	Spr imports
RFCAPEXP(MNUMYR)	MM$87/Day	Rf capital expenditures
RFSAL(MNUMYR)	Tons/yr	Sulfur allowances
RFPQNGL(MNUMPR,MNUMYR,6,2)	$87/bbl,Mbbl/cd	Prc/quan of ngl by PAD district
RFQDINPOT(MNUMPR,MNUMYR)	MMbbl/cd	Quantity other input to refin.
RFQPRCG(MNUMPR,MNUMYR)	MMbbl/cd	Quantity of processing gains

NAME	UNITS	DEFINITION
PCTPLT_PADD(MNUMPR,MNUMYR)	BCF	Gas plant fuel cons./Total NG production
DCRDWHP(MNUMOR,MNUMYR)	$87/bbl	Dometic crude wellhead price
XDCRDWHP(MNUMOR,MNUMYR)	$87/bbl	Expected domestic crude wellhd price
XRFQDCRD(MNUMOR,MNUMYR)	MMbbl/yr	Expected domestic crude production
RFQTDCRD(MNUMOR+2,MNUMYR)	MMbbl/yr	Total domestic crude (incl EOR)
RFDCRDP(MNUMOR,MNUMYR,5)	$87/bbl	Domestic crude price by crude type

REFINERY REPORT OUTPUT VARIABLES

NAME	UNITS	DEFINITION
RFELPURPD(MNUMPR,MNUMYR)	$87/kWh	Electricity purchased by PAD District
RFCGCAPCD(MNUMCR,NMUMYR)	mW	Cogen. capacity by Cen. Div.
RFCGCAPPD(MNUMPR,MNUMYR)	mW	Cogen. capacity by PAD District
RFCGCAPPADDPD(MNUMPR,MNUMYR)	kW/yr	Cogen. capacity by PAD District
RFDSTCAP(MNUMPR,MNUMYR)	Mbbl/cd	Refinery distillation capacity
RFDSTUTL(MNUMPR,MNUMYR)	Percent	Capacity utilization rate
RFIPQCLL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-low sulfur light (P,Q)
RFIPQCMH(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-medium sulfur heavy
RFIPQCHL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-high sulfur light
RFIPQCHH(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-high sulfur heavy
RFIPQCHV(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-high sulfur very heavy
RFIPQMG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports motor gasoline (P,Q)
RFIPQDS(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports distillate (P,Q)
RFIPQRL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports low sulfur resid (P,Q)
RFIPQRH(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports high sulfur resid (P,Q)
RFIPQJF(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports jet fuel (P,Q)
RFIPQLG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports lpg (P,Q)
RFIPQME(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports methanol (P,Q)
RFIPQMT(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports mtbe (P,Q)
RFIMCR(MNUMPR,MNUMYR)	MMbbl/YR	Crude net imports
RFIMTP(MNUMPR,MNUMYR)	MMbbl/YR	Total prod net imports
RFQMG(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of motor gasoline
RFQDS(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of distillate fuel oil
RFQJF(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of jet fuel
RFQRL(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of resid low sulfur
RFQRH(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of resid high sulfur
RFQLG(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of lpg
RFQPF(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of petrochem feedstocks
RFQKS(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of kerosene
RFQOTH(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of other
RFQARO(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of asphalpt and road oil
RFQSTG(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of still gas
RFQPCK(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of petroleum coke
RFPQIPRDT(MNUMPR,MNUMYR,2)	$87/bbl,MMbbl/cd	Total imported product
RFQEXPRDT(MNUMPR,MNUMYR)	MMbbl/cd	Total product exported
RFQEXCRD(MNUMPR,MNUMYR)	MMbbl/cd	Crude exported
RFQICRD(MNUMPR,MNUMYR)	MMbbl/cd	Imported total crude
RFPQUFC(MNUMPR,MNUMYR,2)	MMbbl/cd	Total imports of unfinished crude
RFQIN(MNUMYR)	MMbbl/cd	Industrial product demand
RFQTR(MNUMYR)	MMbbl/cd	Transportion product demand
RFQRC(MNUMYR)	MMbbl/cd	Residential/Commercial product demand
RFQEL(MNUMYR)	MMbbl/cd	Utility product demand
RFQSECT(MNUMYR)	MMbbl/cd	Total sectoral demand
RFDPRDLPG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery production; LPG
RFDPRDTRG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; motor gasoline
RFDPRDRFG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; reformulated mogas
RFDPRDTRH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; high oxygenated mogas
RFDPRDRFH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; reform. hi oxyg. mogas
RFDPRDJTA(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; jet fuel
RFDPRDKER(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; kerosene
RFDPRDN2H(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; no. 2 distillate
RFDPRDN6I(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; low sulfur resid oil
NAME	**UNITS**	**DEFINITION**

RFDPRDN6B(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; high sulfur oil
RFDPRDOTH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; other petroleum
RFDPRDPCF(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; petrochemical feeds
RFDPRDAST(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; asphalt & road oil
RFDPRDDSL(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; low sulfur diesel
RFDPRDSTG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; still gas
RFDPRDCOK(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; petroleum coke
RFDSCUM(MNUMPR,MNUMYR)	MMbbl/cd	Processin unit cumulative cap. expansion
RFBDSTCAP(MNUMPR,MNUMYR)	MMbbl/cd	Refinery base distillation capacity
RFETHD(MNUMYR)	MMbbl/cd	Domestic ethanol
RFMETD(MNUMYR)	MMbbl/cd	Domestic methanol
RFMETCHM(MNUMPR,MNUMYR)	MMbbl/cd	Chem. Demand for methanol
RFIPQRG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported reformulated mogas (P,Q)
RFIPQOT(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported other (P,Q)
RFIPQPF(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported petrochem feeds (P,Q)
RFIPQDL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported low sulfur distillate (P,Q)
RFCRDOTH(MNUMPR,MNUMYR)	MMbbl/cd	Other crude imports by PAD District
BLDIMP(MNUMPR,MNUMYR)	MMbbl/cd	Blending component imports
RFMTBI(MNUMPR,MNUMYR)	MMbbl/cd	Imported MTBE
RFMTBD(MNUMPR,MNUMYR)	MMbbl/cd	Domestic MTBE production.
RFMETI(MNUMPR,MNUMYR)	MMbbl/cd	Imported methanol
RFETHE85(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for E85 production
RFMETM85(MNUMPR,MNUMYR)	MMbbl/cd	Methonal for M85 production

PRICE VARIABLES

NAME	UNITS	DEFINITION
PMGCM(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, Commercial
PMGTR(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, Transportation
PMGIN(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, Industrial
PMGAS(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, All Sectors
PJFTR(MNUMCR,MNUMYR)	$87/MMBtu	Jet Fuel, Transportation
PDSRS(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Residential
PDSCM(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Commercial
PDSTR(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Transportation
PDSIN(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Industrial
PDSEL(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Electricity (+petroleum coke)
PDSAS(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, All Sectors
PKSRS(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, Residential
PKSCM(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, Commercial
PKSIN(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, Industrial
PKSAS(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, All Sectors
PLGRS(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Residential
PLGCM(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Commercial
PLGTR(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Transportation
PLGIN(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Industrial
PLGAS(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, All Sectors
PRLCM(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, Commercial
PRLTR(MNUMCR,MNUMYR)	$87/MMBtu	Resid. Fuel, Low Sulfur, Transportation
PRLIN(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, Industrial
PRLEL(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, Electricity
PRLAS(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, All Sectors
PRHTR(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, High Sulfur, Transp.
PRHEL(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, High Sulfur, Electricity
PRHAS(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, High Sulfur, All Sectors
PRSCM(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Commercial
PRSTR(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Transportation
PRSIN(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Industrial
PRSEL(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Electricity
PRSAS(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, All Sectors
PPFIN(MNUMCR,MNUMYR)	$87/MMBtu	Petrochemical Feedstocks, Industrial
PASIN(MNUMCR,MNUMYR)	$87/MMBtu	Asphalt, Road Oil, Industrial
POTTR(MNUMCR,MNUMYR)	$87/MMBtu	Other Petroleum, Transportation

NAME	UNITS	DEFINITION
POTIN(MNUMCR,MNUMYR)	$87/MMBtu	Other Petroleum, Industrial
POTAS(MNUMCR,MNUMYR)	$87/MMBtu	Other Petroleum, Industrial

PTPRS(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Residential
PTPCM(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Commercial
PTPTR(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Transportation
PTPIN(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Industrial
PTPRF(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Refinery
PTPEL(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Electricity
PTPAS(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, All Sectors
PMETR(MNUMCR,MNUMYR)	$87/MMBtu	Methanol, Transportation
PETTR(MNUMCR,MNUMYR)	$87/MMBtu	Ethanol, Transportation

COGEN VARIABLES

NAME	**UNITS**	**DEFINITION**
CGREQ(MNUMCR,MNUMYR,4,2)	tBtu	Refinery Fuel Consumption
CGRECAP(MNUMCR,MNUMYR,4,2,2)	mW	Refinery Cogen Capacity
CGREGEN(MNUMCR,MNUMYR,4,2)	gWh	Refinery Cogen Generation

A.1.2.1 PMM Input Variables

QUANTITY VARIABLES

NAME	**UNITS**	**DEFINITION**
QMGCM(MNUMCR,MNUMYR)	MMBtu/Yr	Motor Gasoline, Commercial
QMGTR(MNUMCR,MNUMYR)	MMBtu/Yr	Motor Gasoline, Transportation
QMGIN(MNUMCR,MNUMYR)	MMBtu/Yr	Motor Gasoline, Industrial
QMGAS(MNUMCR,MNUMYR)	MMBtu/Yr	Motor Gasoline, All Sectors
QJFTR(MNUMCR,MNUMYR)	MMBtu/Yr	Jet Fuel, Transportation
QDSRS(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, Residential
QDSCM(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, Commercial
QDSTR(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, Transportation
QDSIN(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, Industrial
QDSRF(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, Refinery
QDSEL(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, Electricity (+petroleum coke)
QDSAS(MNUMCR,MNUMYR)	MMBtu/Yr	Distillate, All Sectors
QKSRS(MNUMCR,MNUMYR)	MMBtu/Yr	Kerosene, Residential
QKSCM(MNUMCR,MNUMYR)	MMBtu/Yr	Kerosene, Commercial
QKSIN(MNUMCR,MNUMYR)	MMBtu/Yr	Kerosene, Industrial
QKSAS(MNUMCR,MNUMYR)	MMBtu/Yr	Kerosene, All Sectors
QLGRS(MNUMCR,MNUMYR)	MMBtu/Yr	Liquid Petroleum Gases, Residential
QLGCM(MNUMCR,MNUMYR)	MMBtu/Yr	Liquid Petroleum Gases, Commercial
QLGTR(MNUMCR,MNUMYR)	MMBtu/Yr	Liquid Petroleum Gases, Transportation
QLGIN(MNUMCR,MNUMYR)	MMBtu/Yr	Liquid Petroleum Gases, Industrial
QLGRF(MNUMCR,MNUMYR)	MMBtu/Yr	Liquid Petroleum Gases, Refinery
QLGAS(MNUMCR,MNUMYR)	MMBtu/Yr	Liquid Petroleum Gases, All Sectors
QRLCM(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Low Sulfur, Commercial
QRLTR(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Low Sulfur, Transp.
QRLIN(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Low Sulfur, Industrial
QRLRF(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Low Sulfur, Refinery
QRLEL(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Low Sulfur, Electricity
QRLAS(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Low Sulfur, All Sectors
QRHTR(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, High Sulfur, Transp.
QRHEL(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, High Sulfur, Electricity
QRHAS(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, High Sulfur, All Sectors
QRSCM(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Commercial
QRSTR(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Transportation
QRSIN(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Industrial
QRSRF(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Refinery
QRSEL(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, Electricity
QRSAS(MNUMCR,MNUMYR)	MMBtu/Yr	Residual Fuel, All Sectors

NAME	**UNITS**	**DEFINITION**
QPFIN(MNUMCR,MNUMYR)	MMBtu/Yr	Petrochemical Feedstocks, Industrial
QSGIN(MNUMCR,MNUMYR)	MMBtu/Yr	Still Gas, Industrial
QSGRF(MNUMCR,MNUMYR)	MMBtu/Yr	Still Gas, Refinery
QPCIN(MNUMCR,MNUMYR)	MMBtu/Yr	Petroleum Coke, Industrial

QPCRF(MNUMCR,MNUMYR)	MMBtu/Yr	Petroleum Coke, Refinery
QPCEL(MNUMCR,MNUMYR)	MMBtu/Yr	Petroleum Coke, Electricity
QPCAS(MNUMCR,MNUMYR)	MMBtu/Yr	Petroleum Coke, All Sectors
QASIN(MNUMCR,MNUMYR)	MMBtu/Yr	Asphalt and Road Oil, Industrial
QOTTR(MNUMCR,MNUMYR)	MMBtu/Yr	Other Petr. Transp, (lubes, aviation gas)
QOTIN(MNUMCR,MNUMYR)	MMBtu/Yr	Other Petroleum, Industrial
QOTRF(MNUMCR,MNUMYR)	MMBtu/Yr	Other Petroleum, Refinery
QOTAS(MNUMCR,MNUMYR)	MMBtu/Yr	Other Petroleum, All Sectors
QTPRS(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, Residential
QTPCM(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, Commercial
QTPTR(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, Transportation
QTPIN(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, Industrial
QTPRF(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, Refinery
QTPEL(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, Electricity
QTPAS(MNUMCR,MNUMYR)	MMBtu/Yr	Total Petroleum, All Sectors
QMETR(MNUMCR,MNUMYR)	MMBtu/Yr	Methanol Transportation
QETTR(MNUMCR,MNUMYR)	MMBtu/Yr	Ethanol Transportation
QELRF(MNUMCR,MNUMYR)	MMBtu/Yr	Purchased Elec., Refinery
QNGRF(MNUMCR,MNUMYR)	MMBtu/Yr	Natural Gas, Refinery
QCLRF(MNUMCR,MNUMYR)	MMBtu/Yr	Coal, Refinery
QBMRF(MNUMCR,MNUMYR)	MMBtu/Yr	Biomass, Refinery

INTERNATIONAL MARKET MODEL VARIABLES

NAME	**UNITS**	**DEFINITION**
IT_WOP(MNUMYR,2)	$87/bbl	World oil price (2--units)
Q_ITIMCRSC(MNUMYR,5,5,3)	Mbbl/cd	Crude import supply curve quant.
P_ITIMCRSC(MNUMYR,5,5,3)	$87/bbl	Crude import supply curve prices
		Imported Product Supply Curves (P,Q)
ITIMRGSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Reformulated mogas
ITIMGSSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Tradition mogas
ITIMDSSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Distillate
ITIMLDSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low sulfur distillate
ITIMLRSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low sulfur. Resid.
ITIMHRSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	High sulfur Resid.
ITIMJFSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Jet fuel
ITIMLPSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	LPG
ITIMPFSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Petchemical Feedstocks
ITIMOTSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Other
ITIMMESC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Methanol
ITIMMTSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	MTBE

OIL AND GAS SUPPLY MODEL VARIABLES

NAME	**UNITS**	**DEFINITION**
OGELSCO(MNUMOR,MNUMYR)	Dimensionless	Oil elasticity
OGPRRCO(MNUMOR,MNUMYR)	MMbbl/MMbbl/yr	Oil PR ratio
OGRESCO(MNUMOR,MNUMYR)	MMbbl/Yr	Oil reserves
OGQEORPR(6,MNUMYR)	MMbbl/Yr	Oil supply from EOR by Region
OGTAXPREM(2,MNUMYR)	$87/bbl	OGSM tax simulation variable
OGNGLAK(MNUMYR)	Mbbl/cd	NGL from Alaska

NATURAL GAS TRANSMISSION AND DISTRIBUTION SUPPLY MODEL VARIABLES

NAME	**UNITS**	**DEFINITION**
OGPRDNG(MNUMOR,MNUMYR)	Bcf/Yr	Domestic dry NG production
OGWPRNG(MNUMOR,MNUMYR)	$87/Mcf	Ng wellhead price
PRNG_PADD(MNUMPR,MNUMYR)	Bcf/Yr	Total dry gas production (W/L&P)

PRICE VARIABLES

NAME	**UNITS**	**DEFINITION**
PELIN(MNUMCR,MNUMYR)	$87/MMBTU	Purch. Elec. Industrial
PNGIN(MNUMCR,MNUMYR)	$87/MMBTU	Natural Gas. Industrial

RENEWABLE VARIABLES

NAME	**UNITS**	**DEFINITION**

WPETOH(MNCROP,MNUMCR,MNUMYR,MNETOH)	$87/bbl	Ethanol price/step
WQETOH(MNCROP,MNUMCR,MNUMYR,MNETOH)	Mbbl/cd	Ethanol quan/step

A.1.2.2 Other PMM Variables

VARIABLES USED INTERNALLY IN PMM

NAME	UNITS	DEFINITION
		Refinery products prices
PALMG(MNUMCR,MNUMYR)	$87/bbl	Motor gasoline all combined
PMGTRG(MNUMCR,MNUMYR)	$87/bbl	Traditional mogas
PMGRFG(MNUMCR,MNUMYR)	$87/bbl	RFG mogas
PMGTRH(MNUMCR,MNUMYR)	$87/bbl	TRH mogas
PMGRFH(MNUMCR,MNUMYR)	$87/bbl	RFH mogas
		Refinery products prices
PMG2TR(MNUMCR,MNUMYR)	$87/bbl	TRG mogas with markup
PMG3TR(MNUMCR,MNUMYR)	$87/bbl	RFG mogas with markup
PMG4TR(MNUMCR,MNUMYR)	$87/bbl	TRH mogas with markup
PMG5TR(MNUMCR,MNUMYR)	$87/bbl	RFH mogas with mu
PDS(MNUMCR,MNUMYR)	$87/bbl	Distillate fuel oil
PDSL(MNUMCR,MNUMYR)	$87/bbl	Low sulfur diesel
PJF(MNUMCR,MNUMYR)	$87/bbl	Jet fuel
PRL(MNUMCR,MNUMYR)	$87/bbl	Residual fuel oil low sulfur
PRLUT(MNUMCR,MNUMYR)	$87/bbl	Low sulfur utility resid.
PRH(MNUMCR,MNUMYR)	$87/bbl	High sulfur resid.
PRHUT(MNUMCR,MNUMYR)	$87/bbl	High sulfur utiltiy resid.
PLG(MNUMCR,MNUMYR)	$87/bbl	LPG
PPF(MNUMCR,MNUMYR)	$87/bbl	Petrochemical feedstocks
PPC(MNUMCR,MNUMYR)	$87/bbl	Petroleum coke
PKS(MNUMCR,MNUMYR)	$87/bbl	Kerosene
POTH(MNUMCR,MNUMYR)	$87/bbl	Other
PAS(MNUMCR,MNUMYR)	$87/bbl	Asphalt and road oil
PE85(MNUMCR,MNUMYR)	$87/bbl	E85
PM85(MNUMCR,MNUMYR)	$87/bbl	M85
QCDUPD(MNUMYR)	$87/bbl	Crude used as product
OLEOYRS(MNUMOR,MNUMYR)	MMbbl	End of year reserves for oil
OLEXTRT(MNUMOR,MNUMYR)	MMbbl/day/MMbbl	Production Ratio
OLPELC(MNUMOR)	Dimensionless	Price elasticity beta
OLWHP(MNUMOR)	$87/bbl	Well head price for (year - 1)
OLALP(MNUMOR)	Dimensionless	Well head price alpha
OLBTA(MNUMOR)	Dimensionless	Well head price beta
PCRDRF(MNUMPR,MNUMYR,5,3)	$87/bbl	Price of crude, refinery gate
QCRDRF(MNUMPR,MNUMYR,5,3)	Mbbl/cd	Quantity of crude, refinery gate
QPRDRF(MNUMPR,MNUMYR,18)	Mbbl/cd	Refinery production volume by product
QPRDRFT(MNUMYR)	Mbbl/cd	Total refinery production volumes
QGPLTRF(MNUMPR,MNUMYR,10)	BCF	Refinery gas plant production volumes
QPRDEX(MNUMPR,18)	Mbbl/cd	Refinery production export by product
QPRDEXD(MNUMPR,18,MNUMYR)	Mbbl/cd	Production distress export by product
RFMETM85(MNUMYR)	MMbbl/cd	Methanol for M85
RFCRDDCR(MNUMYR)	Mbbl/cd	Domestic crude production
RFCRDAKA(MNUMYR)	Mbbl/cd	Alaskan crude production
RFCRDL48(MNUMYR)	Mbbl/cd	Lower 48 crude production

NAME	UNITS	DEFINITION
RFCRDTOT(MNUMYR)	MMbbl/cd	Total crude production
RFNGFTOT(MNUMYR)	Mbbl/cd	Total natural gas production
QPRDIMD(MNUMYR)	Mbbl/cd	Total distress imports
PRDTOT(MNUMYR)	Mbbl/cd	Total product demand for report 4
PRPFU(5)	MFOEbbl/day	RHS value for resid. by PAD District
PRPFF(5)	MFOEbbl/day	RHS value for resid. by PAD District
PQUFC1(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 1
PQUFC2(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 2
PQUFC3(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 3

NAME	UNITS	DEFINITION
PQUFC4(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 4
PQUFC5(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 5
PQUFC6(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 6
PQUFC7(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 7
PQUFC8(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 8
PQUFC9(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 9
PQUFC10(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 10
		Refinery fuel use
QDISFU(MNUMPR,MNUMYR)	TBtu/Yr	Distillate
QRESFU(MNUMPR,MNUMYR)	TBtu/Yr	Resid.
QCOLFU(MNUMPR,MNUMYR)	TBtu/Yr	Coal
QLPGFU(MNUMPR,MNUMYR)	TBtu/Yr	LPG
QSTGFU(MNUMPR,MNUMYR)	TBtu/Yr	Still gas
QNTGFU(MNUMPR,MNUMYR)	TBtu/Yr	Natural gas
QCOKFU(MNUMPR,MNUMYR)	TBtu/Yr	Petroleum coke
QOTHFU(MNUMPR,MNUMYR)	TBtu/Yr	Other
		End use markups by sector
MGMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Motor gasoline mark ups All Sectors
MGMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Transportation
MGMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Industrial
MGMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	Commercial
MEMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	M85
ETMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	E85
		Fuel oil
DSMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Distillate
DSMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
JFMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Jet fuel transportation
RLMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Low sulfur Resid.
RLMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
RHMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	High Sulfur Resid.
RHMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
RHMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	LPG
LGMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
PFMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Petrochemical feedstocks
ASMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Asphalt and road oil
KSMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Kerosene
KSMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
KSMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
KSMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
OTMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Other
OTMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
OTMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	

NAME	**UNITS**	**DEFINITION**
OTMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
OTMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Other markups transportation sector
OTMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Other markups industrial sector
NLV(9)	Text	Census division character identifiers
NLV2(9)	Text	Domestic crude supply regn identifers
QNT(9)	Text	Quantity character identifiers
PRD(20)	Text	Product character identifiers
IPRD(12)	Text	Imported product chrctr identifers
PADD(5)	Text	PAD District character identifiers
CRDTYP(5)	Text	Crude type character identifiers
MGSCHAR(65)	Text	Mogas share character identifiers

NAME	UNITS	DEFINITION
BNDS(2)	Text	Bounds character identifiers
RFCESWTC	Text	Capacity expansion switch
MPSSWTC	Text	MPS matrix load switch
RFADVBAS	Text	Advance basis load switch
RPT1SWTC	Text	Report 1 switch
RPT7SWTC	Text	Report 7 switch
RFETSWTC	Text	Ethanol supply curve switch
PRCUNIT(40)	Text	Process unit character identifier
RFHIST	Text	History switch
RFOTHFU(19)	Text	Other fuel use character identifier
MGSPCS(65,MNUMYR)	Many	Motor gasoline specifications
MGSHR(MNUMYR,6,MNUMCR)	Percent	Motor gasoline market shares
PRDDMD(MNUMCR,MNUMYR,20)	Mbbl/cd	Product demand
PRDDMDME(MNUMYR)	Mbbl/cd	Chemical methanol demand
LOWBND	None	Variable for passing data to OML
UPBND	None	Variable for passing data to OML
PRICLP	None	Variable for passing data to OML
PCOKL	None	Variable for passing data to OML
PCOKH	None	Variable for passing data to OML
PUCUM(MNUMPR,40,MNUMYR)	Mbbl/cd	Process unit cumulative builds
PUINV(MNUMPR,40,MNUMYR)	Mbbl/cd	Process unit investment builds
FO1PMM	None	Variable for file unit identifier
FO2PMM	None	Variable for file unit identifier
PMMINF	None	Infeasible solution switch
RPT1YR1	Text	Report 1 switch
RPT1YR2	Text	Report 1 switch
RPT1YR3	Text	Report 1 switch
RPT1YR4	Text	Report 1 switch
RPT1YR5	Text	Report 1 switch
RPT1YR6	Text	Report 1 switch
PUBASE(MNUMPR,40,MNUMYR)	Mbbl/cd	Processing units base capacity
PUBASEUT(MNUMPR,40,MNUMYR)	Pecent	Processing units base utilization
RFMETI(MNUMYR)	MMbbl/cd	Imported methanol
RFMTBD(MNUMYR)	MMbbl/cd	Domestic MTBE
RFMTBI(MNUMYR)	MMbbl/cd	Imported MTBE
RFEMISST(MNUMPR,MNUMYR,12)	Many	Total refinery emissions
RFFMT(MNUMPR,MNUMYR,30)	Percent	Refinery fuel mix
RFCGSTEAM(MNUMPR,MNUMYR	Percent	Steam, PAD District percent adjustment
RFSTEAM(MNUMPR,MNUMYR)	MMlb/day	Steam by PAD District
RFCGCONS(MNUMPR,MNUMYR)	tBtu	Refinery cogeneration PAD District
RFCGREC(MNUMPR,MNUMYR)	kWh	Receipts of electricity
RFCGGENPD(MNUMPR,MNUMYR)	TBtu	Refinery cogeneation by PAD District
RFCGGRIDPD(MNUMPR,MNUMYR)	TBtu	Refinery cogen. to grid by PAD District
RFCGSELFPD(MNUMPR,MNUMYR)	TBtu	Refinery cogen. Self
RFCGFUELPD(MNUMPR,MNUMYR)	TBtu	Refinery cogen. Fuel
RFCGGENCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Generation
RFCGGRIDCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. To grid by census division
RFCGSELFCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Self by census division
RFCGFUELCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Fuel by census division
FLOWCRD(MNUMYR,14)	Mbbl/cd	Crude pipeline flow
CAPCRD(MNUMYR,14)	Percent	Crude pipeline utilization
FLOWPRD(MNUMYR,21)	Mbbl/cd	Product pipeline flow
NAME	**UNITS**	**DEFINITION**
CAPPRD(MNUMYR,21)	Pecerent	Product pipeline utilization
FLOWLPG(MNUMYR,10)	Mbbl/cd	LPG pipeline flow
CAPLPG(MNUMYR,10)	Percent	LPG pipeline utilization
RFPRDFX(MNUMCR,MNUMYR,20)	$87/bbl	Refinery capital cost by product
RFQNGLRF(MNUMPR,MNUMYR)	MMbbl/cd	Quantity of ngl inputs to refinery
FHLADD(MNUMPR)	Mbbl/cd	Additonal supply imports of HL crude
N6XQNT(9)	Fraction	Supply step adjustment for N6I/B
N6XPRC(9)	Fraction	Price step adjustment for N6I/B
IRACN	$87/bbl	Refiner acquisition cost min. tolerance
IRACX	$87/bbl	Refiner acquisition cost max. tolerance
QPRDIMD(MNUMCR,23,MNUMYR)	MMbbl/cd	Quantity of distress product import
RFNGFTOT(MNUMYR)	MCF/cd	Domestic natural to refineries
QSUBFU(MNUMPR,MNUMYR)	MMbbl/cd	Subtotal refinery fuel use w/o nat. gas

QTOTFU(MNUMPR,MNUMYR)	MMbbl/cd	Total refinery fuel use with natural gas
RFIPQSB(MNUMPR,MNUMYR,2)	MMbbl/cd,$87/bbl	Subtotal imported product w/o Methanol
RFIPQTL(MNUMPR,MNUMYR,2)	MMbbl/cd,$87/bbl	total imported product with Methanol
MUFTAX(15)	$87/MMBtu	Federal motorgasoline tax
RWOP(MNUMYR)	$87/bbl	PMM local expected WOP
FRSTIT	Text	Write basis on first/last iteration switch
PRDEXPTOT(MNUMYR)	MMbbl/cd	Total allowable product exports
LHCDIST(2,MNUMY,7,30)	Percent	Model testing variable
LHCRUN	Integer	Model testing switch
DSLSPLT	Percent	Low sulfur diesel and distillate split
WOPMTPLY	Percent	Distress import price multiplier
WOPZ9EXP	Percent	Distress export price multiplier
Z9EXPRD	Text	Distress export index list
SUBNM	Text	Subroutine name index
SUBNMX	Text	Passing subroutine name index
PMMRGNS	Integer	PMM refining regions index
DMDRGNS	Integer	PMM demand regions index
RFETHMGS(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for motor gasoline
RFETHETB(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for ETBE
RFFUELU(MNUMYR)	MMbbl/cd	Total refinery fuel use w/o nat. gas
CRDOTHOT(MNUMPR,MNUMYR)	MMbbl/cd	Total other crude suplied
CRDUNACC(MNUNPR,MNUMYR)	MMbbl/cd	Unaccouted crude
CRDSTWDR(MNUMPR,MNUMYR)	MMbbl/cd	Crude stock withdrawals
NGLMK(MNUMPR,MNUMYR,6,2)	MMbbl./cd	NGL to market
NGLRF(MNUMPR,MNUMYR,6,2)	MMbbl/cd	NGL from refinery
RFMETETH(MNUMPR,MNUMYR)	MMbbl/cd	Methanol for ether
PRDSTKWDR(MNUMPR,MNUMYR)	MMbbl/cd	Product stocks withdrawals
MISCINP(MNUMPR,MNUMYR)	MMbbl/cd	Miscellaneous inputs
BLDPRD(MNUMPR,MNUMYR)	MMbbl/cd	Product blending component
OTHOXY(MNUMPR,MNUMYR)	MMbbl/cd	Other oxgenates
XRFWOP(MNUMYR,2)	MMbbl/cd	Local expected WOP
XRFELP(MNUMPR,MNUMYR)	MMbbl/cd	Local expected electricity price
XRFNGP(MNUMPR,MNUMYR)	MMbbl/cd	Local expected natural gas price
RFETBD(MNUMPR,MNUMYR)	MMbbl/cd	ETBE oxygenate quantity
RFTAED(MNUMPR,MNUMYR)	MMbbl/cd	TAE oxygenate quantity
RFTAMD(MNUMPR,MNUMYR)	MMbbl/cd	TAME oxygenate quantity
RFTHED(MNUMPR,MNUMYR)	MMbbl/cd	THE oxygenate quantity
RFTHMD(MNUMPR,MNUMYR)	MMbbl/cd	THM oxygenate quantity
NGRFUPIT(MNUMPR,MNUMYR)	MMbbl/cd	Natural gas fuel use previous iteration
FCCACT(MNUMPR,MNUMYR,78)	Mbbl/cd	FCC unit activity variable by mode
FCCMOD(78)	Text	FCC unit modes
ALKMOD(9)	Text	Alkulation unit mode
ALKACT(MNUMPR,MNUMYR,9)	Mbbl/cd	Alkulation unit activity variable by mode
PMMOBJ(MNUMYR)	M$87/day	Objective function value by year
RFROSSWTC	Text	ROS switch, on or off
RFPCKYR	Integer	Pack file year
IRACBND(2)	$87/bbl	IRAC bounds
CAPEXPFCT(5,40,MNUMYR)	Percent	Processing unit capacity expansions factor
RPTFY	Integer	Reproting first year
RPTLY	Integer	Reporting last year
NAME	**UNITS**	**DEFINITION**
PMMBSYR	Integer	PMM base year, 1995
HISTLYR	Integer	PMM last history year, 1994
STEOBMSW	Integer	STEO benchmarking switch
RFBMLPG	$87/bbl	LPG benchmarking factor
RFBMTRG	$87/bbl	TRG benchmarking factor
RFBMRFG	$87/bbl	RFG benchmarking factor
RFBMTRH	$87/bbl	TRH benchmarking factor
RFBMRFH	$87/bbl	RFH benchmarking factor
RFBMJTA	$87/bbl	JTA benchmarking factor
RFBMN2H	$87/bbl	N2H benchmarking factor
RFBMN6I	$87/bbl	N6I benchmarking factor
RFBMN6B	$87/bbl	N6B benchmarking factor
RFBMOTH	$87/bbl	OTH benchmarking factor
RFBMPCF	$87/bbl	PCF benchmarking factor
RFBMAST	$87/bbl	AST benchmarking factor

NAME	UNITS	DEFINITION
RFBMDSL	$87/bbl	DSL benchmarking factor
RFBMN67	$87/bbl	N67 benchmarking factor
RFBMN68	$87/bbl	N68 benchmarking factor
RFBMCOK	$87/bbl	COK benchmarking factor
RFBME85	$87/bbl	E85 benchmarking factor
RFBMM85	$87/bbl	M85 benchmarking factor
RFBMKER	$87/bbl	KER benchmarking factor
QEXCRDIN(MNUMPR,MNUMYR)	Mbbl/cd	Exported crude excep alaskan
PRLMARG(MNUMCR,MNUMYR)	$87/bbl	Marginal value of low sulfur residual oil
PRHMARG(MNUMCR,MNUMYR)	$87/bbl	Marginal value of high sulfur residual oil
PRLUTMAR(MNUMCR,MNUMYR)	$87/bbl	Marginal value of low sulfur residual oil
PRHUTMAR(MNUMCR,MNUMYR)	$87/bbl	Marginal value of high sulfur residual oil
		Delivered petroleum product prices
RFDLMG(MNUMCR,MNUMYR)	$87/bbl	Motor gasoline
RFDLLPG(MNUMCR,MNUMYR)	$87/bbl	LPG
RFDLTRG(MNUMCR,MNUMYR)	$87/bbl	TRG
RFDLRFG(MNUMCR,MNUMYR)	$87/bbl	RFG
RFDLTRH(MNUMCR,MNUMYR)	$87/bbl	TRH
RFDLRFH(MNUMCR,MNUMYR)	$87/bbl	RFH
RFDLJTA(MNUMCR,MNUMYR)	$87/bbl	JTA
RFDLN2H(MNUMCR,MNUMYR)	$87/bbl	N2H
RFDLDSL(MNUMCR,MNUMYR)	$87/bbl	DSL
RFDLPCF(MNUMCR,MNUMYR)	$87/bbl	PCF
RFDLKER(MNUMCR,MNUMYR)	$87/bbl	KER
RFDLOTH(MNUMCR,MNUMYR)	$87/bbl	OTH
RFDLN6I(MNUMCR,MNUMYR)	$87/bbl	N6I
RFDLN6B(MNUMCR,MNUMYR)	$87/bbl	N6B
RFDLN67(MNUMCR,MNUMYR)	$87/bbl	N67
RFDLN68(MNUMCR,MNUMYR)	$87/bbl	N68
RFDLAST(MNUMCR,MNUMYR)	$87/bbl	AST
RFDLCOK(MNUMCR,MNUMYR)	$87/bbl	COK
RFDLE85(MNUMCR,MNUMYR)	$87/bbl	E85
RFDLM85(MNUMCR,MNUMYR)	$87/bbl	M85
		Refinery Gate product prices
RFGTMG(MNUMPR+1,MNUMYR)	$87/bbl	Motor gasoline
RFGTLPG(MNUMPR+1,MNUMYR)	$87/bbl	LPG
RFGTTRG(MNUMPR+1,MNUMYR)	$87/bbl	TRG
RFGTRFG(MNUMPR+1,MNUMYR)	$87/bbl	RFG
RFGTTRH(MNUMPR+1,MNUMYR)	$87/bbl	TRH
RFGTRFH(MNUMPR+1,MNUMYR)	$87/bbl	RFH
RFGTJTA(MNUMPR+1,MNUMYR)	$87/bbl	JTA
RFGTN2H(MNUMPR+1,MNUMYR)	$87/bbl	N2H
RFGTDSL(MNUMPR+1,MNUMYR)	$87/bbl	DSL
RFGTPCF(MNUMPR+1,MNUMYR)	$87/bbl	PCF
RFGTKER(MNUMPR+1,MNUMYR)	$87/bbl	KER
RFGTOTH(MNUMPR+1,MNUMYR)	$87/bbl	OTH
RFGTN6I(MNUMPR+1,MNUMYR)	$87/bbl	N6I
RFGTN6B(MNUMPR+1,MNUMYR)	$87/bbl	N6B

NAME	**UNITS**	**DEFINITION**
RFGTAST(MNUMPR+1,MNUMYR)	$87/bbl	AST
RFGTCOK(MNUMPR+1,MNUMYR)	$87/bbl	COK
RFGSPEC(9)	Text	RFG specifications
TRGSPEC(7)	Text	TRG specifications
RFGSPCLM(MNUMPR,MNUMYR,9)	Text	RFG specification row status
RFGSPCDL(MNUMPR,MNUMYR,9)	$87/bbl	RFG specification row dual activity
TRGSPCLM(MNUMPR,MNUMYR,7)	Text	TRG specification row status
TRGSPCDL(MNUMPR,MNUMYR,7)	$87/bbl	RFG specification row dual activity
FCCDUAL(MNUMPR,MNUMYR,78)	$87/bbl	RFG specification row dual activity

Legend for Codes

MNUMYR = NEMS year index, 1 through 26
MNUMCR = census region index, 1 through 11
MNUMPR = PAD District index, 1 through 6
MNUMOR = Oil and Gas Region Index, 1 through 15
MNCROP = Ethanol supply crop index, 1 and 2

MNETOH = Ethanol supply curve point index 1 through 5

A.2 Data Sources

The PMM data have been developed by EIA and others since DOE received the first model database from Turner, Mason Associates during 1975-76. These data were used extensively during 1983-1986 during the development of the EIA Refinery Yield Model (RYM). The RYM database underwent substantial review and update by oil industry experts when the National Petroleum Council (NPC) used the RYM during the development of their 1986 study on U.S. refining flexibility. In 1985, EIA provided the updated RYM/NPC data and OMNI matrix and report generator programs to Oak Ridge National Laboratories (ORNL), and its consultant ENSYS, to support a study for the U.S. Navy.[1] The data used for this version of PMM was provided by ENSYS to EIA in September 1992 and is based on some ENSYS in-house data sources as well as review and commentary received from major oil companies. Much of the data has been updated from 1985 to 1992. The most recent vintage of data was provided by ENSYS to EIA in May 1995 but has not yet been incorporated into PMM. The data sources include:

- The original Refinery Yield Model (RYM) Data Base provided by EIA in about 1981 to ORNL. This data was then combined with the 1985 RYM/NPC updates and used by their consultant, ENSYS.
- *Oil & Gas Journal*, *Hydrocarbon Processing*, NPRA papers, API papers, ASTM specs and correlation methods, *Chemical Engineering*, Gary & Handwerk (mainly correlations), AIChE papers, *Petroleum Review*
- An extensive review of foreign journals obtained with the aid of ORNL for the high-density jet fuel study
- Contractor reports and data - M.W. Kellogg, UOP, IFP, Snam Projetti and Foster and Wheeler
- Consultant reports and data as published - Bonner & Moore, A.D. Little, Chem Systems and Purvin & Gertz.

A.2.1 Process Technology and Cost Data

Refining process technology and cost data need periodic review and update. This is because environmental legislation, lighter product slates, and heavier crude slates have spurred new process technology developments affecting existing processes, new processes and costs. Sources for new developments include research and other papers in industry journals, papers from industry conferences and surveys (such as NPRA), engineering and licensing contractor data, and published consultant studies.

A.2.2 Refinery Capacity Construction and Utilization Data

The base capacity for refinery process units, as published by EIA, provide the base year values. The planned construction of refinery process units, as published annually by the *Oil & Gas Journal (OGJ)*, together with

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[1]Oak Ridge National Laboratory, EnSys Energy and Systems, *Enhancement of EIA Refinery Evaluation Modeling System Refinery Yield Model Extension and Demonstration on Gasoline and Diesel Quality Issues*, (August 1988).

published articles on national, company, or individual refinery activities are used to supplement and cross-check the base data from EIA. These data require annual updating and careful cross-checking for error, omissions, and operating status.

Construction project data are gathered principally from annual surveys published in the *Oil & Gas Journal* and in *Hydrocarbon Processing*, again supplemented, cross-checked and updated by individual announcements or published studies. The approach used is to review all announced projects, but to only include as active those that have reached the engineering, construction, or start-up stage.

It is also necessary to track installed and projected capacity for MTBE and TAME plants, both in-refinery and merchant. Principal sources for these data are EIA surveys, *Fuel Reformulation*, and the *Pace Petrochemical Service* publications.

A.2.3 Crude Supply and Product Demand Data

The crude oil supply is provided by two of the NEMS models, OGSM, which provides the production function to estimate the domestic oil production, including Alaska, and the International Energy Model which provides volumes and prices of imported crude oils in the form of supply curves. Individual crude oil streams for both domestic and imported crude oils are grouped in five categories differentiated by API gravity, sulfur content, and the yield of material boiling at a temperature higher than 1050 degrees Fahrenheit. The import supply curve values are stored in the NEMS restart file. Each year of a NEMS run contains quantities and import prices for crude oil in three step supply increments for each importing PAD District.

Both domestic and imported crude oils are grouped in the five categories shown below. While the domestic and foreign categories have the same gravity and sulfur definitions, the composite characteristics of each type may differ because different crude streams make up the composites. The five domestic crude groups are tagged with the codes DLL, DMH, DHL, DHH, and DHV. The imported crude oil codes are FLL, FMH, FHL, FHH, and FHV. In addition, Alaska North Slope and Alaska South are included as individual crude oil streams for a total of 12 crude groups.

Table A2. Aggregate Crude Oil Categories for PMM/NEMS

Description	Code	API Gravity	Sulfur, Wt%	Bottoms Yield, 1050 F+ Vol %
Low Sulfur-Light	LL	> 24	0.5 MAX	< 15%
Medium Sulfur - Heavy	MH	> 24	0.35-1.1	> 15%
High Sulfur - Light	HL	> 32	> 1.1	< 15%
High Sulfur - Heavy	HH	24-33	> 1.1	> 15%
High Sulfur - Very Heavy	HV	< 23	> 0	> 15%

Natural Gas Liquids (NGL's)

> The NGL's are produced by the gas plant model matrix that is a part of PMM. See Appendix F.

Other Hydrocarbons and Alcohols

Other hydrocarbons such as propane and butanes are supplied by the output of the gas plant model. Ethanol is supplied by the Renewable Fuels Model of NEMS in Census Divisions 3 and 4. The supply of ethanol is represented as a step function with each increment of supply available at a higher price.

Some methanol is imported with the balance required by PMM supplied by the methanol plant in each refining region. Methyl Tertiary Butyl Ether (MTBE) is produced by MTBE plants (both merchant and refinery locations) in each refining region; additional supplies are imported.

Products

> Product demands are available from the NEMS restart file for a given scenario by year as produced by the various demand models of NEMS.

A.2.4 Product Specification/Grade Split Data

For the United States, surveys by industry organizations such as NPRA, API, NPC and NIPER, together with government sources such as Department of Defense, provide relatively frequent and detailed insights into actual U.S. product qualities and grade splits. These data are important for establishing case studies.

A.2.5 Transportation Data

PMM transportation data for the United States on capacities and rates have been developed from the OSPR NACOD Model and updated for environmental costs reflecting the Oil Pollution Control Act. The transportation costs were obtained from a recent National Petroleum Council study in 1993.

A.2.6 Product Yield and Quality Blending Data

In addition to the general sources already mentioned, a number of further sources relating to specific properties are given below:

> *Cetane Number - API Refining Dept., Vol. 61, p.39 and appendix for the modified ASTM D976-80 Equation (George Unzelman).*

> *Net Heat of Combustion - ASTM D3338 (API range 37.5 - 64.5) (relaxing ASTM D2382.*

Wt. percent hydrogen - ASTM Method D3343 (replacing D1018)

Smoke point vs. hydrogen content - empirical correlation developed by ENSYS Smoke point to Luminometer Number conversion, ASTM D1322.

Viscosity prediction - based on the work of PLI Associates (Dr. Paul S. Kydd) and from the Abbott, Kaufman and Domashe correlation of viscosities. (See PLI report- "Fuel and Engine Effect Correlations, Task 1.1, Computerize Fuel Property Correlations and Validate". Viscosity interpolation included and based on computerized formulae for ASTM charts.

Viscosity blending indices - computerization of Gary & Handwerk formulae - p.172 (left hand side).

Static and Dynamic Surface Tensions - API Technical DataBook method.

Flash point Blending Index Numbers - Gary & Handwerk, p.173.

Pour Point blending Indices - ibid., p.175.

RVP blending indices have been gathered from several public and in-house sources and have been verified against Gary & Handwerk, p.166.

RON and MON blending deltas are reflective of base gasoline sensitivity have been drawn from many sources and averaged.

A.2.7 Units of Measurement

The general rule adopted in the model is that quantities of oil are in thousands of barrels per day, prices or costs are in dollars per barrel and quantities of money are, therefore, in thousands of dollars per day.

Exceptions to the above rule are:

1.   Gases lighter than propane are measured in thousands of barrels fuel oil equivalent (FOE) per day. These are based on the following conversion factors:

Gas stream	Code	bblFOE/lb	cf/bblFOE
Hydrogen	HH2	.008190	23,077
Hydrogen sulfide	H2S	.001040	10,145
Methane/natural gas	NGS	.003414	6,917
Ethane	CC2	.003245	3,861
Process gas	PGS	.003245	3,861
Ethylene	C2E	.003219	4,180

One barrel FOE is 6.3 million Btu.

2.   The assumed Btu content for other major refinery streams is shown below:

Stream	Code	MMBtu/bblFOE
Gasoline	TRG	5.253
Jet Fuel	JTA	5.670
No. 2 Heating Oil	N2H	5.825
Residual Oil	N6I,N6B	6.287
LPG	LPG	3.625
Methanol/gasoline	M85	2.820
Ethanol/gasoline	E85	3.500

3. Yields of coke are measured in short tons per barrel and demands are in short tons per day. A factor of 5.0 crude oil equivalent (COE) barrels per short ton is used.

4. Yields of sulfur are also measured in short tons per barrel and demands are in short tons per day. A factor of 3.18 barrels per short ton is used.

5. Process unit capacities are generally measured in terms of feedstock volume. Exceptions are units, principally those with gaseous feeds and liquid products, whose capacities are measured in terms of product volume. These include:
OLE, ETH, C24, ALK, CPL, DIP, DIM, ARP, C4I, H2P, and SUL.
Note also that unit activity level of H2P, and SUL activities represents the production of 0.1 thousand fuel oil equivalent barrels of hydrogen and 0.1 thousand short tons of sulfur per day, and uses 0.1 units of capacity.

6. Quality and specification units are those specified in each ASTM test method or are dimensionless (as in the case of blending indices). Gasoline sulfur contents and specs, SPM, are in parts per million by weight, while those for distillates, SPC, are in percent weight.

7. 　　　　　steam in thousands of pounds per day (Mlb/day). Steam generation capacity is in millions of pounds per day (MMlb/day). The consumption of .00493 fuel oil equivalent bbl per day to raise 1 lb/hr of steam is equivalent to 1225 Btu per lb steam.

8. Electricity consumption is in kWh/bbl. Generation is in MkWh/day.

A.3 PMM Model Data Tables

This section describes in detail the function and content of the PMM model data tables used to generate the initial PMM matrix for NEMS. The entries in these tables are Mbbl/cd for volume and $/bbl for costs, unless otherwise noted. With the shift of computer processing to the EIA RS6000 in 1995, the OMNI code was replaced with FORTRAN in conjunction with subroutines from the Optimization Modeling Library (OML). The data table formats used by OMNI were no longer valid which required a change in table format, organization and design from the AEO95 version. The most significant change was in the refinery process unit table design in which the table rows representing "policy" limits (variable operating cost (OVC, LOS, etc.), utilities (KWH and STM) and capacity consumption (CAP) were separated into three tables labeled

(uns)POL, (uns)UTI, and (uns)CAP. The process yields were placed in tables named (uns)REP. The symbol (uns) represents a process unit. This was done to accelerate the FORTRAN matrix generation process.

   All data tables are located in a directory on the RS6000 named:
                              /refine/db6/mrm/default/data/mrm5
The reference **(filename)** in the following pages refers to the individual file name with a **.dat** extension which contains the tables described. The symbols (R) and (D) used in the table names represent a refining region (R) or Census division (D) where:

(R)	Refining Region	(D)	Census Division
E	PAD District I	1	New England
C	PAD District II	2	Mid Atlantic
G	PAD District III 3		East North Central
M	PAD District IV	4	West North Central
W	PAD District V	5	South Atlantic
		6	East South Central
		7	West South Central
		8	Mountain
		9	Pacific, including California

A.3.1 Matrix Control

This section describes the tables used to control the number of constraints (rows) and column variables in the matrix as well as the stipulations for the limits on constraints and variables.

(main)

TABLE RFNREG   *LIST OF ACTIVE REFINING REGIONS*

Column names   One column, PAD.

Row names   One character region codes, E, C, G, M, W.

Entries   numeric value for PADD, 1-5.

TABLE DEMNDREG LIST OF ACTIVE CENSUS DIVISION DEMAND REGIONS

Column names   One column, REGION.

Row names   Two character codes, first character is demand region, second character is refining region E, C, G, M, W.

Entries   numeric value for Census Division, 1-9.

TABLE RFNEXP   *LIST OF REFINING REGIONS LINKED TO EXPORT REGIONS*

Column names   One column, RFID.

Row names   Two character codes, first character is exporting Census division, second character is refining region E, C, G, M, W.

Entries   numeric value for PADD, 1-5.

TABLE EXPROD   *LIST OF EXPORT PRODUCTS*

Column names   One column, DUMMY.

Row names   Three character product codes

Entries   none

TABLE FORCRD   ***LIST OF FOREIGN IMPORT CRUDES***

Column names   One column, DUMMY.

Row names   Three character crude stream group codes

Entries   none

TABLE WOP   ***WORLD OIL PRICE BY YEAR***

Column names   One column, WOP.

Row names   Numeric value for year, e.g. 6 for 1995.

Entries   World Oil Price in 1987 $/bbl.

TABLE USERYEAR   ***YEAR FOR MODEL RUN***

Column names   One column, YEAR.

Row names   Three character code, e.g. Y95.

Entries   Numeric value for year, e.g. 6 for 1995.

TABLE YRDOLLAR   ***CONVERSION FROM 1987 TO 1991 DOLLARS***

Column names   One column, 1991.

Row names   1987

Entries   Numeric value for converting 1987$ to 1991$.

TABLE ZIRACFAC   ***FACTOR FOR IRAC SPREAD***

Column names   One column, DELTA.

Row names   ZIRAC

Entries   Range on average price, $/bbl.

TABLE TRSOVC   *FACTOR TO CONVERT OVC TO 1991$*

Column names   One column, OVC.

Row names   One character refining region code.

Entries   Conversion of variable operating costs to 1991$.

TABLE INVFACT   *INVESTMENT LOCATION AND ENVIRONMENTAL FACTORS*

Column names   LOC, ENV

Row names   One character refining region code.

Entries   Column LOC contains the investment location factor multiplier, refining region III, U.S. Gulf coast is assumed to be 1.0. Column ENV contains the environmental investment cost multiplier, currently set at 1.0 for all regions.

(akaexp)

TABLE EXPAKA   *PRICE/QUANTITY VALUES FOR ALASKA EXPORTS*

Column names   Two columns, P and Q

Row names   Six rows, three negative shifts N1 N2, N3 and three positive shifts, P4, P5, and P6.

Entries   P column is $/bbl shift from reference price, Q column is bound value on volume supplied.

TABLE PRQAKA   *NGL PRICE QUANTITY FROM ALASKA NORTH SLOPE*

Column names   VOL, TRP, and EXPPRC

Row names   OGSM code A for Alaska.

Entries   Volume limit on NGL supply, MBbl/cd, Transportation cost to region W, pseudo supply price, $/bbl.

TABLE NGLAKA *NGL COMPOSITION FROM ALASKA*

Column names One column, PER.

Row names Three character NGL stream codes.

Entries Volume fraction composition of NGL's.

(avoids)

TABLE SADELQ *DELTA FRACTION OF QUANTITIES FOR PRODUCT SHIFTS*

Column names Six columns, three negative shifts N3, N2, N1 and three positive shifts, P1, P2, and P3.

Row names First three characters finished product codes.

Entries Percentage (as a fraction) of demand quantity Q0 as an upper bound. The quantities are based on price shifts of 1 percent, 3 percent, and 9 percent using an elasticity of 0.1 for light products gasoline, jet fuel, heating oil and diesel, and an elasticity of 0.3 for all other products.

  These column activities allow the shift of demands within a price range to help speed convergence in NEMS.

TABLE SADELPX *FRACTION OF PRICES FOR EACH QUANTITY SHIFT*

Column names One column, FACTORS

Row names Six rows, three negative shifts N1, N2, N3 and three positive shifts, P1, P2, and P3.

Entries Percentage (as a fraction) of price of import step R3 for imported products.

TABLE PRDAVOID *LIST OF PRODUCTS FOR AVOIDS*

Column names One column, SOWHAT

Row names Three character product codes.

Entries None.

(ngprod)

TABLE SPNGF   *SUPPLY STEP PRICES FOR NATURAL GAS TO REFINERY*

Column names   One column, ALLREG

Row names   Two character names, first character is N (negative shift) or P (positive shift), second character is a number from 1 to 8 representing steps on the supply curve.

Entries   Price increments in $/Mcf from reference well head price.

TABLE SQNGF   *SUPPLY STEP QUANTITIES FOR NATURAL GAS TO REFINERY*

Column names   Two columns, MAX and MIN

Row names   Two character names, first character is N (negative shift) or P (positive shift), second character is a number from 1 to 8 representing steps on the supply curve.

Entries   Volume increments in Bcf from reference quantity supplied.

TABLE SCVAL   *SUPPLY OF NATURAL GAS TO REFINERY*

Column names   Five columns, one for each refining region.

Row names   One row, VOL.

Entries   Volume estimate reference quantity supply in Bcf.

(prdexp)

TABLE EXPLIM   *LIMIT ON U.S. PRODUCT EXPORTS*

Column names   One column FIX

Row names   One row, @ implies all regions.

Entries   Fixed limit on product exports in Mbbl/cd

(unfinish)

TABLE UNFEQT   *COEFFICIENTS FOR UNFINISHED OIL IMPORTS*

Column names   Two columns, SLOPE, CONST, that describe the regression equation coefficients.

Row names   One row, XYZ

Entries   Slope and intercept for equation that correlates unfinished oil imports to crude input.

TABLE UNFIMP   *UNFINISHED OIL IMPORT SHARES*

Column names   Three columns, E, G, and Z. E and G represent import refining regions. Z represents multiplier of World Oil Price (WOP) for import prices.

Row names   Row UNF represents total unfinished oils. Rows NPP, HGM, and ARB are unfinished oil streams imported to U.S.

Entries   Coefficients under refining regions represent volume fractions. Column Z values are multipliers of WOP applied to import price.

TABLE UNFBND   *LIMITS ON UNFINISHED OIL IMPORTS*

Column names   Two columns, E and G, represent import refining regions.

Row names   Rows NPP, HGM, and ARB are unfinished oil streams imported to United States.

Entries   Volume limits on individual import streams.

TABLE INVLIM   *INVESTMENT LIMIT BY REFINING REGION (R)*

Column names   One column, MAX.

Row names   One character refining region code.

Entries   Limit of investment in millions of dollars.

TABLE INVUSA   ***INVESTMENT LIMIT FOR U.S.***

Column names   One column, MAX.

Row names   One row, @ implies all regions.

Entries   Limit of investment in millions of dollars.

(emish)

TABLE EMUNS   ***EMISSIONS FROM PROCESS UNITS***

Column names   Five columns, representing type of emission - VOC, CO1, NOX, SOX, and CAR
                      (Carbon).

Row names   First three characters process unit codes.

Entries   Emissions in Mlb/Mbbl for VOC, NOX, SOX. Units of MM lbs/Mbbl for CO1,
                      CO2, CAR.

TABLE EMFUM   ***EMISSIONS FROM FUEL BURNING***

Column names   Five columns, representing type of emission - VOC, CO1, NOX, SOX, and CAR
                      (Carbon).

Row names   First three characters stream codes burned in refinery fuel system.

Entries   Emissions in Mlb/Mbbl for VOC, NOX, SOX. Units of MM lbs/Mbbl for CO1,
                      CO2, CAR.

(fixcols)

TABLE (R)RCOL   ***LIST OF VARIABLES TO BE EXCLUDED FOR REGION (R)***

Column names   One column, FCC

Row names   Three character FCC operating mode names

Entries   A 1.0 indicates that column will be fixed at level of 0.0

A.3.2 Crude Oil Availability

Crude oil supply availability is provided from two sources: (1) domestic production from the Oil and Gas Supply Model (OGSM), and (2) foreign imports to each refining region with three supply step increments.

(domcrude)

TABLE DCRSUP   DOMESTIC CRUDE OIL IMPORTS BY OGSM REGION

Column names   One column for each OGSM region

Row names   Rows for selected years from Y90 to Y10.

Entries   Production volume in each OGSM region

These values are available from the NEMS restart file for a given scenario.

TABLE DCRSHR   SHARE BY LOWER 48 CRUDE GROUP

Column names   One column for each OGSM region

Row names   Five domestic aggregate crude groups plus Alaskan groups.

Entries   Fractional share of production volume in each OGSM region

TABLE CREXP   VOLUME OF CRUDE EXPORTS FROM U.S.

Column names   Two columns, CRDEXP represents crude oil exports, CRDSPR represents the SPR fill rate.

Row names   One row, VOL.

Entries   Export volume in Mbbl/cd

(crdimprt)

TABLE ICR(crt)(R)   *CRUDE OIL IMPORTS BY CRUDE GROUP*

Column names   Six columns, C1,Q1,C2,Q2,C3,Q3

Row names   NEMS year code

Entries   Columns Q(n) represent the availability in Mbbl/cd of each crude. Columns C(n) show the landed price in $/bbl at each refining region.

These values are available from the NEMS restart file for a given scenario.

(crdval)

TABLE ICRDAV   *CRUDE OIL QUALITIES*

Column names   Six columns, QTY, P, API, SUL, GR and S

Row names   Crude codes

Entries   Column QTY contains the projected availability in Mbbl/cd of each crude. These volumes are only used for determining the relative volumes of each crude oil. For reporting purposes, the table also includes data on the gravity, sulfur content, and 'grade' of each crude. The grade consists of two letters indicating the group LL, MH, HL, HH, HV, the first indicative of the sulfur content and the second, of API gravity.
Column S contains a code letter indicating the source of the crude where: A = Alaska, D = Domestic (i.e. lower 48 States), F = Foreign, S = U.S. strategic reserve

A.3.3 Other Raw Materials Availability

(ethanol)

TABLE SUPETH(D)   ETHANOL SUPPLY BY CENSUS DIVISION (D)

Column names   Six columns, C1,R1,C2,R2,C3,R3

Row names   NEMS Year code

Entries   Columns R(n) represent the availability in Mbbl/cd of Ethanol. Columns C(n) show the supply price in $/bbl in each Census division.

These values are available from the NEMS restart file for a given scenario.

(utility)

TABLES (R)UAP   UTILITY PURCHASES - REFINERY R

Column names   CST, MIN, MAX, FIX, FCT.

Row names   Codes for purchased utilities.

Entries   Column CST contains the purchase price of the utility in dollars per unit. Columns MIN, MAX, and FIX permit the application of limits to the amount purchased. In the current model, fuel (FUL) is not purchased and is excluded from the table[2]. Electricity is purchased in kWh and the process tables express power consumption in kWh per barrel. Purchase of steam (STM) may also be activated in this table, although general practice is to omit it or fix it at zero on the basis that refineries normally generate steam internally.

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[2]Purchased fuel may take the form of purchased natural gas input via *Tables (R)NCP*.

A.3.4 Product Imports

<p style="text-align:center">(prdimprt)</p>

TABLE IPR(PRD)(R) PRODUCT IMPORTS TO REGION (R)

Column names   Six columns, C1,R1,C2,R2,C3,R3

Row names   NEMS Year code

Entries   Column R(n) represent the availability in Mbbl/cd of each product (PRD) imported. Columns C(n) show the landed price in $/bbl at each refining region.

These values are available from the NEMS restart file for a given scenario.

TABLE NEMSRSD   IMPORTED RESIDUAL OIL SUPPLY QUANTITY AND PRICE

Column names   Two columns, R1B is fraction of step 1 import quantity, R1PR is multiplier of step 1 price in increments of 2 percent.

Row names   R2 through R9. Step name increments.

Entries   R1B is fraction of step 1 import level. R1PR is price level over step 1 price.

TABLE IMPLIM   LIMIT ON U.S. PRODUCT IMPORTS

Column names   One column MAX

Row names   One row, @ implies all regions.

Entries   Limit on product imports in Mbbl/cd

A.3.5 Product Demands

(demand)

TABLES (prd)   *PRODUCT DEMAND*

Column names   One column for each Census Division.

Row names   NEMS Year code.

Entries   Demand in Mbbl/cd

These demands are available from the NEMS restart file for a given scenario.

TABLE (D)PRDEXP   *PRODUCT EXPORTS*

Column names   One column VOL for volume exported

Row names   First three characters of export finished product codes.

Entries   Export volume in Mbbl/cd

TABLE EXPLIM   *LIMIT ON PRODUCT EXPORTS*

Column names   Two columns, YRPC and FIX for percent per year growth and fixed volume for the start year.

Row names   The start year, i.e. 1995

Entries   YRPC value is multiplier for growth. FIX column is in Mbbl/cd.

TABLE MULTEXPR   *PRICE MULTIPLIER FOR PRODUCT EXPORTS*

Column names   One column MULT.

Row names   Price

Entries   Multiplier for export price as function of step 1 import price.

TABLE RFNEXREG   ***REFINERY EXPORT REGION LIST***

Column names   One column REFINERY

Row names   One character code for export region.

Entries   Code for refining region.

TABLE CKSMIX   ***PRICE AND CONVERSION FACTOR FOR COKE***

Column names   Two columns, CKL and CKH for low sulfur and high sulfur coke, respectively.

Row names   OBJ, CKL, CKH, and COK

Entries   Price ratio for coke (multiplied by WOP). Conversion from tons to bbls, and 1.0 coefficient for material balance.

TABLE PRODLIST   ***LIST OF PRODUCT FOR DEMANDS***

Column names   One column DUMMY

Row names   First three characters of finished product codes.

Entries   None.

TABLE DEMMET   ***CHEMICAL METHANOL DEMAND***

Column names   One column CHEM for volume demand by chemical industry.

Row names   NEMS Year code.

Entries   Demand volume in Mbbl/cd

A.3.6 Crude and Product Transportation

Transportation links are specified for movements between all regions in the model; from domestic crude oil supply regions (Oil and Gas Supply Model - OGSM), crude oil import regions, refining regions, and demand regions. Modes of transportation are provided for marine vessel, pipeline, and barge/truck. Explicit pipelines were identified and aggregated where necessary to represent links from refining regions to Census divisions. The table name structure uses as the first two characters to represent the mode - TP for tanker movements, PL for pipeline and BV for Barge/Truck. Characters 3 and 4 are CR for crude oil, PR for products, and LG for LPG. Shipping costs are in $/bbl from a source to a destination region. The value must be negative to allow movement. A positive value indicates a disallowed movement. An explicit zero indicates a no cost movement.

(transit)

TABLES TPCR(S)   ***DOMESTIC CRUDE MOVEMENTS (TANKER) EX OGSM REGION (S)***

Column names   Crude group domestic, three characters.

Row names   First character is mode code; second character, code for destination refining region.

Entries   Shipping cost in $/bbl to destination region.

TABLES PLCR(S)   ***DOMESTIC CRUDE MOVEMENTS (PIPELINE) EX OGSM REGION (S)***

Column names   Crude group domestic, three characters.

Row names   First character is mode code; second character, code for destination refining region.

Entries   Shipping cost in $/bbl to destination region.

TABLES PLCR(R)   ***ALL CRUDE MOVEMENTS (PIPELINE) EX REGION (R)***

Column names   Crude group domestic and foreign, three characters.

Row names   First character is mode code; second character, code for destination region.

Entries   Shipping cost in $/bbl to destination region.

TABLES TPPR(R)   ***PRODUCT SHIPPING COSTS (TANKER) EX REFINERY R***

Column names   Codes for finished products that are shipped by tanker.

Row names   Transportation mode (one character) and destination region codes (one character) for a total of two characters.

Entries   Shipping cost in $/bbl.

TABLES PLPR(R)   ***PRODUCT SHIPPING COSTS (PIPELINE) EX REFINERY R***

Column names   Codes for finished products that are shipped by pipeline.

Row names   Transportation mode (one character) and destination region codes (one character) for a total of two characters.

Entries   Shipping cost in $/bbl.

TABLES BVPR(R)   ***PRODUCT SHIPPING COSTS (BARGE/TRUCK) EX REFINERY R***

Column names   Finished product codes for shipments by barge and/or truck.

Row names   Transportation mode (one character) and destination region codes (one character) for a total of two characters.

Entries   Shipping cost in $/bbl.

TABLES TPME(R)   ***METHANOL SHIPPING COSTS EX REFINERY R***

Column names   MET for methanol.

Row names   Transportation mode (one character) and destination region codes (one character) for a total of two characters.

Entries   Shipping cost in $/bbl.

TABLES TPET(D)   ***ETHANOL SHIPPING COSTS EX CENSUS DIVISION D***

Column names   ETH for ethanol.

Row names   Transportation mode (one character) and destination region codes (one character)
                    for a total of two characters.

Entries   Shipping cost in $/bbl.

TABLES PLLG(R)   ***LPG & PCF SHIPPING COSTS (PIPELINE) EX REFINERY R***

Column names   LPG and Petrochemical Feed (PCF) products that are shipped by pipeline.

Row names   Transportation mode (one character) and destination region codes (one character)
                    for a total of two characters.

Entries   Shipping cost in $/bbl.

TABLE MVCCAP   ***MARINE VESSEL (CRUDE) CAPACITY***

Column names   MAX for maximum capacity

Row names   TVC followed by transportation mode (one character) and CP

Entries   Capacity in thousands of dead weight tons (DWT)

TABLE PLCCAP   ***PIPELINE (CRUDE) CAPACITY***

Column names   MAX for maximum capacity

Row names   TPC followed by source region code (one character), transportation mode (one
                    character) and destination region code (one character)

Entries   Capacity in Mbbl/cd

TABLE MVPCAP   ***MARINE VESSEL (PRODUCTS) CAPACITY***

Column names   MAX for maximum capacity

Row names   TVP followed by transportation mode (one character) and CP

Entries   Capacity in thousands of dead weight tons (DWT)

TABLE BVPCAP   ***MARINE BARGE (PRODUCTS) CAPACITY***

Column names	MAX for maximum capacity
Row names	TVP followed by transportation mode (one character) and CP
Entries	Capacity in thousands of dead weight tons (DWT)

TABLE PLPCAP   *PIPELINE (PRODUCTS) CAPACITY*

Column names	MAX for maximum capacity
Row names	TPC followed by source region code (one character), transportation mode (one character) and destination region code (one character)
Entries	Capacity in Mbbl/cd

TABLE PLLCAP   *PIPELINE (LPG PRODUCTS) CAPACITY*

Column names	MAX for maximum capacity
Row names	TPL followed by source region code (one character), transportation mode (one character) and destination region code (one character)
Entries	Capacity in Mbbl/cd

A.3.7 Refinery Capacities and Operations

(:refproc)

TABLES CAP(R)   *REFINING CAPACITIES - REFINERY R*

Column names   CAP, PUL, AND BLD.

Row names   Process unit codes.

Entries   Column CAP contains existing unit capacities in thousands of barrels per calendar day capacity (MBbl/CD).

Column PUL contains fractional utilizations, which convert nameplate calendar day capacity to capacity available to the PMM model. The PUL factors represent actual utilizations and will vary from unit to unit, from region to region, and from case to case. These factors are used to control over optimization.

Column BLD contains a 1.0 if a unit can be expanded, otherwise a 0.0 means no capacity expansion for that unit.

(accunit)

TABLE ACUCUTS   *ATMOSPHERIC DISTILLATION YIELD FOR CRUDE OILS*

Column names   Three character crude stream group code AMH for Alaska North Slope, ALL for Alaska Light, D(ll) for domestic crude oils and F(ll) for imported crude oils.

Row names   Three character intermediate stream codes.

Entries   Volume fractions (bbl Output/bbl Input).

Atmospheric distillation refinery process unit. This unit characterizes the crude oils by differentiating the yields of the following fractions:

Name	Quality	Description	Stream Mnemonic code
GAS (C2 & lighter)			PGS
C3			CC3
IC4			IC4
NC4			NC4
LSR (C5-175)	LON	low octane	SRL
LSR (C5-175)	ION	intermediate octane	SRI
LSR (C5-175)	HON	high octane	SRH
LT NAPH (175-250)	P	paraffinic	LNP
LT NAPH (175-250)	I	intermediate	LNI
LT NAPH (175-250)	N	naphthenic	LNN
NAPH (250-325)	P	paraffinic	NPP
NAPH (250-325)	I	intermediate	NPI
NAPH (250-325)	N	naphthenic	NPN
H N/L J(325-375)	P/LF	paraffinic low freeze pt. index	JPL
H N/L J(325-375)	I/LF	intermediate low freeze pt. index	JIL
H N/L J(325-375)	N/LF	naphthenic low freeze pt. index	JNL
H N/L J(325-375)	P/HF	paraffinic high freeze pt. index	JPH
H N/L J(325-375)	I/HF	intermediate high freeze pt. index	JIH
H N/L J(325-375)	N/HF	naphthenic high freeze pt. index	JNH
KERO(375-500)	LF/LL/LS	low fz pt., low smoke pt., low sulfur	KLL
KERO(375-500)	LF/LL/HS	low fz pt., low smoke pt., high sulfur	KLH
KERO(375-500)	LF/HL/LS	low fz pt., high smoke pt., low sulfur	KHL
KERO(375-500)	LF/HL/HS	low fz pt., high smoke pt., high sulfur	KHH
KERO(375-500)	HF/LL/LS	high fz pt., low smoke pt., low sulfur	1LL
KERO(375-500)	HF/LL/HS	high fz pt., low smoke pt., high sulfur	1LH
KERO(375-500)	HF/HL/LS	high fz pt., high smoke pt., low sulfur	1HL
KERO(375-500)	HF/HL/HS	high fz pt., high smoke pt., high sulfur	1HH
HKERO(500-550)	LF/LL/LS	low fz pt., low smoke pt., low sulfur	3LL
HKERO(500-550)	LF/LL/HS	low fz pt., low smoke pt., high sulfur	3LH
HKERO(500-550)	LF/HL/LS	low fz pt., high smoke pt., low sulfur	3HL
HKERO(500-550)	LF/HL/HS	high fz pt., low smoke pt., low sulfur	3HH
HKERO(500-550)	HF/LL/LS	high fz pt., low smoke pt., low sulfur	4LL
HKERO(500-550)	HF/LL/HS	high fz pt., low smoke pt., high sulfur	4LH
HKERO(500-550)	HF/HL/LS	high fz pt., high smoke pt., low sulfur	4HL
HKERO(500-550)	HF/HL/HS	high fz pt., high smoke pt., high sulfur	4HH
DSL B(550-650)	LP/LC/LS	low pour pt., low cetane index, low sulfur	DLL
DSL B(550-650)	LP/LC/HS	low pour pt., low cetane index, high sulfur	DLH
DSL B(550-650)	LP/LC/MS	low pour pt., low cetane index, medium sulfur	DLM
DSL B(550-650)	LP/HC/MS	low pour pt., high cetane index, medium sulfur	DHM
DSL B(550-650)	LP/HC/LS	low pour pt., high cetane index, low sulfur	DHL
DSL B(550-650)	LP/HC/HS	low pour pt., high cetane index, high sulfur	DHH
DSL B(550-650)	HP/LC/LS	high pour pt., low cetane index, low sulfur	2LL
DSL B(550-650)	HP/LC/MS	high pour pt., low cetane index, medium sulfur	2LM
DSL B(550-650)	HP/LC/HS	high pour pt., low cetane index, high sulfur	2LH
DSL B(550-650)	HP/HC/LS	high pour pt., high cetane index, low sulfur	2HL
DSL B(550-650)	HP/HC/MS	high pour pt., high cetane index, medium sulfur	2HM
DSL B(550-650)	HP/HC/HS	high pour pt., high cetane index, high sulfur	2HH
ATMOS RED CRUDE	(A-M)	Type A through M	ARA-M

Data sources are the parent Turner Mason model data (vintage 1978) provided to ORNL by EIA (vintage 1985) and thereafter to ENSYS and in-house ENSYS assay data. These have been collected and compared from many sources and progressively built into the model. Assay data for stored SPR crude oils were obtained from U. S. Department of Energy, *"Strategic Petroleum Reserve Crude Oil Stream Quality Characteristics"*, August 1, 1990.

Table ACUCUTS yields have been volume balanced to 0; i.e., total yields equal 1.0 exactly. Process losses are accounted for using *Tables PFAREP* and *RELREP*.

TABLE ACUPOL	*ATMOSPHERIC DISTILLATION NON-YIELD VALUES FOR CRUDE OILS*

Column names   OVC for variable operating cost and LOS for losses

Row names   Three character crude stream group codes

Entries $/bbl for costs. Volume fractions (bbl Output/bbl Input) for LOS.

TABLE ACUUTI	*ATMOS. DISTILLATION UTILITY CONSUMPTION FOR CRUDE OILS*

Column names   KWH and STM

Row names   Three character crude stream group codes

Entries   Electricity (kWh) and steam (lb/bbl).

TABLE INVLIM	*INVESTMENT LIMIT BY REGION*

Column names   MAX

Row names   One character region code and @ for total U.S.

Entries   Million dollars of total capacity expansion investment.

(setrows)

TABLES (R)POL	*REFINERY POLICY ROW CONSTRAINTS - REFINERY R*
Column name	TYPE.

Row names   The three character row names correspond to processing constraints and are discussed below.

Entries   A non-blank entry in the TYPE column causes generation of a row of corresponding type, either a max, min or fixed.

The process constraint rows in the current formulation are as follows:

> SVR, SVH, SVL, SVC limit severity on FCC, RFH, RFL and RFC respectively.
>
> PFH, PFL, PFU, PFF limit H_2S, very low (0.3 percent), low (1 percent), and high (3 percent) sulfur fuel oil[3] to refinery fuel respectively,
>
> FLX limits the use of flexicoking activities (which are actually depicted as modes of operation of the fluid coker) to the level of known flexicoker capacities,

MSL, MSR, FCR, MSD, MSZ, FCU are used to control FCC activities:

- MSL: maximum use of light olefin modes
- MSR: maximum low sulfur residue feed
- FCR: maximum high sulfur residue feed
- MSD: maximum distillate feed
- MSZ: maximum use of ZSM high octane catalyst
- FCU: maximum ultra-low sulfur feed operations

MXU, L00, L05, H00, H05, C05, RCU control reformer operations:

- MXU: maximum use of R62 high octane catalyst
- L00, L05: maximum use of 100 and 105 severity on the RFL unit
- H00, H05: maximum 100 and 105 severity on the RFH unit
- C05: maximum 105 severity operation of the RFC unit
- RCU: maximum ultra-low pressure and low benzene operations on the RFC unit

DKU and DDU limit deep desulfurization of kerosene/heavy kerosene and of diesel/light cycle oil in the distillate desulfurizer.

(limpol)

TABLE UNITPOL   *PROCESS UNITS WITH POLICY ROW CONSTRAINTS*
Column name   DUMMY

Row names   The three character row names correspond to processing units that have policy limits. These units are described below as tables LIM(uns).

Entries   None.

Note that the entries in tables LIM(uns), which represent fraction of throughput, will appear as entries in the column Z(r)FLO(uns). The current set of (uns) are:

> FCC, RFL, RFH, RFC, DDS, FUM, KRF, and ETH.

---

[3]PFL, PFU and PFB are used to set the amount of residual fuel input to refinery fuel, generally based on historical data. If left uncontrolled, resid input to refinery fuel can swing wildly and unrealistically.

TABLES LIM(UNS)   REFINERY POLICY LIMITS

Column name   Three character policy limit code.

Row names   One character row names correspond to refining regions.

Entries   A value representing a volume fraction of the process unit capacity for the restriction, i.e. 0.99 stipulates that this mode will be limited to 99% of the units total capacity. The total capacity is the sum of the existing capacity, builds, and new capacity expansion.

(refproc)

TABLE INV   INVESTMENT PARAMETERS REFINERY UNITS

Column names   INV, FXOC, CAPREC.

Row names   Process unit codes.

Entries   Column INV contains investment in $/bbl, FXOC has the fixed operating cost in $/bbl, and CAPREC has the daily annualized investment cost.

This table provides the investment parameters required for the total annualized cost of investment and fixed cost coefficients which are placed on the process unit expansion activities. These values are generated offline.

The capital recovery factor is built up from cost of capital, economic life, depreciation life and tax rate. Straight-line depreciation is assumed and depreciation is considered as an expense to be offset as a tax credit against the tax burden. The calculated capital recovery factor is on an after-tax basis and the resultant investment purchase vector costs are on the same basis.

(nrfplant)

TABLE INVMOH   INVESTMENT PARAMETERS METHANOL PLANT

Column names   INV, CAPREC, FXOC, TOTEXP

Row names   Process unit MOH.

Entries   Column INV contains investment in $/bbl, CAPREC has the daily annualized investment cost, FXOC has the fixed operating cost in $/bbl, and TOTEXP is the sum of CAPREC and FXOC.

This table provides the methanol plant investment parameters required for the total annualized cost of investment and fixed cost coefficients which are placed on the process unit expansion activities. These values are generated offline.

TABLE GASPLT	*GAS LIQUIDS PROCESSING PLANT*
Column names	Five columns, (R)01 for each refining region.
Row names	DGP, (gas plant feed), PGS, CC3, IC4, NC4, NAT, (Natural Gas Liquids NGL's), OVC operating cost, LOS processing loss.
Entries	Gas plant feed in Bcf/day, yields in Mbbl/Bcf.

TABLE GASSHFT	*ALLOW SHIFT OF ETHANE AND PROPANE TO NATURAL GAS*
Column names	Two columns, SC2 for shift of ethane to natural gas, SC3 for shift of propane to natural gas.
Row names	CC1, (natural gas), LOS processing loss, and OBJ.
Entries	Amount shifted from gas plant yield to natural gas in Mbbl/Bcf. OBJ represents credit for gas plant operating costs.

TABLE GASCAP	*CAPACITY OF GAS PLANT*
Column names	Five columns, (R)01 for each refining region.
Row names	CC1, dry gas supply limit, FAC, gas residue factor, CAP, gas plant capacity, LIM, limit on propane shift.
Entries	Gas plant feed and CAP in Bcf/day, FAC is volume fraction, LIM in Mbbl/cd.

TABLE MOHPLT	*METHANOL PLANT*
Column names	Five columns, (R)01 for each refining region.
Row names	CC1, (natural gas feed), MET methanol output, OVC operating cost.
Entries	Natural gas plant feed in MMcf/day, yields in Mbbl/cd of methanol.

TABLE MOHCAP   ***CAPACITY OF METHANOL PLANT***

Column names   Five columns, (R)01 for each refining region.

Row names   One row, CAP.

Entries   Plant capacity in Mbbl/cd.

A.3.8 Product Blending and Specifications

(gasoblnd)

TABLES Q(r)GSL   *REGIONAL GASOLINE SPECIFICATIONS*
Column names   Finished gasoline codes

Row names   Two character quality codes, followed by X (maximum) or N (minimum).

Entries   Columns contain specification levels for the corresponding qualities.

TABLES (R)SSR   *SUBSPEC RFG QUALITY SPECIFICATIONS*
Column names   SSR and RFH

Row names   Product qualities codes using six characters; the first three are RFG, the next two
                    are quality codes, the last is either X for maximum or N for minimum.

Entries   Product quality specifications. The quality coefficients of SSR reflect a
                    reformulated gasoline that is to be blended with 7.8% Ethanol and therefore has a
                    lower octane and other qualities to accommodate the quality barrels delivered by
                    Ethanol.

TABLES (R)SST   *SUBSPEC TRG QUALITY SPECIFICATIONS*
Column names   SST and TRH

Row names   Product qualities codes using six characters; the first three are TRG, the next two
                    are quality codes, the last is either X for maximum or N for minimum.

Entries   Product quality specifications. The quality coefficients of SST reflect a traditional
                    gasoline that is to be blended with 7.8% Ethanol and therefore has a lower octane
                    and other qualities to accommodate the quality barrels delivered by Ethanol.

TABLE GCB   *GASOLINE QUALITIES (EX OCTANE)*

Column names   Quality codes

Row names   Intermediate product codes

Entries   Blending values

TABLE MCOBV   *GASOLINE COMPONENT OCTANE RATINGS*

Column names   Eight columns, R00, R05, R15, R30, M00, M05, M15, M30 of which the PMM
                      model uses just two, R00 and M00 (lead-free research and motor octanes)

Row names   Intermediate stream gasoline component codes

Entries   Research and motor octane blending numbers for each component at four levels of
                      lead.
                      Since the **PMM** model reduces all gasoline grades to an equivalent lead-free basis,
                      the only entries relevant in these "BV" tables are those under unleaded ROO and
                      MOO octane columns. Non-zero entries are added to the base octanes from *Table
                      MCOBV* and used in the relevant gasoline blend.

TABLE GSPETH   *MINIMUM OXYGEN FRACTION IN RFG*

Column names   One column, RE

Row names   One row, RFGN

Entries   Minimum fraction of oxygen in reformulated gasoline. EPA regulation requires
                      15% in 1995 and 30% thereafter.

(distblnd)

TABLE Q(r)DFO   *REGIONAL DISTILLATE/FUEL OIL SPECIFICATIONS*

Column names   Finished distillate fuel oil codes; Distillates JTA, N2H, DSL and residual fuel oils N6I,N6B.

Row names   Two character quality codes, followed by X (maximum) or N (minimum).

Entries   Columns contain specification levels for the corresponding qualities.

When a compact Level 2 formulation is invoked, the Distillate Desulfurization (DDS) and Deep hydrotreating (DHT) process units column activities are deleted and the distillate fuel oil blending submatrices are supplemented with blending activities that reflect the untreated streams, utilities and other inputs needed to produce a barrel of hydrogen treated stream. The following tables are used to supply the appropriate coefficients. The letters (DFO) represent the five distillate fuel oil products (JTA= Jet Fuel, N2H = No. 2 Heating Oil, DSL = Low Sulfur Diesel fuel, N6I = Low Sulfur Residual Oil, N6B = High Sulfur Residual Oil).

TABLES FN(DFO)   *UNTREATED STREAM QUALITIES FOR (DFO) FUEL BLENDING*

Column names   Product qualities codes.

Row names   Three character untreated intermediate stream codes.

Entries   Product quality specifications. The Sulfur coefficients are the difference between the product specification and the component sulfur content on a weight basis.

TABLES BX(DFO)   ***DDS TREATED STREAM QUALITIES & INPUTS FOR (DFO) FUEL BLENDING***

Column names   Three character pseudo codes for the combination of the untreated/treated stream combination JTA = J01 to J20, N2H = Q01 to Q67, DSL = L01 to L65, N6I = R01 to R60, N6B = S01 to S59.

Row names   Product qualities codes using three characters; the first two are quality codes, the last is either X for maximum or N for minimum. Other rows represent the utilities, operating cost, capacity of the DDS unit and untreated intermediate stream inputs required.

Entries   Product quality specifications. The Sulfur coefficients are the difference between the product specification and the component sulfur content on a weight basis.

TABLE BHDSL   ***DHT TREATED STREAM QUALITIES AND INPUTS FOR DSL FUEL BLENDING***

Column names   Three character pseudo codes for the combination of the untreated/treated stream combination from the DHT unit = H01 to H24.

Row names   Product qualities codes using three characters; the first two are quality codes, the last is either X for maximum or N for minimum. Other rows represent the utilities, operating cost, capacity of the DHT unit and untreated intermediate stream inputs required.

Entries   Product quality specifications. The Sulfur coefficients are the difference between the product specification and the component sulfur content on a weight basis.

(recipes)

TABLE RCP   RECIPE BLEND CONTROL

Column names	Two columns, A and CST, plus intermediate stream codes
Row names	Finished product codes followed by a number. The intention is to provide for different recipes for a given product. The row ending in a zero must be present.
Entries	A non-blank entry in column A activates the corresponding blend. Column CST contains any cost met in making the blend, e.g. TEL cost for production of aviation gasoline. The remaining columns contain the volume fractions of the components making up the blend.

TABLE TRSPMM   PIPING NETWORK AND MISCELLANEOUS TRANSFERS

This unit allows the transfer of one refinery stream to another - the transfer vector names are in the form *xxxyyy* where *xxx* is the source stream code and *yyy* is the destination stream code.

Selected refinery minor finished product sales transfers are included in *Table TRSPMM*, namely:

- optional condensation of C_3 and C_4 streams into sales LPG. This is useful where data are not separately available for propane and butane sales (Would normally be de-activated through asterisks in *Column 1*.)
- condensation of benzene, toluene, and xylene into AROmatics and BTX sales.

Table TRSPMM is also used for condensation of feed streams for several of the key refinery process units. This economizes on detail in refinery process unit representations at the expense of adding a relatively small number of LP transfer vectors.

The original transfers were derived from the parent Turner Mason model provided to EIA and has been amended and extended by ENSYS and EIA.

TABLE CKSMIX   SALABLE COKE RECIPES

Column names	Two columns, representing low sulfur coke and high sulfur coke.
Row names	Coke stream codes and Product coke, COK. OBJ is scaled selling price for coke.
Entries	Price for coke in 1987 dollars divided by WOP. Conversion from tons to barrels of salable coke.

TABLE BLNSP(D)   *RECIPE BLENDING FOR KEROSENE AND RESIDUAL OIL TO UTILITIES*

Column names   Three columns, KER, N67, and N68.

Row names   Stream codes for components of each blend and blended product codes.

Entries   Volume fraction of each component in final blends.
                        A table exists for each Census division.

TABLE BLOX(D)YXX   *RECIPE BLENDS FOR HIGH OXYGEN GASOLINES IN CENSUS (D)*

Column names   Four columns, E85, M85, TRH, and RFH.

Row names   Stream codes for components of each blend and blended product codes plus OBJ row.

Entries   Volume fraction of each component in final blends. Row OBJ contains tax credit for blends.

A.3.9 Refining Technology

The tables described in this section are essential to the representation of refining technology. The table entries are in volume fractions (bbl Output/bbl Input) except for costs ($/bbl) and utilities for electricity (kWh/bbl) or steam (lb/bbl). All the table names and descriptions in this section contain refinery process unit yields <u>only</u> and are named (uns)REP -- where REP stands for **RE**finery **P**rocess. Three additional sets of tables exist that with a name structure of (uns) POL, (uns)UTI, and (uns)CAP. The rows in these tables contain the <u>column</u> names from table (uns)REP. The POL tables contain columns listing the policy rows (OVC, LOS, etc.). The UTI tables contain columns listing the utilities (KWH, STM). The CAP tables have single column named CAP with entries for the operating mode capacity consumption.

(refproc)

TABLE VCUREP   CRUDE VACUUM DISTILLATION UNIT
Vacuum distillation refinery process unit. This unit separates atmospheric distillation tower bottoms into the following fractions:

- Heavy diesel cut (650-690 degrees Fahrenheit), according to sulfur content, pour point and cetane index
- Light gas oil (690-800 degrees Fahrenheit), according to sulfur content
- Heavy gas oil (800-1050 degrees Fahrenheit), according to sulfur content
- Vacuum residuum (1050 + degrees Fahrenheit), according to sulfur content, with the high metal/asphaltene content residua being undercut below 1050 degrees Fahrenheit.

The atmospheric residua which feed the vacuum distillation unit tower are classified according to similar API gravity, sulfur content, viscosity, and gas oil content into 13 categories. These provide sufficient differentiation for the RYM regional model:

Table A3. Atmospheric Residual Oil Qualities

Stream Code	Atm Resid Sulfur	Atm Resid API
ARA	3.10	17.5
ARB	2.67	17.7
ARC	1.54	19.9
ARD	1.30	12.4
ARE	0.87	19.3
ARF	0.34	25.4
ARG	0.32	22.8
ARH	2.70	14.0
ARI	0.32	17.1
ARJ	1.22	21.7
ARK	0.70	21.2
ARL	4.54	8.2
ARM	3.92	15.0

Data sources are based on in-house ENSYS data and ENSYS calculations and estimates.

All the following tables described in this section are located in file name **(refproc)**. The table entries are in volume fractions (bbl Output/bbl Input) except for costs ($/bbl) and utilities for electricity (kWh) or steam (lb/bbl).

(refproc)

TABLE KRDREP   DELAYED COKER

Delayed coking of vacuum residua and FCC decant oil streams produce petroleum market coke and lighter products. Care has been taken to weight balance the yields and to match both low and high sulfur coke productions against actual regional makes. The naphtha fractions produced are of necessity stabilized and reformed (the annualized cost of stabilizing the C5-175 fraction is included in the OVC unit operating cost

row). The middle distillates require stabilization and hydrotreating before blending to distillate fuels. The coker gas oil produced may be desulfurized and routed either to FCC feed or residual fuel oil blending.

Data sources are in-house ENSYS data gathered from a variety of published sources, including J. H. Gary and G.E. Handwerk, *"Petroleum Refining Technology and Economics"*, 1975 and the EIA RYM model data as provided to ORNL by EIA and thereafter to ENSYS.

TABLE KRFREP   FLUID AND FLEXI COKER

Fluid coking of vacuum residua to produce coke and lighter products. Care has been taken to weight balance the yields and to match both low and high sulfur coke productions against actual regional makes. The naphtha fractions produced are of necessity stabilized and reformed (the annualized cost of stabilizing the C5-175 fraction is included in the OVC unit operating cost row). The middle distillates require stabilization and hydrotreating before blending to distillate fuels. The coker gas oil produced may be desulfurized and routed either to FCC feed or residual fuel oil blending.

Flexicoking is also represented in this program module, reflecting the gasification of the coke produced to fuel gas.

The data sources include the following:

> Busch, R. A. et al, *"Flexicoking + Hydrotreating Processes for Quality Products"*, presented at the AIChE Spring Meeting, April 1979.

> Blaser, D. E. et al, *"Fluid Coking/Flexicoking, a Flexible Process for Upgrading Heavy Crudes"*, Exxon Research and Engineering Company, October 26, 1978.

TABLE SDAREP   PROPANE DE-ASPHALTER

Residua produced by the vacuum distillation unit are solvent extracted to produce asphalt, FCC feed, and heavy fuel oil blending components. Data sources are in-house ENSYS data gathered from a variety of published sources.

Because of the limited number of vacuum residua depicted in the model, it is not possible for this unit to convert one residuum into another, plus gas oil and retain reasonable volume, weight and sulfur balances. Accordingly, the model activities represent only the partial conversion of one residuum into another.

TABLE VBRREP   VISBREAKER

Visbreaking of vacuum residua to produce lowered viscosity residual blendstocks. Visbreaking is a mild thermal cracking process and produces a proportion of lighter products.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data. The range of potential feeds has been extended by ENSYS.

TABLE NDSREP   NAPHTHA HYDROTREATER

Hydrotreating of various refinery naphtha streams prior to reforming or blending with naphtha sales. The data source is the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data.

TABLE DDSREP   HEAVY NAPHTHA, KEROSENE, AND MIDDLE AND HEAVY DISTILLATE DESULFURIZER

This unit represents the desulfurization of a broad and comprehensive set of refinery streams, ranging from 325 IBP to 690 EP degrees Fahrenheit. Various degrees of desulfurization intensity are also represented, ranging from normal (90 percent desulfurization) to the ultra low sulfur mode for blending to meet 0.05 weight percent diesel fuel. The different modes are also reflected through the use of the CAP row, with coefficients ranging from 0.8 to 3.33 to represent the different catalyst to oil ratios required to achieve different degrees of desulfurization. The increase in the CAP coefficients is tantamount to forcing a reduction in unit throughput and space velocity to reduce the sulfur level of the product stream.

High and medium and low sulfur (adequate for conventional, but not ultra-low sulfur fuels) feeds are included in ***Table DDS***. These include virgin heavy naphtha; light and heavy kerosene fractions; diesel and Number 2 fuel oil streams; FCC light cycle oil streams, reflecting different FCC conversion levels and gas oil feed sulfur levels; middle distillate furfural extraction unit raffinates; de-waxed diesel fractions; and select JP8-X and JP11 cuts from specialty naphthenic crude oils used for producing high density jet fuels.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and ENSYS analysis of published sources. These include:

Shih, S. S. et al, *"Deep Desulfurization of Distillate Components"*, Paper 264B presented at the AIChE Fall Meeting, November 1990.

McCulloch, D. C. et al, *"Higher Severity Diesel Hydrotreating"*, Paper AM-87-58 presented at the NPRA Annual Meeting, March 1987.

Johnson, A. D., *"Study Shows Marginal Gains from Hydrotreating"*, Oil & Gas Journal, May 30, 1983, p.78.

Yoes, J. R. and Asim, M. Y., *"Confronting New Challenges in Distillate Hydrotreating"*, Paper AM-87-59 presented at the NPRA Annual Meeting, March 1987.

TABLE FDSREP   GAS OIL DESULFURIZER/MILD HYDRO-CRACKER

This unit represents the desulfurization of light and heavy gas oils, including coker gas oil, to produce hydro-treated gas oils for FCC feed and heavy fuel oil blending. A light hydrocracking mode is also represented to produce a very low sulfur content gas oil for the purpose of removing sulfur from light and heavy catalytic gasolines in order to produce reformulated gasoline at the 50 ppm sulfur level.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data. The mild gas oil hydrocracking data were obtained from:

> Belt, B. A., *"New Approaches to FCC Hydrotreating"*, Paper 44C presented at the AIChE Spring Meeting, March 1990.

TABLE RDS   RESIDUUM DESULFURIZER

This unit represents the desulfurization of vacuum and atmospheric residua, gas oils and asphalt. Two levels of desulfurization are represented: 77 percent and 85 percent desulfurization. The heavy products are generally in the 0.5- to 1.0-weight percent sulfur content level and may be used as low sulfur residual fuel oil blendstocks, or to provide the FCC with feed for residuum cracking.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS , in-house ENSYS data, and other published sources, including the following:

> Billon, A. et al, *"Hyvahl F and T Processes for High Conversion and Deep Refining of Residues"*, Paper AM-88-62 presented at the NPRA Annual Meeting, March 1988.

TABLE LUB   LUBE OIL AND WAX PRODUCTION

This is a rather simplified representation which transfers 800-1050 degree Fahrenheit hydrofined gas oil and paraffin base gas oil to combined lube oil and wax sales. The unit contains the estimated fuel, power, steam, and operating cost requirements to produce these products.

Data sources are the EIA RYM model data.

TABLE HCR   DISTILLATE HYDROCRACKER

This process unit hydrocracks a range of distillates to produce either predominantly light, medium, and heavy naphtha for gasoline blending and reformer feed, or distillate for jet fuel and middle distillate products (particularly low sulfur blends). These two modes of operation require large quantities of hydrogen, from 1800 to 3600 cf/bbl of feed, depending on the feedstock and severity of the operation. The primary feeds are light and heavy gas oils:

LGP, LGL,   paraffinic, low, medium, and high sulfur light gas oils,

LGM, and LGH: 690 to 800 degrees Fahrenheit.

HGP, HGL,   paraffinic, low, medium, and high sulfur heavy gas oils,
HGM, and HGH: 800 to 1050 degrees Fahrenheit.

LC6:   high aromatic content, high sulfur light cycle oil

The lighter virgin distillates may also be routed to hydrocracker feed. These streams are gathered into feeds
HFL and HFH in *Table TRSPMM* as follows:

DSL B(550-650)LP/LC/LS	CRACKER FD LO S	DLLHFL
DSL B(550-650)LP/HC/LS	CRACKER FD LO S	DHLHFL
DSL B(550-650)LP/HC/HS	CRACKER FD HI S	DHHHFH
DSL B(550-650)HP/LC/LS	CRACKER FD LO S	2LLHFL
DSL B(550-650)HP/HC/LS	CRACKER FD LO S	2HLHFL
DSL C(650-690)LP/LC/LS	CRACKER FD LO S	6LLHFL
DSL C(650-690)LP/HC/LS	CRACKER FD LO S	6HLHFL
DSL C(650-690)HP/LC/LS	CRACKER FD LO S	7LLHFL
DSL C(650-690)HP/HC/LS	CRACKER FD LO S	7HLHFL
DIST(550-650) HS/LM	CRACKER FEED	DHLHFH
DIST(650-690) HS/LM	CRACKER FEED	6HLHFH
LGO FD(690-800) PFFN	CRACKER FD LO S	LGPHFL
LGO FD(690-800) LO S	CRACKER FD LO S	LGLHFL
LGO FD(690-800) HI S	CRACKER FD HI S	LGHHFH
COKER DIST (375-620)	CRACKER FD HI S	CKDHFH
COKER DIST (375-570)	CRACKER FD HI S	CCLHFH
COKER DIST (575-620)	CRACKER FD HI S	CCHHFH
CKR DIST RAFFINATE	CRACKER FD HI S	CLRHFH
CKR DIST EXTRACT	CRACKER FD HI S	CLEHFH

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house
ENSYS data. Published sources include the following:

Alcock, L. et al, *"BP Hydrocracks For Mid Distillates"*, Oil & Gas Journal, July 6, 1974,
p.102.

J. H. Gary and G.E. Handwerk, *"Petroleum Refining Technology and Economics"*, 1975.

Logwinuk, A. K., *"The ART Process Offers Increased Refinery Flexibility"*, Petroleum
Review, October 1985, p.41.

TABLE HCV   RESIDUUM HYDROCRACKER

This unit hydrocracks a range of vacuum residua producing a synthetic crude containing the full range of streams from light gas oils to gas oil and bottoms fractions. Hydrogen consumption is of the order of 1500 cf/bbl net residuum feed. The feedstocks are vacuum resids produced by the vacuum distillation unit VCU and subsequently condensed to a smaller set of streams in *Table TRSPMM*:

VAC RES	V HI SUL(3.8)	RSV
VAC RES	HI SUL (2.3)	RSH
VAC RES	INT SUL (1.5)	RSM
VAC RES	LO SUL (0.9)	RSI
VAC RES	VLO SUL (0.5)	RSL

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data. Published sources include:

Seko, M. et al, *"Super Oil Cracking (SOC) Process for Upgrading Vacuum Residues"*, Paper AM-88-61 presented at the NPRA Annual Meeting, March 1988.

Suchanek, A.J. and Christian, B. R., *"New Diversity Shown for the ART Process"*, Paper AM-88-74 presented at the NPRA Annual Meeting, March 1988.

Boening, R.E. et al, *"Recent Data on Resid Hydrocracker", Hydrocarbon Processing"*, September 1987, p.59.

TABLE HCN   NAPHTHA HYDROCRACKER

This unit consumes of the order of 1500 cf/bbl of hydrogen to hydrocrack naphthas. The naphthas are hydrocracked to produce primarily propane, isobutane, and normal butane. While this process has a history of commercial operation, it is not in wide-spread use. However, the advent of reformulated gasoline has renewed interest because the naphtha hydocracker functions to supply feed to alkylation and oxygenate process units. The propane may be de-hydrogenated to produce alkylate feed or the ether DIPE, the isobutane may be used directly for alkylation plant feed or de-hydrogenated to produce isobutylene to make MTBE or ETBE and the normal butane may be isomerized to produce isobutane. An additional fit with reformulated gasoline production is the fact that naphtha is subtracted from the reformer feed, thus lowering the quantities of benzene and aromatics that are produced.

Data sources are based on in-house ENSYS data, calculations and estimates.

TABLE TCG   THERMAL CRACKER-LIGHT GAS STREAMS
TABLE TCN   THERMAL CRACKER-(250-375) NAPHTHA STREAMS
TABLE TCV   THERMAL CRACKER-DESULFURIZED VACUUM GAS OIL STREAMS

The above process units are olefin plant petrochemical units which are characteristic of petrochemical plant operations. They are included in the model because they have potential relevance to the production of reformulated gasoline since they produce light olefins (ethylene, propylene and iso and normal butylenes) for alkylation plant feed and (the isobutylene) for MTBE and ETBE plant feed. They can also be used directly in any representation of the petro-chemical sector via the **PMM** "oxy-refinery" feature.

Process unit TCG may use ethane, propane or iso or normal butanes as feedstocks.

Process unit TCN consumes reformer feed naphtha (which would otherwise produce high aromatics content reformate).

Process unit TCV consumes desulfurized light and heavy gas oils produced by process unit FDS.

Data sources are based on published data:

> Zdonik, S. B. and Meilun, E. C., *"Olefin Feedstock and Product Flexibility"*, Chemical Engineering Progress, September 1983.
>
> Barendrect, S. et al, *"BUTACRACKING - Steam Cracking For Butane Upgrading"*, Paper 26E, presented at the AIChE Spring Meeting, April 1991.

TABLE JPS   JET FUEL CUT POINT ADJUSTMENT
This unit adjusts the cut point of the 375 to 500 degree Fahrenheit atmospheric tower kerosene cut to a 470-degree endpoint cut in order to make the freezing point specification for JP-8 and Jet A/A-1 jet fuels in the optimal manner conforming to industry practice. This can be regarded as a "pseudo-unit" corresponding to an atmospheric tower cut point adjustment when making a jet fuel run, or as a real side-stream fractionator. Data sources are based on in-house ENSYS data, calculations, and estimates.

TABLE JFP   LIGHT CYCLE OIL/COKER DISTILLATE PRE-FRACTIONATION
This is a specialty unit which prepares cracked aromatic streams for furfural unit extraction and hydrogenation (units FEX and HDN) for the production of high density jet fuels. High density jet fuels are experimental fuels which increase the flight range of volume limited aircraft. The cuts are 70 Overhead/30 Bottoms for LCO and 80 Overhead/20 Bottoms for coker distillate. The fractionated streams may also be routed to conventional distillate products and heavy fuel oils, thus increasing blending flexibility.

Data sources are based on in-house ENSYS data, calculations and estimates.

TABLE DHT   DISTILLATE DEEP HYDROTREATER

This process hydrogenates middle distillate aromatics and achieves deep desulfurization (to levels beyond those available with conventional distillate desulfurization, see *Table DDS*). Potential feeds include kerosene, diesel, and light cycle oils, covering the boiling range from 375 to 650 degrees Fahrenheit. The deep hydrotreating process can be used to raise jet fuel smoke point, raise diesel fuel cetane number, and produce ultra low sulfur/aromatics fuels (less than 0.05 percent sulfur and less than 10 percent aromatics content). Conventional distillate desulfurization units, on the other hand, are generally capable of reducing the aromatics content by only 1 to 2 percent aromatics. This process is an alternative to middle distillate furfural extraction, but avoids the problem of aromatics disposition. However, hydrogen consumption is high, from 750 to 900 cf/bbl feed for virgin distillates and from 1100 to 2100 cf/bbl for the more aromatic FCC cycle oils.

This process may be linked to the production of reformulated gasoline since some reformulated gasoline production schemes involve very high conversion FCC operations, which in turn increase the aromaticity of the light cycle oils produced. Deep distillate hydrotreating makes it possible to more easily produce specification diesel fuel under these circumstances, without downgrading cycle oils to heavy residual fuel oil.

Data sources are in-house ENSYS data and published data, including:

> Suchanek, A.J. and Hamilton, G. L., *"Diesel by SYNSAT - Low Pressure/Low Cost/Low Aromatics"*, Paper AM-91-35 presented at the NPRA Annual Meeting, March 1991.

> Nash, R.M., *"Meeting the Challenge of Low Aromatics Diesel"*, Paper AM-89-29 presented at the NPRA Annual Meeting, March 1989.

TABLE FEX   DISTILLATE FURFURAL EXTRACTION

This process extracts aromatics from distillate with the aromatics being concentrated in the furfural phase. Furfural extraction also lowers the sulfur content of the treated raffinate. Potential feeds include kerosene, diesel fractions, light cycle oils, and coker distillates, covering the boiling range from 375 to 690 degrees Fahrenheit. The reduction in distillate aromatics content can be used to raise jet fuel smoke point and/or raise diesel fuel cetane number and produce ultra low aromatics fuels (less than 10 percent aromatics content). Conventional desulfurization units, on the other hand, are generally capable of reducing the aromatics content by only 1 to 2 percent.

This process is an alternative to middle distillate deep hydrotreating, but necessitates the disposition of the aromatics produced, generally by attempting to dump to other distillates, or by using them to reduce the viscosity and perhaps the sulfur content of heavy residual fuel oils. However, the significant hydrogen

consumption associated with deep hydrotreating is avoided, ranging from 750 to 900 cf/bbl feed for virgin distillates and from 1100 to 2100 cf/bbl for the more aromatic FCC cycle oils.

The furfural extraction unit is also used to extract aromatics from virgin distillate streams, FCC cycle oil and coker distillate overhead cuts prior to the hydrogenation of the aromatic extracts to produce distillate range naphthenes. The naphthenes are blended to produce experimental high density jet fuels.

Data sources are based on ENSYS calculations and estimates and in-house ENSYS data. Published data sources include:

> Refinery Handbook, Furfural Extraction of Gas Oils, Hydrocarbon Processing, September 1982, p.183.

> Benham, A. L. et al, *"REDEX Process Extracts Aromatics"*, Hydrocarbon Processing, September 1967, p.135.

TABLE HDN   HIGH DENSITY JET FUEL HYDROPROCESSING

This unit hydroprocesses several types of streams to produce highly naphthenic blending components for high density jet fuel. The feedstocks are:
- light pyrolysis fuel oil
- FCC light cycle oil 70 percent overhead cuts
- the corresponding light cycle oil furfural extracts
- coker distillate 80 percent overhead cuts
- the corresponding coker distillate furfural extracts
- the aromatic furfural unit extracts produced from virgin distillate streams, ranging from 375 to 500 degree Fahrenheit boiling range.

This unit employs severe processing conditions and the fuel, power, and steam costs are high. Hydrogen consumption can reach 2400 cf/bbl for the virgin distillate stream aromatic extracts and 3500 cf/bbl for the other highly refractory streams.

The former Soviet Union has utilized high density jet fuels to increase the mission range of volume-limited military jet aircraft. Data were gathered and pieced together from several published Russian and other foreign sources with the help of ORNL. Other published sources used include:

> Korosi, A. et al, *"Hydroprocessing of Light Pyrolysis Fuel Oil for Kerosene Jet Fuel"*, Technical Report AFWAL-TR-80-2012, February 1980.

> Hall, L. W., *"Production of Jet Fuel Samples from Light Cycle and Light Pyrolysis Oil"*, Technical Report AFWAL-TR-87-2001, March 1987.

TABLE DEW   CATALYTIC GAS OIL DEWAXING

This is a catalytic process based on the Mobil process for converting the paraffin wax components in intermediate and heavy middle distillate streams in order to meet the freezing and pour point specifications for low pour distillate and heavy fuel oils. This process is an alternative to solvent dewaxing, where finished refinery waxes are sold. It may accompany or replace the use of pour point depressants.

This unit feeds high pour refinery streams covering the range of 550 to 690 degrees Fahrenheit, where the high boiling paraffin waxes are concentrated. Approximately 200 cf/bbl of hydrogen is consumed.

Published sources include:

> Collins, J. M. and Unzelman, G. H., *"Alternatives Available to Meet Diesel Cetane Quality Challenge"*, Oil & Gas Journal, May 30, 1983, p.71.

TABLE RFH   REFORMER-SEMI REGENERATIVE-450 PSI REACTOR
TABLE RFL   REFORMER-SEMI REGEN/CYCLIC-200 PSI REACTOR
TABLE RFC   CONTINUOUS REFORMER LOW PRESS./HIGH DENSITY BIMET.CATALYST

Naphtha reforming refinery process units. These individual key processes represent the different stages of reformer technology development. Paraffinic, naphthenic, and intermediate naphtha feeds are represented to produce reformates spanning the range of 80 to 105 clear research octane number. The low end of the reforming severity range is geared to accommodating the lower aromatic content of reformulated gasoline; the high end represents the limit of current reforming technology. The effect of low through high reforming severity on reformer throughput capacity is represented in row CAP, with coefficients ranging from 0.9 to 1.2, with an entry of 1.0 representing 95-100 RONC reformate production.

The severity rows SVH, SVL and SVC contain the reformate RONC octane. Several operating mode limitation rows are also available in the reformer tables to link to *Tables (R)POL* constraints:

> L00, H00 to limit maximum 100 RONC reforming severity
> C05, L05, H05 to limit maximum 105 RONC reforming severity
> MXU to limit the proportion of UOP type R-62 high density bimetallic reforming catalyst
> RCU to limit very low pressure and low benzene advanced modes on the continuous reformer (RFC).

The specific reformer feed streams represented include the following:

> 158-175 degrees Fahrenheit   very light virgin naphtha
> 175-250 degrees Fahrenheit   light virgin naphtha
> 250-325 degrees Fahrenheit   intermediate virgin naphtha

325-375 degrees Fahrenheit	heavy virgin naphtha
250-400 degrees Fahrenheit	heavy FCC gasoline
175-375 degrees Fahrenheit	coker naphtha
250-325 degrees Fahrenheit	heavy hydrocrackate
215-250 degrees Fahrenheit	light virgin naphtha, prefractionated to remove benzene precursors.

The capability to reform 325-375 virgin naphtha feed stock is not immediately apparent in the reformer data tables because it is represented in *Table TRSPMM* by combining naphtha desulfurizer feeds, namely:

H N/L J(325-375) P/LF	NAPHTHA(250-325) P	JPLNPP
H N/L J(325-375) I/LF	NAPHTHA(250-325) I	JILNPI
H N/L J(325-375) N/LF	NAPHTHA(250-325) N JNLNPN	
H N/L J(325-375) P/HF	NAPHTHA(250-325) P	JPHNPP
H N/L J(325-375) I/HF	NAPHTHA(250-325) I	JIHNPI
H N/L J(325-375) N/HF	NAPHTHA(250-325) N JNHNPN	

The reformer products include hydrogen (95 percent purity), fuel gas, LPG, and full boiling range reformate.

The gradation of reformate feed cut ranges is consistent with (a) maximizing reformer feed, e.g. for foreign regions where gasoline demand is high, but also (b) controlling benzene content of reformate for use in reformulated gasoline. This latter can be achieved in the model by eliminating the 158-175 fraction and, if necessary, the 175-250 fractions from reformer feed. In addition, the model now has the option to pre-fractionate light naphtha at 215 degrees Fahrenheit to produce feedstock to the RFC unit for very low benzene reformate production. (See *Table GCB* for comparison of reformate benzene contents.)

Altogether, the PMM model contains several methods for benzene reduction or removal:

1. Reformer feed pre-fractionation as discussed above,
2. Reformate splitting (*Table RES*)
3. Extraction of benzene (for sale) from reformate aromatics (*Table ARP*)
4. Very low pressure reformate operation (*Table RFC*)
5. Alkylation of benzene in reformate (*Table ALM*).

RFC unit ultra-low pressure reforming, at 90 psi, reduces the reformate benzene content by approximately 30 percent for reformulated gasoline production. Commercial plant data have not yet been obtained to verify the model reforming yields.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data and published data compared and gathered from a variety of sources. Sources include:

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March 1990.

Jones, P. *"The Conversion Refinery: The Catalytic Magic Wand"*, Petroleum Review, May 1987.

McClung, R. G. and Novak, W. J., *"Improve Reformer Operation with Trace Sulfur Removal"*, Paper AM-87-47 presented at the NPRA Annual Meeting, March 1987.

Gerritsen, Dr. L. A., *"Catalytic Reforming of Heart Cut FCC Naphthas"*, Paper AM-85-56 presented at the NPRA Annual Meeting, March 1985.

TABLE SPL   NAPHTHA SPLITTER

This is a feed preparation unit which fractionates light naphtha for reformer feed. C5-175 degrees Fahrenheit straight run gasoline is fractionated to produce C5-158 light gasoline for gasoline blending and 158-175 degrees Fahrenheit light naphtha for reformer feed. This represents the light end range of currently feasible reformer feed. The splitter now also enables splitting 175-250 degrees Fahrenheit light naphtha at 215 degrees Fahrenheit to produce a 175-215 degrees Fahrenheit light naphtha and a 215-250 degrees Fahrenheit low benzene reformer feedstock.

The fractionated light naphthas produced may also be blended to JP4 military jet fuel and to naphtha sales.

Data sources are in-house ENSYS data and the following:

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March 1990.

TABLE RES   REFORMATE SPLITTER

This unit splits the reformates produced from 250-375 degrees Fahrenheit intermediate/heavy naphtha into an overhead and a bottoms cut. These fractions may be separately blended into conventional and reformulated gasolines to aid in meeting reformulated gasoline specifications. The aromatics concentrate in the bottoms cut and the benzene in the overhead.

Data sources are in-house ENSYS data and ENSYS calculations, estimates and published data, including:

van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March 1990.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE ARP   AROMATICS EXTRACTION

This unit employs solvent extraction of reformate and reformate fractions to produce benzene, toluene, and xylene (BTX) aromatics for sale, and light and heavy raffinates for gasoline and jet/distillate fuel blending. All of the reformates produced in the semi-regenerative, continuous and cyclic reformers are potential unit feeds, along with their overhead and bottoms cuts produced in the reformate splitter.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data and ENSYS calculations and estimates.

TABLE ALM   ALKYMAX

This unit is patterned after the UOP Alkymax process for alkylating benzene with C_2 and C_3 olefins (ethylene and propylene) to produce higher boiling aromatics. The reformates produced from 158-250 light/intermediate naphtha are reacted with fuel gas containing ethylene or with propylene to produce an essentially benzene-free reformate. These reformates are then blended to meet reformulated gasoline benzene specification. *(Note: the <u>aromatics</u> concentration in the gasoline blend is hardly altered.)*
Data sources include the following:

B. M. Wood et al, *"Alkylate Aromatics in the Gasoline via the UOP ALKYMAX Process"*, Copyright 1990, provided by UOP to ORNL.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE CYC   CYCLAR

Cyclar refinery process unit based on the UOP cyclar process to cyclarize propane and butane to produce BTX. A fractionated benzene stream is produced along with a TX (toluene, xylene) stream designated as cyclar gasoline. This is a de-hydrogenation process which produces approximately 2000 cf/bbl feed of hydrogen.

The data sources include the following:

Anderson, R. F. et al, *"Cyclar - One Step Processing of LPG to Aromatics and Hydrogen"*, Paper 83D presented at the AIChE Spring Meeting, March 1985.

TABLE FCC   FLUID CATALYTIC CRACKER

This key process unit is capable of catalytically cracking gas oil, light gas oil, distillate and residua streams to produce light ends, FCC gasoline, light cycle oil (distillate) and decant oil (resid). The primary feeds represented are:

Feed stream	Description
HGP:	paraffinic low sulfur gas oil (800-1050 degrees Fahrenheit)
HGL:	low sulfur gas oil (800-1050 degrees Fahrenheit)
HGM:	medium sulfur gas oil (800-1050 degrees Fahrenheit)
HGH:	high sulfur gas oil (800-1050 degrees Fahrenheit)
GOH:	hydrofined gas oil (800-1050 degrees Fahrenheit)
GOU:	hydrofined gas oil (800-1050 degrees Fahrenheit) ultra low sulfur
DFF:	distillate feed (550-690 degrees Fahrenheit)
DHK:	desulfurized atmospheric residuum (1050 degrees Fahrenheit +). Produced by unit RDS.
HGX:	gas oil raffinate produced by propane solvent de-asphalting
Atmospheric Residua:	several residua of sufficiently low asphalt and metals content (which tend to be the lower sulfur content residua) to conform to current FCC technology limitations.

In order to contain the already large number of FCC feed vectors, several streams are composited into the above primary feeds in *Table TRSPMM* as listed below:

DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6LLHGL
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6HLHGL
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	7LLHGL
DSL C(650-690) PFFN HGO FD(800-1050) PFFN		7HLLGP
COKER GAS OIL	HGO FD(800-1050) HI S N	CGOHGH
LGO FD(690-800) HI S N	HGO FD(800-1050) HI S N	LGHHGH
LGO FD(690 800) MD S N	HGO FD(800-1050) MD S N	LGMHGM
LGO FD(690-800) LO S N	HGO FD(800-1050) LO S N	LGLHGL
LGO FD(690-800) PFFN	HGO FD(800-1050) PFFN	LGPHGP
HGO FD(800 1050) LO S N	HYD G.O. LOS N UNH	HGLGOH
DIST LS/LM	DIST FCC FEED	DLLDFF
DSL B(550-650) HP/HC/LS	DIST FCC FEED	2HLDFF
DSL C(650-690) LP/HC/LS	H DIST FCC FEED	6HLDFF
DSL C(650-690) HP/HC/LS	H DIST FCC FEED	7HLDFF
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6LLHGL
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6HLHGL

DSL C(650-690) LO S N   HGO FD(800-1050) LO S N   7LLHGL

The FCC is characterized by several modes of operation and provision for activating restrictions on flexibility have been built in for constraining advanced FCC catalyst technology options and limiting over-optimization. The FCC representation now accurately equates FCC gasoline, distillates, and decant oil product sulfur with feed sulfur. The available options are:

Option	FCC gasoline codes	Constraints
Conventional zeolite catalyst		
high sulfur feed/product	FI6, FI7, FI8	MSD, MSR, FCR
med.sulfur feed/product	FC6, FC7, FC8	
low sulfur feed/product	FR6, FR7, FR8	
ultra-low sulfur feed/product	FQ6, FQ7, FQ8*	
High octane zeolite catalyst		
high sulfur feed/product	ZI6, ZI7, ZI8	MSD,MSR,MSZ
med.sulfur feed/product	ZC6, ZC7, ZC8	and FCR
low sulfur feed/product	ZR6, ZR7, ZR8	
ultra-low sulfur feed/product	RC6, RC7, RC8	
Low olefin content gasoline		
high sulfur feed/product	6ZI, 7ZI, 8ZI	MSZ
med.sulfur feed/product	6ZF, 7ZF, 8ZF	
low sulfur feed/product	6ZR, 7ZR, 8ZR	
ultra-low sulfur feed/product	6RF, 7RF, 8RF	
High light olefin yield		
high sulfur feed/product	85I	MSL
med.sulfur feed/product	85F	
low sulfur feed/product	85R	
ultra-low sulfur feed/product	85U	
Ultra-Low Sulfur Modes		FCU
All Modes		SVR

> *   *This feed sulfur/catalyst mode currently not activated, although FCC gasoline properties are held in **Table GCB**, etc.*

MSD and MSR refer to constraints on distillate/light gas oil and atmospheric residuum proportions. A value of "1" in the FCR row signals a residuum which is eligible for FCC residuum cracking, generally higher than 20 API, with the associated sulfur content lower than 0.7 percent. MSZ and MSL limit the proportion of specialty zeolite catalysts. The above references to low sulfur FCC gasoline refer to the production of

catalytic gasolines generally suited to making reformulated gasoline at the 50-ppm level. FCU is the constraint on all ultra-low sulfur modes.

The low olefin content gasoline mode is directed at reducing the olefin content of reformulated gasoline by reducing the olefins in the catalytic gasoline, principally the light catalytic gasoline. This mode also lowers the octane somewhat and reduces the yield of C_5 and lighter olefins.

The high light-olefin yield operation takes a different approach to reformulated gasoline production and utilizes enhanced octane ZSM-5 catalyst with OHS additive to maximize the yield of light olefins to produce feedstocks for the oxygenate and alkylation refinery process units. The operating cost row OVC coefficient has been raised by $0.60/bbl of gas oil feed to account for the unit revamp and increased fractionation costs associated with this operation. This is a high conversion operation in the 80 to 85 percent range.

The FCC conversion range represented in the model is from 65 to 85 percent conversion to 430 degrees Fahrenheit- FCC gasoline. The SVR row may be used to constrain or report the overall conversion level. The light end yields contained in the model reflect an overall C3 recovery of 75 percent. Light cycle oil characterizations (qualities) are a function of conversion and FCC feed sulfur level. Decanted (clarified) oil characterizations are a function of sulfur level only:

LCO ULOW	0.05S 60P CONV	LC7
LCO ULOW	0.05S 80P CONV	LC8
LCO	0.25S 60P CONV	LC1
LCO	0.25S 80P CONV	LC2
LCO	0.85S 60P CONV	LC3
LCO	0.85S 80P CONV	LC4
LCO	2.00S 60P CONV	LC5
LCO	2.00S 80P CONV	LC6
CLARIFIED OIL	0.10 SUL	COX
CLARIFIED OIL	0.65 SUL	COL
CLARIFIED OIL	2.20 SUL	COM
CLARIFIED OIL	5.50 SUL	COH

The four levels of LCO and decant oil sulfur correspond to the four base levels of FCC feed sulfur, namely: 0.05 percent, 0.30 percent, 1.00 percent, 2.50 percent. Actual feeds may produce mixes of products depending upon actual feed sulfur level.

Weight fraction catalytic coke yields are contained in the model (row COK) and are set to be activated for checking the FCC weight balance and to provide input to any EIA type reports which contain FCC catalytic coke production.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data include the following published data:

"Fuels for Tomorrow", staff article, Oil & Gas Journal, June 18, 1990, p.52.

Chin, A. A. et al, *"FCC Cracking of Coker Gas Oils"*, Paper 91C presented at the AIChE Fall Meeting, November 1989

Humphries, A. et al, *"The Resid Challenge: FCC Catalyst Technology Update"*, Paper 70C presented at the AIChE Spring Meeting, April 1991.

Stokes G. M. et al, *"Reformulated Gasoline Will Change FCC Operations and Catalysts"*, Oil & Gas Journal, July 2, 1990, p.58.

Keyworth, D. A. and Reid, T. A., *"Octane Enhancement From LPG"*, Paper 5A presented at the AIChE Summer Meeting, August 1989.

"Innovative Improvements Highlight FCC's Past and Future", staff article, Oil & Gas Journal, January 8, 1990, p.33.

Deady, J. et al, *"Strategies For Reducing FCC Gasoline Sensitivity"*, Paper AM-89-13 presented at the NPRA Annual Meeting, March 1989.

Dwyer, F.G. et al, *"Octane Enhancement In FCC Via ZSM-5"*, Paper AM-87-63 presented at the NPRA Annual Meeting, March 1987.

Yanik, S. J. et al, *"A Novel Approach to Octane Enhancement Via FCC Catalysis"*, Paper AM-85-48 presented at the NPRA Annual Meeting, March 1985.

Krikorian, K. V. and Brice, J. C., *"FCC's Effect on Refinery Yields"*, Hydrocarbon Processing, September 1987, p.63.

TABLE FGS   GASOLINE FRACTIONATION

This idealized unit, representing a probable series of distillation towers, fractionates:

- Whole catalytic gasoline specific to the different FCC unit operating modes
- Coker naphtha produced by the coker units KRD and KRF
- Purchased natural gasoline.

The whole FCC gasoline is fractionated to produce reactive amylenes for alkylation and oxygenate plant feed; normal amylene for gasoline blending, alkylation or hydrogenation; reactive hexylenes for oxygenate plant feed; normal hexylene for gasoline blending or hydrogenation; light catalytic gasoline, containing isopentane, normal pentane and iso and normal hexanes plus the C_7 to 250 degrees Fahrenheit fractions; heavy catalytic gasoline (250 - 400 degrees Fahrenheit) for reformer feed and gasoline blending; and the front end of light cycle oil for distillate blending.

Coker naphtha (175 - 375 degrees Fahrenheit) is fractionated to produce iso amylene, the other reactive amylenes and reactive hexylenes, and the remaining naphtha bottoms.

Natural gasoline is fractionated to produce iso and normal butane and light and medium naphtha cuts.

Data sources are in-house ENSYS data, calculations and estimates supported by the following:

> Keefer, P. and Masters, K., *"Ultimate C4/C5 Olefin Processing Scheme for Maximizing Reformulated Gasoline Production"*, Paper AM-91-50 presented at the NPRA Annual Meeting, March 1991.
>
> Stokes G. M. et al, *"Reformulated Gasoline Will Change FCC Operations and Catalysts"*, Oil & Gas Journal, July 2, 1990, p.58.

TABLE ETS   ETHYLENE CRYOGENIC FRACTIONATION

This unit distills ethylene from refinery gas for alkylation plant feed using cryogenic (low temperature technology). All feed and product streams are in bblFOE and the saturate co-product PGS (ethane) is used for refinery fuel gas and to meet any refinery sales requirements.
Data sources are based on in-house ENSYS data, calculations, and estimates.

TABLE OLE C_2-C_5 DE-HYDROGENATION ("OLEX")

This process unit dehydrogenates saturated C2/C3/C4 and IC5 refinery streams to produce on the order of 1500 cf/bbl of hydrogen per bbl of feed and the corresponding olefin streams for alkylation and oxygenate plant feeds. The propylene may be used for alkylation (or ether DIPE) plant feed and petrochemical sales, the normal butylene for alkylation plant feed, the isobutylene for MTBE/ETBE oxygenate production and alkylation plant feed and the isoamylene for TAME/TAEE oxygenate production and alkylation plant feed. This process is suited for reformulated gasoline production and aids in RVP reduction through removing butane and isopentane from the gasoline pool.

Data sources include the following:

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

Buonomo, G. et al, *"The Fluidized Bed Technology for Paraffins Dehydrogenation: Snam Progetti-Yarsintez Process"*, presented to DEWITT 1990 Petrochemical Review, Houston, Texas, March 27-29, 1990.

TABLE C4I   BUTANE ISOMERIZATION

This unit isomerizes normal butane to produce isobutane. The isobutane may be used for alkylation plant feed and, potentially, for dehydrogenation to produce isobutylene for MTBE and ETBE production.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data.

TABLE C4S   BUTENE TRANSFER PSEUDO-UNIT

This unit splits FCC and coker total butylenes into 70 percent normal butylene (C4E) and 30 percent isobutylene (I4E). No costs are attached to this unit because the total stream is normally fed to MTBE/ETBE plants without fractionation and only the isobutylene is consumed. The costs of processing the total butylene stream are included in the oxygenate plant costs.

The problem of reflecting the C4E/I4E split on alkylation plant costs is complex. The alkylate produced by normal butylene is approximately 4 RONC/MONC higher than that produced by isobutylene. Therefore, if the alkylation unit is preferentially consuming normal butylene from FCC/coker mixed butylenes, pre-fractionation costs should be attached to the alkylation plant for taking advantage of this option. However, if, as is often the case, oxygenate and alkylation units are both present in the LP solution (to produce reformulated gasoline), then the MTBE/ETBE unit is situated upstream of the alkylation unit so as to avoid the fractionation costs. The practice in this model is not to add additional alkylation plant feed pre-fractionation costs. This could cause over optimization (understate costs) for some cases.

Data sources are in-house ENSYS data.

TABLE ETH,ETM   OXYGENATE PRODUCTION

A process unit which consumes methanol or ethanol to produce a wide range of oxygenates. The olefin feeds and corresponding oxygenate products are:

Table A4. Oxygenate Products

Oxygenate Products

Methanol Feed	Code	MTBE	TAME	THME
Isobutylene	I4E	X		
Reactive Amylenes	R5E		X	
Reactive Hexylenes	R6E			X
Ethanol Feed	Code	ETBE	TAEE	THEE
Isobutylene	I4E	X		
Reactive Amylenes	R5E		X	
Reactive Hexylenes	R6E			X

The *Tables (R)POL* constraint NME can be used to constrain or eliminate all modes other than iso-butylene/MTBE.

The data for THME and THEE were estimated by ENSYS, since there is little or no commercial experience to provide operating data. Other data sources include the following:

Bakas, S.T. et al, *"Production of Ethers from Field Butanes and Refinery Streams"*, presented at the AIChE Summer Meeting in San Diego, California, August 1990.

Prichard, *"Novel Catalyst Widens Octane Opportunities"*, NPRA Annual Meeting, San Antonio, Texas, March 29-31, 1987.

Miller, D. J., *"Ethyl Tertiary Butyl Ether (ETBE) Production"*, Paper 42B presented at the AIChE Summer Meeting, August 1989.

Des Courieres, J., *"The Gasoline Ethers: MTBE, ETBE, TAME & TAEE: Their Production"*, Paper 13A presented at the AIChE Summer Meeting, August 1990.

Chemical Engineering Progress, August 1991, p.16.

Unzelman, G. W., *"Future Role of Ethers in U. S. Gasoline"*, Paper AM-89-06 presented at the NPRA Annual Meeting, March 1989.

Refinery Handbook, Ethers, Hydrocarbon Processing, November 1990, p.126.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG
SK 05-91, provided by UOP to ORNL.

Prichard, G., *"Novel Catalyst Widens Octane Opportunities"*, Paper AM-87-48
presented at the NPRA Annual Meeting, March 1987.

TABLE DIP   PROPYLENE OXYGENATE PRODUCTION

This unit is modeled after a recently announced Mobil process which reacts propylene and water to produce a propylene ether (DIPE).

TABLE C24   DIMERIZATION OF ETHYLENE TO 1-BUTENE

This unit dimerizes ethylene to 1-butene for alkylation plant feed. It produces a small byproduct quantity of 1-hexene.

Data sources are based on in-house ENSYS data, calculations, and estimates.

TABLE C4T   ISOMERIZATION OF BUTENE-1 TO BUTENE-2

This unit isomerizes butene-1 to butene-2 for the purpose of improving alkylate quality and reducing the alkylation plant acid consumption. Approximately 13 cf/bbl of hydrogen is consumed to hydrogenate butadiene and reduce the mercaptan content. Alkylate octanes are increased 1.8 RONC and 0.8 MONC and alkylation plant operating costs are reduced by approximately 30 percent.

Data sources include the following:

Novalany, S. and McClung, R. G., *"Better Alky from Treated Olefins"*, Hydrocarbon Processing, September 1989, p.66.

TABLE ALK   ALKYLATION

The isobutane sulfuric acid alkylation of the following feed streams is represented:

ETHYLENE (FOE)	C2E
PROPYLENE	UC3
MIXED BUTYLENES	UC4
N-BUTYLENE	C4E
TRT/ISOM BUTENE-2 T4E	
ISOBUTYLENE	I4E
NORMAL AMYLENE	C5E
REACTIVE AMYLENE(ISO)	R5E

The feedstocks are reacted with iso-butane to produce alkylate product. The range of feedstocks has been extended because of the high significance of alkylates as reformulated gasoline blendstocks.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data. Published sources include:

Leonard, J. et al, *"What to do with Refinery Propylenes"*, Paper 5B, presented at the AIChE Summer Meeting, August 1989.

Masters, K. R., *"Alkylation's Role in Reformulated Gasoline"*, presented at the AIChE Spring Meeting, April 1991.

Masters, K. and Prohaska, E.A., *"Add MTBE Unit Ahead of Alkylation"*, Hydrocarbon Processing, August 1988, p.48.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE CPL   CATALYTIC POLYMERIZATION

A process using solid phosphoric acid catalyst to polymerize propylene and butylenes to produce olefinic polymer gasoline.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data.

TABLE DIM   DIMERSOL

A process using liquid phosphoric acid catalyst to polymerize propylene to produce dimer, which is lighter and higher in octane than olefinic polymer gasoline.

Data sources include:

> Leonard, J. et al, *"What to do with Refinery Propylenes"*, Paper 5B, presented at the AIChE Summer Meeting, August 1989.

TABLE H56   HYDROGENATION OF NORMAL AMYLENE AND HEXYLENE

This unit hydrogenates the normal C_5/C_6 olefins to produce low octane normal pentanes and hexanes for isomerizer unit feed, where the octanes are raised. Hydrogen consumptions are in the range of 1300-1500 cf/bbl.

Data sources are based on in-house ENSYS data, calculations and estimates.

In an era of reformulated gasolines, this process provides a means of removing the reactive normal C_5 and C_6 olefins from the gasoline pool. As described elsewhere, the iso C_5 and C_6 olefins are likely to be dealt with by alkylation or etherification.

TABLE PHI   PENTANE/HEXANE ISOMERIZATION

This is a partial recycle isomerizer (without molecular sieve) which produces isopentane- and isohexane-rich isomerates from the following potential feed streams:

NATURAL GASOLINE	NAT
LSR GASO(C5-175)ION	SRI
LSR GASO(C5-158)	GLI
NORMAL PENTANE	NC5
NORMAL HEXANE	NC6

Data sources are in-house ENSYS data and the following sources:

> Schmidt, R. J. et al, *"Catalyst and Engineering Innovations Improve Isomerization Techniques"*, Paper AM-87-61, presented at the NPRA Annual Meeting, March 1987.

> *"UOP Process Solutions for Reformulated Gasoline"*, Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE TRI   PENTANE/HEXANE (TOTAL RECYCLE) ISOMERIZATION

This is a total recycle isomerizer with molecular sieve which produces a high octane isomerate, approximately 4 RONC and 7 MONC greater than produced by unit PHI. The capital and operating costs are also higher.

Data sources include the following:

> Sager, T.C. et al, *"Cost Effective Isomerization Options for Tomorrow's Light Gasoline Processing Options"*, Paper AM-89-12, presented at the NPRA Annual Meeting, March 1989.

> Refinery Handbook, Hysomer and TIP System, Hydrocarbon Processing, September 1984, p.21.

TABLE H2P   HYDROGEN PRODUCTION VIA STEAM REFORMING
TABLE H2X   HYDROGEN PRODUCTION VIA PARTIAL OXYDATION

These process units produce hydrogen by steam reforming and partial oxidation, respectively. The steam reforming feeds include natural gas, propane, butane, and light naphtha. The partial oxidation plant feeds include low, intermediate, and high sulfur fuel oils.

Hydrogen is expressed in bblFOE throughout the model. Correspondence is 19,646 cf/bblFOE, equivalent to 50.9 bblFOE/MMcf of hydrogen. The hydrogen is produced at 97 percent purity, containing 3 percent methane.

Data sources are in-house ENSYS data.

TABLE HLO   HYDROGEN TRANSFER TO FUEL

This is essentially a model calibration table which permits the downgrading of produced hydrogen (95 percent purity) to fuel gas. The transfer ratio is established by matching the refinery hydrogen plant usage against known utilized capacity and reflects the fact that not all produced hydrogen, notably from catalytic reforming, is reclaimed for hydrotreating refinery streams.

TABLE SUL   SULFUR PLANT

This unit reacts hydrogen sulfide with steam over iron oxide catalyst to produce sales grade sulfur. The unit is modeled after the Claus process with the capability to add a Stretford unit to reduce the hydrogen sulfide in the tail gas. The sulfur quantity is expressed in short tons and the coefficients in the unit are scaled by 0.1 to increase the LP solution efficiency.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS and in-house ENSYS data.

TABLE FUM   REFINERY FUEL PSEUDO-UNIT

Pseudo-unit for routing refinery streams to refinery fuel. This unit mixes refinery gases, naphthas, distillates and fuel oils to the model "FUL" row for internal refinery process unit fuel consumption. The feed coefficients reflect the bblFOE conversion factors.

The LP solution activities associated with this unit should be controlled and/or scrutinized since an over-constrained or otherwise infeasible model may be characterized by dumping high value streams to refinery fuel.

Data sources are not pertinent except for the bblFOE conversion factors. These are based on ENSYS calculations and estimates.

TABLE STG   STEAM GENERATION
TABLE KWG   POWER GENERATION

Steam and power generation refinery utility units. These represent the generation of steam (in units of Mlb/day) from refinery fuel (in bblFOE) and electricity (in kilowatthours) from steam (Mlb/day). An efficiency of 31 percent is assumed for power generation and 70 percent for steam generation. The power and steam are consumed in the various refinery process units.

Data sources are the EIA RYM model data provided to ORNL and thereafter to ENSYS, in-house ENSYS data and ENSYS calculations and estimates.

TABLE RELREP   REFINERY LOSS PSEUDO-UNIT

This pseudo-unit is used to represent refinery light end losses and to adjust refinery loss to match calibration cases. The unit's single vector allocates light ends loss, as a fraction (currently 0.5 percent) of the crude run, across the light ends streams namely process gas, C_3's, C_4's, and light naphtha. The loss vector is equated with crude run via row FRL which is generated in *Tables RELPOL*. Each crude processing vector in *Table ACUCUTS* has a 1 entry against FRL.

Estimates of the loss factors are based on in-house ENSYS data and estimates based on calibration runs and knowledge of refinery losses.

TABLE PFAREP   PRODUCED FUEL ADJUSTMENT PSEUDO-UNIT

This pseudo-unit is used to represent refinery propane and butane losses to refinery fuel gas (C_2 and lighter). The unit's single vector allocates C_3 and C_4 losses (transfers) to fuel gas as a fraction (currently 0.4 percent) of total crude run. The transfer vector is equated with crude run via row APF which is generated in *Table PFAPOL*. Each crude processing vector in *Table ACUCUTS* has a 1 entry against APF. Estimates of the fuel adjustment factors are based on in-house ENSYS data and estimates based on calibration runs and knowledge of refinery losses.

(cogener)

TABLE CGNREP   COGENERATION

This refinery process unit is used to produce steam and generate electricity for sale to the power grid. The fraction sold is contained in input table SELCGN, the electricity not sold is consumed by refinery process units. Data sources are from EIA.

Column names	One column, CGN
Row names	One row, FUL
Entries	Fuel consumption

TABLE SELCGN   COGENERATION SALES BY PADD

Column names	One column, SOLD
Row names	PADD Codes, E,C,G,M,W.
Entries	Fraction sold in each PADD.

TABLE SELCGN   COGENERATION SALES BY PADD

Column names	One column, SOLD
Row names	PADD Codes, E,C,G,M,W.
Entries	Fraction sold in each PADD.

APPENDIX B

Mathematical Description of Model

APPENDIX B. Mathematical Description of Model

Each refiner is trying to minimize the cost of meeting demands. Therefore, the market moves toward lower-cost refiners who have access to crude oil and markets. A key premise is that the selection of crude oils, refinery process utilization, and logistics will adjust to minimize the overall cost of supplying the market with petroleum products.

In order to generate refined product prices, the PMM contains a static linear program model of the U.S. petroleum refining and marketing system that meets demand for refined products while minimizing costs. The PMM, like the other NEMS models, is written in FORTRAN. The RS6000 software includes the Optimization Modeling Library or OML, a set of FORTRAN callable subroutines. The LP portion of the PMM is a complete problem matrix prepared prior to NEMS processing. The LP remains in fast memory throughout the NEMS run, thereby avoiding many disk I/O operations.

It is necessary to view the PMM in the context of the NEMS program to understand its function. For each cycle, the main NEMS model calls the demand models to calculate energy demands. Each supply model is then called to calculate energy prices. When the prices and demands converge to within the specified tolerance, the NEMS iteration is complete and the next yearly NEMS cycle begins. If the computed prices have not converged, new demand quantities are computed, passed to the supply models, and the cycle is repeated. In the case of the PMM, a supply model, the refined product prices are obtained as the marginal prices from an optimal solution to the PMM LP. These product prices are output to the NEMS demand models. The LP matrix is updated with the new demands for refined products and the cycle continues until convergence is reached. The demand level modifications to the PMM LP and the re-optimization of the LP matrix, which remains in core memory, are accomplished by executing FORTRAN callable subroutines.

For AEO96 the original generation of the PMM matrix is performed using OML[1] and FORTRAN. OML (Optimization Modeling Library) is a library of FORTRAN callable subroutines for data table manipulation, matrix generation, and solution retrieval programs for report writing.. The matrix is solved with the optimizer, C-WHIZ[2].

B.1 Mathematical Formulation

The table of column activity definitions and row constraints defined in the PMM matrix incorporate certain premises which are described in Appendix A. The general structure of the matrix is shown in Table B1.

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[1]Ketron Management Science, Inc., *Optimization Modeling Library, OML User Manual*, (November 1994).

[2]Ketron Management Science, Inc., *C-WHIZ Linear Programming Optimizer, User Manual*, (July 1994).

B.2 Matrix Indices

Several indices are used in the column and row definitions presented below. The definition of these indices are shown in Table B2.

Table B2. Index Definitions

Index Symbol	Description
(b)	Domestic crude oil production region
(c)	Crude oil type
(d)	Marketing region
(h)	Product recipe
(i)	Intermediate stream
(m)	Processing mode or shipping mode
(s)	Refinery stream
(p)	Refined product
(q)	Pricing level
(r)	Refinery region
(s)	Refinery stream
(u)	Processing unit type
(v)	Crude oil source
(y)	Product specification quality

B.3 Column Definitions

Table B3. Column Definitions

Column Notation	Description
$B_{a,d,q}$	Volume of alcohol (a) purchased in demand region (d) at price level (q). At present, this column exists only for ethanol.
$D_{p,d}$	Sales volume of product (p) in demand region (d).
$Dn_{p,d,q}$	Increment of sales volume decrease from the base of $D_{d,p}$ for product (p) in demand region (d) at price level (q).
$Dp_{p,d,q}$	Increment of sales volume increase from the base of $D_{d,p}$ for product (p) in demand region (d) at price level (q).
$E_{u,r}$	Stream day capacity added during this simulated period for processing unit type (u) in refinery region (r).
$G_{i,p,r}$	Volume of intermediate stream (i) blended into spec blended product (p) at refinery region (r).
$H_{p,h,r}$	Volume of product (p) manufactured in refinery region (r) using recipe (h).
$H_{p,h,d}$	Volume of product (p) made by recipe (h) in demand region (d) by splash blending.
$I_{p,d}$	Volume of distress import of product (p) into demand region (d) where d = 2,3,7,8,9.
$I_{p,r,q}$	Volume of refined product (p) imported into refinery region (r) at price level (q).
$K_{u,r}$	Base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded.
$L_{u,r}$	Cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is fixed.
M_r	Volume of methanol consumed by the chemical industry in refinery region (r).

Column Notation	Description
Mt	Total volume of U.S. methanol consumption by the chemical industry, an input.
$NZAMHN_q$	Volume at price discount q of Alaskan Crude (AMH) exports.
$NZAMHP_q$	Volume at price increment q of Alaskan Crude (AMH) exports.
$O_{c,v,b}$	Export volume of crude oil (c) with source code (v) produced in domestic region (b).
P_b	Volume of domestic crude oil produced at producing region (b).
$Pi_{c,r,q}$	Volume of imported crude oil type (c) imported by refinery region (r) at price level (q).
$Q_{p,r}$	Volume of spec product (p) manufactured in refinery region (r).
$Ra_{c,v,r}$	Crude oil volume distilled in refinery region (r) from source (v) of crude oil type (c).
$R_{u,r,m}$	Manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).
Tu	Total volume of imported unfinished oil over all refinery regions.
$T_{i,r}$	Volume of unfinished oil component (i) processed in refinery region (r).
$Tx_{s,p,r}$	Volume of stream (s) transferred into product (p) in refinery region (r).
$Tx_{p,p',r}$	Volume of product (p) transferred into product (p') storage in refinery region (r).
$Tx_{s,s',r}$	Volume of stream (s) transferred to stream (s') at refinery region (r).
$U_{l,r}$	Quantity of utility (l) that is purchased in refinery region (r): (l) = KWH, STM, and NGF (power, steam, and natural gas fuel) with units in thousands of kWh, Mlbs., and MMcf respectively.
Vcj	Total dead weight ton capacity of Jones Act crude oil tankers. This column is constrained to some maximum.
V_{pc}	Total dead weight tons of Jones Act product tanker of shipping class (pc). This column is constrained to some maximum.
Vcts	Total crude oil transhipped from PAD District III to PAD District II. This column is constrained to some maximum.

Column Notation	Description
$Vcp_{b,r}$	Total crude oil shipped by pipeline from domestic producing region (b) to refinery region (r). This column is constrained to some maximum.
$Vpp_{r,d,m}$	Total volume of light products (p) shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.
$Vtpl_{r,d,m}$	Total volume of LPG products (p) shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.
$W_{a,d,r,m}$	Volume of alcohol (a) shipped from demand region (d) to refinery region (r) via mode (m).
$W_{p,r,d,m}$	Volume of product (p) shipped from refinery region (r) to demand region (d) via mode (m).
$W_{p,d,d',m}$	Volume of product (p) transhipped from demand region (d) to demand region (d') via mode (m).
$X_{p,d}$	Volume of product (p) exported from demand region (d).
$Y_{c,v,b,r,m}$	Volume of crude oil type (c) with source code (v) shipped from domestic region (b) to refinery region (r) via mode (m).
$Y_{c,v,r,r',m}$	Volume of domestic crude oil type (c) with source code (v) transhipped from refinery region (r) to refinery region (r') via mode (m).
Zt	Total volume of crude oil processed over all refinery regions.
ZET_d	Total volume of ethanol supplied from region (d).
ZOX_r	Total quantity of percent oxygen-barrels in reformulated gasoline produced in region (r).
$ZZAMHTOT$	Export volume of Alaskan Crude Oil.

B.4 Objective Function

The objective function has been established based on the premise that costs associated with product imports, non-crude oil inputs, and crude oil supplies are based on a given world oil price. With this in mind, the following objective function has been defined for PMM.

Given:

$PR_{p,d}$ is the unit price of product (p) sold in demand region (d). It is the price associated with the demand volume for that product in the specified demand region, i.e. it is associated with $D_{p,d}$. Similarly, each of the other 'PR' coefficients represents the unit price of the activity it is associated with.

PRAMH is the target price for Alaskan crude exports.

$PRAMHN_q$ is the discount from Alaskan crude target price.

$PRAMHP_q$ is the premium added to the Alaskan crude target price.

$C_{u,r,m}$ is the variable cost per unit of column $R_{u,r,m}$, i.e. the cost of one unit of manufacturing activity in mode (m) operation in processing unit (u) at refinery region (r). Similarly, each of the other 'C' coefficients represents the unit cost of the activity it is associated with in the objective function as stated below.

TE_d is the sum of federal and state tax credits for use of ethanol in gasoline.

Maximize the difference between the following sum of product revenues and costs. Thus the objective function is represented as the maximization of a quantity defined by the following revenue terms:

$$\Sigma_d\Sigma_p\ D_{d,p}*PR_{d,p} + \Sigma_p\Sigma_d\Sigma_q\ Dp_{p,d,q}*PR_{p,d,q} + \Sigma_p\Sigma_h\Sigma_r\ H_{p,h,r}*PR_{p,h,r} + \Sigma_p\Sigma_h\Sigma_d H_{p,h,d}*PR_{p,h,d}$$

$$+ \Sigma_p\Sigma_d\ X_{p,d}*PR_{p,d} + \Sigma_c\Sigma_v\Sigma_b O_{c,v,b}*PR_{c,v,b} + \Sigma_d\ ZET_d * TE_d + ZZAMHTOT * PRAMH$$

$$+ \Sigma_q\ NZAMHP_q * PRAMHP_q$$

minus the following cost terms:

$$\Sigma_p\Sigma_d\Sigma_q\ Dn_{p,d,q}*C_{p,d,q} + \Sigma_a\Sigma_d\Sigma_q\ B_{a,d,q}*C_{a,d,q} + \Sigma_p\Sigma_r\ I_{p,r}*C_{p,r} + \Sigma_p\Sigma_d\ I_{p,d}*C_{p,d}$$

$$+ \Sigma_b\ P_b*C_b + \Sigma_c\Sigma_r\Sigma_q\ Pi_{c,r,q}*C_{c,r,q} + \Sigma_i\Sigma_r\ T_{i,r}*C_{i,r} + \Sigma_l\Sigma_r\ U_{l,r}*C_{l,r}$$

$$+ \Sigma_u\Sigma_r\Sigma_m\ R_{u,r,m}*C_{u,r,m} + \Sigma_u\Sigma_r\ E_{u,r}*C_{u,r} + \Sigma_u\Sigma_r\ L_{u,r}*C_{u,r} +$$

$$+ \Sigma_s\ \Sigma_i\ \Sigma_r\ \Sigma_l\ W_{a,d,r,m}*C_{a,d,r,m} + \Sigma_p\Sigma_r\Sigma_d\Sigma_m\ W_{p,r,d,m}*C_{p,r,d,m} + \Sigma_p\Sigma_d\Sigma_{d'}\Sigma_m\ W_{p,d,d',m}*C_{p,d,d',m}$$

$$+ \Sigma_c\Sigma_v\Sigma_b\Sigma_r\Sigma_m\ Y_{c,v,b,r,m}*C_{c,v,b,r,m} + \Sigma_c\Sigma_v\Sigma_r\Sigma_{r'}\Sigma_m\ Y_{c,v,r,r',m}*C_{c,v,r,r',m}$$

$$+ \Sigma_q\ NZAMHN_q * PRAMHN_q$$

B.5 Row Constraints

1. The implicit world oil price, WOP (the refiner's acquisition cost of imported crude oil), must be at least some fraction of premised WOP:

$$\Sigma_b \, P_b * C_b + \Sigma_c \Sigma_r \Sigma_q \, Pi_{c,r,q} * C_{c,r,q} - \text{WOP} * \text{Nwop} * Zt \; \geq \; 0$$

where:

P_b the volume of domestic crude oil produced in production region (b).

C_b the crude oil cost applicable to P_b. \$/bbl

$Pi_{c,r,q}$ the volume of imported crude oil acquired by refinery region (r) of crude type (c) at price level (q). The volume of each crude type (c) is upper bounded by each step of the supply curve.

$C_{c,r,q}$ is crude oil cost applicable to $Pi_{c,r,q}$. \$/bbl

WOP   is the premised World Oil Price. \$/bbl

Nwop   is minimum fraction of the WOP by which refiners must acquire crude oils by volume weighted average; of course Nwop $\leq$ 1.

Zt   is total processed crude oil over all refinery regions.

         I.e., the average refiner acquisition cost of crude oil will be at least some input fraction of WOP.

         Note: The index (v) denoting crude oil source is always "F" for imported crude. Therefore, no summation on (v) occurs for $Pi_{c,r,q}$.

2. The implicit world oil price, WOP (the refiner's acquisition cost of imported crude oil), must not be greater than some fraction of premised WOP:

$$\Sigma_b \, P_b * C_b + \Sigma_c \Sigma_r \Sigma_q \, Pi_{c,r,q} * C_{c,r,q} - \text{WOP} * \text{Nwop} * Zt \; \leq \; 0$$

where:

Xwop   is the maximum fraction of the WOP by which refiners must acquire crude oils by volume weighted average, of course Xwop $\geq$ 1.

         I.e., the average refinery acquisition cost of crude oil must not exceed some input fraction of WOP.

Note: This constraint in conjuction with the previous constraint confine the imported crude oil volumes so that their composite unit cost is close to the WOP. Since the costs of the 5 types of imported crude oil bracket the WOP, there is a continuum of import possibilities. Of course the crude oils vary in cost according to crude quality and transportation cost. However, to avoid infeasibilities due to an overly restrictive constraint, it is presently the practice to allow a variation of 50 cents per barrel. This is also made necessary when maximum import restrictions are placed on all but a "swing" crude oil. Clearly, if the tolerance is sufficiently relaxed, a single crude type could be imported rather than a reasonably balanced mix.

3. Calculate total crude oil processed by summing all crude oil volumes processed over all refinery regions:

$$\Sigma_c \Sigma_v \Sigma_r \, Ra_{c,v,r} \; - \; Zt \;\; = \;\; 0$$

where:

$Ra_{c,v,r}$ is the crude oil volume distilled in refinery region (r) from source (v) of crude oil type (c).
i.e. the total U.S. refined crude oil volume equals the sum of all crude oils refined over all regions.

4. Place an upper bound on product import volume:

$$\Sigma_p \Sigma_r \Sigma_q \, I_{p,r,q} \;\; \leq \;\; IPmax$$

where:

$I_{p,r,q}$ is the volume of product (p) imported into refinery region (r) at cost level (q).

Ipmax   is the maximum assumed volume of imported products allowed into the U.S., an input value.

I.e., the sum of product volumes imported at all price levels over all refinery regions must not exceed some maximum.

5. Assure that the volumes of methanol consumed in each refinery region sum to the assumed total volume.

$$\Sigma_r \, M_r \; - \; Mt \;\; = \;\; 0$$

where:

M_r is methanol consumed by the chemical industry in refinery region (r).

Mt   is total U.S. methanol consumption by the chemical industry, an input.

I.e., methanol consumed by the chemical industry in each refinery region must sum to the projected chemical industry total.

Note: The PMM models domestic methanol production aggregated to the refinery region level as though the plants were processing units integral to the refinery. The methanol production is allocated to two demands: chemical industry demand and transportation sector demand.

6. Limit capital investment for refinery expansion in each refinery region:

$$\Sigma_u \, E_{r,u} * A_{r,u} \quad \le \quad Emax_r \quad \forall \quad r$$

where:

$E_{r,u}$ is a capacity addition for this operating year for processing unit type (u) in refinery region (r).

$A_{r,u}$ is the capital investment required per unit of capacity for processing unit type (u) in refinery region (r), million dollars per Mbbl/d.

$Emax_r$ is the upper limit on capital expenditures in refinery region (r), an input. $MM

I.e., total capital expenditures are limited for each refinery region. This limit allows the user to place limits on expansion for a given scenario. The default values are large such that they are not constraining, except in PADD I where a limit of $500 million dollars is the default. This value is based on analyst judgement to reflect the low expectation of refinery expansion on the East Coast.

Note: For NEMS production runs, this constraint has not been operative except for PAD District I. The assumption has been that environmental waivers and permits will preclude capacity additions in this region.

7. Limit total U.S. refinery capital investment:

$$\Sigma_r \Sigma_u \, E_{r,u} * A_{r,u} \quad \le \quad Emax$$

where:

Emax   is the upper limit on capital investment over all refinery regions, an input. $MM

I.e., total capital expenditures are constrained to some maximum. This limit allows the user to place limits on expansion for all regions in the United States. The default value is $50 billion and is not constraining.

Note: This constraint has been used to determine maximum product import needs by setting Emax to zero. It has not been operative in any production runs thus far. However, like the previous row, it is a potential policy exploration handle. For

instance, one could hypothesize that in a capital-short domestic environment, total industry investment is limited.

8. Limit the volume of unfinished oil processed in U.S. refineries:

$$\Sigma_c \Sigma_v \Sigma_r \, Ra_{c,v,r} \; - \; B1 * Tu \; \geq \; B0$$

where:

$Ra_{c,v,r}$ is the crude oil volume distilled in refinery region (r) from source (v) of crude oil type (c).

Tu   is total processed unfinished oil over all refinery regions.

B0,B1   are regression equation coefficients (see Appendix A). B0 = 11,674.3, B1 = 4.087.

         I.e., the maximum allowable unfinished oil processed is a linear function of total crude oil processed.

9. Limit the volume of each unfinished oil component processed in each refinery region:

$$A_{i,r} * Tu \; - \; T_{i,r} \; \geq \; 0 \quad \forall \; r, i$$

where:

$T_{i,r}$ is the volume of unfinished oil component (i) processed in refinery region (r).

$A_{i,r}$ is the fraction of component (i) of total unfinished oil that is processed in refinery region (r), an input.

         I.e., the volume distribution of each type of unfinished oil processed at each refinery region is constrained to the historical pattern.

10. Balance by volume, at the demand regions, each alcohol purchased by the petroleum industry and domestic methanol shipped in from the refinery regions against alcohol blended by recipe in the demand region and alcohol shipped out of the demand region:

$$\Sigma_q \, B_{a,d,q} + \Sigma_r \Sigma_m \, W_{a,r,d,m} - \Sigma_p \Sigma_h \, H_{p,h,d} * A_{h,a} - \Sigma_r \Sigma_m \, W_{a,d,r,m} \; = \; 0 \quad \forall \; a, d$$

where:

$B_{a,d,q}$ is the volume of alcohol (a) purchased in demand region (d) at price level (q). At present, this column exists only for ethanol.

$W_{a,r,d,m}$ is the volume of alcohol (a) received in demand region (d) from refinery region (r) via shipping mode (m). This column exists only for methanol.

$H_{p,h,d}$	is the volume of recipe product (p) containing alcohol (a) consumed in demand region (d).
$A_{h,a}$	is the recipe fraction, by volume, of alcohol (a) in product (p), an input.
$W_{a,d,r,m}$	is the volume of alcohol (a) shipped from demand region (d) to refinery region (r) via mode (m). This column is valid only for ethanol. It is assumed that all ethanol purchases are made in the demand regions. Thus, ethanol needed by the refinery for processing or blending must be shipped from the demand regions.
	I.e., in each demand region, all alcohol that is purchased or produced and shipped in from the refinery regions must be either splash blended into or shipped to a refining center.

11. For those products which are not blended by recipe at the demand regions, each demand region, and for each product, imports plus what is received via domestic shipment must equal the volume blended into recipes plus regular sales volume:

$$I_{p,d} + \Sigma_r \Sigma_m W_{p,r,d,m} - X_{p,d} - \Sigma_{p'} \Sigma_h H_{p',h,d} * A_{p,h} - D_{p,d} + \Sigma_q Dn_{p,d,q} - \Sigma_q Dp_{p,d,q} \;=\; 0 \quad \forall \;\; d, p$$

where:

$I_{p,d}$	is volume of product (p) imported into demand region (d).
$W_{p,r,d,m}$	is product (p) received in region (d) from refinery region (r) via mode (m).
$X_{p,d}$	is volume of product (p) exported from demand region (d).
$H_{p',h,d}$	is volume of product (p') manufactured by recipe (h) at demand region (d). This column exists only when product (p) is consumed to produce product (p) by a recipe blended at the demand region, i.e. splash blended at the terminals.
$A_{p,h}$	is the volume fraction of product (p) consumed by recipe (h), an input.
$D_{p,d}$	is a base sales volume of product (p) in demand region (d), this activity is fixed at the last NEMS iterative demand value; i.e., it does not impact the solution.
$Dn_{p,d,q}$	is an increment of sales volume decrease from the base of $D_{d,p}$ for product (p) in demand region (d) at price level (q).
$Dp_{p,d,q}$	is an increment of sales volume increase from the base of $D_{d,p}$ for product (p) in demand region (d) at price level (q).
	I.e., in each demand region, for each product, a balance is made whereby the volume imported and the volume shipped in from the refinery regions must equal the volume splash blended at the terminal plus straight sales volume.
	Note: The columns $Dn_{p,d,q}$ and $Dp_{p,d,q}$ represent and allow incremental increases and decreases around the base demand value, $D_{p,d}$. An increase in volume around this

base is activated with an average input price determined by the demand elasticity of the product. The situation for incremental volume decreases is similar, except the price is given a negative value since the increment is essentially being backed out of the base volume. The purpose of this structure, as opposed to having a single fixed $D_{p,d}$, is to reduce wide swings in demand between NEMS iterations and thus make the marginal price more stable. This is called the "avoids" structure.

12. Balance, at each demand region, the volumes for each of the recipe products M85 and E85 - the products which are blended at the demand terminals - so that manufactured volume plus imports equals the recipe sales volume for these terminal splash blended recipes:

$$\Sigma_h \, H_{p',h,d} + I_{p',d} - D_{p',d} \;\; = \;\; 0 \quad \forall \;\; p', d$$

where:

$p' \in p$ so that p' is a subset of all products and in fact, p' = E85 and M85.

$H_{p',h,d}$ is volume of product (p') made by recipe (h), produced at demand region (d) by splash blending.

$I_{p',d}$ is volume of product (p') imported into demand region (d).

$D_{p',d}$ is the sales volume of product (p') in demand region (d).

       I.e., for each demand region, all M85 and E85 blended at the terminals plus M85 and E85 imported into the demand region must equal sales of the corresponding products.

13. For Census Divisions (demand regions) 5 and 6, balance the volume of each product that is shipped into the demand region with volume shipped out of the demand region:

$$\Sigma_m \, W_{p,r,d',m} + \Sigma_d \Sigma_m \, W_{p,d,d',m} - \Sigma_d \Sigma_m \, W_{p,d',d,m} \;\; = \;\; 0 \quad \forall \;\; d', p$$

where:

$d' \in d$ and in fact, d' = Census Divisions 5 (South Atlantic) and 6 (South Central).

$W_{p,r,d',m}$ is volume of product (p) received by demand region (d') from refinery region (r) via pipeline (P/L) mode (m). These columns are generated only for the pipeline shipping mode when (d') is CD 6.

$W_{p,d,d',m}$ is volume of product (p) received in demand region (d') via transhipment from demand region (d) by mode (m), e.g. from 6 to 5 or from 5 to 2. For these columns, d' = d is not allowed.

$W_{p,d',d,m}$ is volume of product (p) transhipped from demand region (d') to demand region (d) by mode (m). However, for these columns, d' = d is allowed; in this case the activity represents P/L sales

> I.e., pipeline product received in CD 5 or CD 6 must balance P/L product sales and transhipments.

> Note: CD 5 and CD 2 (Mid Atlantic) receive much of their product volumes via pipeline (P/L) originating in PAD District III. Thus PAD District II production which is transported via P/L is split into one activity representing P/L product which is sold in CD 6 and another activity which is product transhipped through CD 6 into CD 5. Similarly, this latter component is split into two column activities, one which represents P/L product sales in CD 5, and another which represents product transhipped through CD 5 to CD 2.

14. Balance the domestic production of each crude type at each producing region against exports and shipments to domestic refineries:

$$P_b * A_{c,v,b} - O_{c,v,b} - \Sigma_r \Sigma_m Y_{c,v,b,r,m} = 0 \quad \forall \quad b, c, v$$

where:

P_b is total volume of domestic crude oil produced at producing region (b).

$A_{c,v,b}$ is the fraction by volume of P_b that is crude type (c) with source code (v), an input.

$O_{c,v,b}$ is the export volume of crude oil (c) with source code (v) produced in domestic region (b).

$Y_{c,v,b,r,m}$ is volume of crude oil type (c) with source code (v) produced in domestic region (b) that is shipped to refinery region (r) via mode (m).

> I.e, for each production region and crude oil type, domestic production must be balanced against exports and shipments to refinery regions.

15. Limit shipments of crude oil on Jones Act marine tankers:

$$\Sigma_c \Sigma_v \Sigma_b \Sigma_r \Sigma_{m'} Y_{c,v,b,r,m'} * A_c - Vcj = 0$$

where:

$m' \in m$ m' is the set of shipping modes that correspond to Jones Act crude oil tankers.

$Y_{c,v,b,r,m'}$ is volume of crude oil type (c) with source code (v) produced in domestic region (b) that is shipped to refinery region (r) via mode (m').

A_c is dead weight tons per barrel of crude oil of type (c), about 0.1344.

Vcj   is total dead weight tons of Jones Act crude oil. This column is constrained to some maximum.

I.e., total Jones act crude oil shipments are limited by the existing fleet.

Note: This constraint is stated in the form 'X - MAX = 0' with bounds on MAX rather than in the form 'X ≤ MAX' (which is more straight forward from a mathematical standpoint) because this allows the analyst to add a minimum constraint or change over to a fixed constraint within the fortran code without a regeneration of the MPS file. Thus it is an artifice of convenience.

16. Limit shipments of refined product on Jones Act marine tankers by product class (clean, dirty...):

$$\Sigma_{p'}\Sigma_r\Sigma_d\Sigma_{m'} \, W_{p',r,d,m'}{}^*A_{p'} - V_{pc} \; = \; 0 \qquad \forall \quad \text{product class (pc)}$$

where:

$m' \in m$ m' is the set of shipping modes that correspond to Jones Act product tankers carrying product class (pc).

$p' \in p$ p' is the set of products which correspond to the product class (pc) of the particular constraint row.

$W_{p',r,d,m'}$ is volume of product (p') shipped from refinery region (r) to demand region (d) via mode (m').

A_c is dead weight tons per barrel of product (p), an input.

V_{pc} is total dead weight tons of Jones Act product of a shipping class (pc). This column is constrained to some maximum.

I.e., Jones Act product shipment volume is limited by tanker availability.

17. Allow and limit transhipments of crude oil from the Gulf Coast to the PAD District II refining region:

$$\Sigma_v\Sigma_c \, Y_{c,v,G,C,m} - Vcts \; = \; 0$$

where:

$Y_{c,v,G,C,m}$ is volume of crude oil type (c) with source code (v) that is transhipped from the PAD District III (code=G) refinery region to the PAD District II (code=C) refinery region.

Vcts   is total crude oil transhipped from PAD District III to PAD District II. This column is constrained to some maximum

I.e., the volume of crude oil shipped from the Gulf Coast to PAD District II refineries is limited.

18. For each domestic crude oil producing region and refinery region (r) allowable combination, allow and limit pipeline shipments of crude oil:

$$\Sigma_c \Sigma_v \Sigma_m \ Y_{c,v,b,r,m} - Vcp_{b,r} \ = \ 0 \quad \forall \quad b, r$$

where:

$Y_{c,v,b,r,m}$ is volume of Crude oil type (c) that is shipped from domestic producing region (b) to refinery region (r) via pipeline mode (m).

$Vcp_{b,r}$ is total crude oil shipped by pipeline from domestic producing region (b) to refinery region (r). This column is constrained to some maximum.

I.e., limit the crude oil volume shipped by pipeline from each applicable producing region//refinery region pair.

19. For each refinery/demand region applicable combination, limit pipeline shipments of light products to available capacity:

$$\Sigma_{p'} \Sigma_r \Sigma_d \Sigma_m \ W_{p',r,d,m} - Vpp_{r,d,m} \ = \ 0 \quad \forall \quad r, d, m$$

where:

$p' \in p$ p' is the set of light products which can be shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$W_{p',r,d,m}$ is volume of product (p') shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$Vpp_{r,d,m}$ is total volume of light products (p') shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.

I.e., the volume of light products that can be shipped by pipeline from each refinery region to each demand region is limited by the available pipeline capacity.

20. For each refinery/demand region applicable combination, limit pipeline shipments of liquid petroleum gas volumes to available LPG pipeline capacity:

$$\Sigma_{p'} \Sigma_r \Sigma_d \Sigma_m \ W_{p',r,d,m} - Vtpl_{r,d,m} \ = \ 0 \quad \forall \quad r, d, m$$

where:

$p' \in p$ p' is the set of LPG products which can be shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$W_{p',r,d,m}$ is volume of LPG product (p') shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$Vtpl_{r,d,m}$ is total volume of LPG products (p') shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.

I.e., the volume of LPG products that can be shipped by pipeline from each refinery region to each demand region is limited by the available pipeline capacity.

21. Refinery 'policy' table entries are adhered to:

$$\Sigma_u \Sigma_m R_{u,r,m} * A_{e,u,r,m} - A_{e,r} * Z_r FLO_u \quad \le, \ge, = 0 \quad \forall \quad e, r$$

where:

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{e,u,r,m}$ is the coefficient entered into the processing unit (u) table for refinery region (r) in the operating mode (m) column at policy row (e), an input.

$A_{e,r}$ is the fractional amount of total capacity value entered in the policy table in row (e) for refinery region (r), an input, i.e., constraints may be introduced by the analyst via the "policy" rows.

Note: The type of row ($\le, \ge, =$) is determined by the entry in column heading TYPE of the policy table (r)POL where $A_{e,r}$, appears. It may also be a non-constraining row, in which case the row is free. The total processing unit throughput is the base for the policy limits in each refinery region:

$$Z_r FLO_u - K_{u,r} - A_{u,r} * (L_{u,r} + E_{u,r}) \quad = \quad 0 \quad \forall \quad r, u$$

where:

$Z_r FLO_u$ is the sum of the base, build, and expanded capacity in processing unit (u) at refinery region (r).

$K_{u,r}$ is the base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded rather than fixed. See note below.

$A_{u,r}$ is the stream factor for processing unit (u) at refinery region (r) defined as the ratio of calendar day capacity to stream day capacity.

$L_{u,r}$ is the cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is, of course, fixed.

$E_{u,r}$ is the stream day capacity added during this simulated period for processing unit (u) at refinery region (r). This column is generally upper bounded.

22. For each applicable combination of domestic crude oil and refinery region, balance shipments received directly from the producing region plus transhipments received from other refinery regions against crude oil consumed at the refinery and crude that is transhipped to other refinery regions:

$$\Sigma_b \Sigma_m \ Y_{c,v,b,r,m} \ + \ \Sigma_{r'} \Sigma_m \ Y_{c,v,r',r,m} \ - \ \Sigma_{r'} \Sigma_m \ Y_{c,v,r,r',m} - Ra_{c,v,r} \quad = \quad 0 \quad \forall \ c, v, r$$

where:

$Y_{c,v,b,r,m}$ is volume of crude oil type (c) with source code (v) produced in domestic region (b) that is shipped to refinery region (r) via mode (m).

$Y_{c,v,r',r,m}$ is volume of domestic crude oil type (c) with source code (v) that is received at refinery region (r) by transhipment through refinery region (r') via mode (m).

$Y_{c,v,r,r',m}$ is volume of domestic crude oil type (c) with source code (v) that is transhipped through refinery region (r) to refinery region (r') via mode (m).

$Ra_{c,v,r}$ is volume of domestic crude oil type (c) with source code (v) that is processed through the atmospheric tower at refinery region (r).

     I.e., for each domestic crude oil at each refinery region, the volume consumed at the refinery plus what is shipped out of the refinery region must equal what is shipped into the refinery region.

23. For each applicable combination of imported crude oil and refinery region, balance imports received directly plus imports transhipments received from other refinery regions against crude oil consumed at the refinery and crude that is transhipped to other refinery regions:

$$\Sigma_q \ Pi_{c,r,q} \ + \ \Sigma_{r'} \Sigma_m \ Y_{c,F,r',r,m} \ - \ \Sigma_{r'} \Sigma_m \ Y_{c,F,r,r',m} - Ra_{c,F,r} \quad = \quad 0 \quad \forall \ c, r$$

where:

$Pi_{c,r,q}$ is the quantity of imported crude oil acquired by refinery region (r) of crude type (c) at price level (q).

$Y_{c,F,r',r,m}$ is volume of imported crude oil type (c) that is received at refinery region (r) by transhipment from refinery region (r') via mode (m).

$Y_{c,F,r,r',m}$ is volume of imported crude oil type (c) that is transhipped from refinery region (r) to refinery region (r') via mode (m).

$Ra_{c,F,r}$ is volume of imported crude oil type (c) that is processed through the atmospheric tower at refinery region (r).

     I.e., each imported crude oil must be balanced at each refinery by matching imports and what is received through transhipment against refinery consumption and what is transhipped to other refineries.

24. Balance each product at each refinery region:

$$Q_{p,r} + \Sigma_h H_{p,h,r} + \Sigma_q I_{p,r,q} + \Sigma_{p'} Tx_{s,p,r} - \Sigma_{p'} Tx_{p,p',r} - \Sigma_{p'}\Sigma_h H_{p',h,r}*A_{p,h}$$

$$- \Sigma_m\Sigma_d W_{p,r,d,m} = 0 \quad \forall \ p, r$$

where:

$Q_{p,r}$ is volume of spec product (p) manufactured in refinery region (r). When product (p) is a spec product, column $H_{p,h,r}$ does not exist.

$H_{p,h,r}$ is volume of product (p) manufactured in refinery region (r) using recipe (h). When this column is active for product (p), column $Q_{p,r}$ does not exist.

$I_{p,r,q}$ is volume of refined product (p) imported into refinery region (r) at price level (q).

$Tx_{s,p,r}$ is the volume of stream (s) transferred into product (p) in refinery region (r).

$Tx_{p,p',r}$ is the volume of product (p) transferred into product (p') storage in refinery region (r).

$H_{p',h,r}$ is the volume of product made by recipe (h) at refinery region (r) in which product (p') is an ingredient.

$A_{p,h}$ is the volume of product (p) consumed per unit of recipe (h), an input.

$W_{p,r,d,m}$ is the volume of product (p) shipped from refinery region (r) to demand region (d) via mode (m).

     I.e., for each product at each refinery, the volume manufactured plus volume imported plus volume transferred from another higher quality product must equal to the volume transferred to other lower quality products plus the amount consumed by recipe plus the volume shipped to market.

25. Balance each utility at each refinery region:

$$U_{l,r} + \Sigma_u\Sigma_m R_{u,r,m}*A_{l,u,r,m} - \Sigma_p Q_{p,r}*A_{l,p,r} - \Sigma_p\Sigma_h H_{p,h,r}*A_{l,h,r} = 0 \quad \forall \ r, l$$

where:

$U_{l,r}$ is the quantity of utility (l) that is purchased in refinery region (r). Of course (l) = KWH, STM, and NGF (power, steam, and natural gas fuel) with units in thousands of kWh, lbs., and Mcf respectively.

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{l,u,r,m}$ is the quantity of utility (l) consumed (-) or manufactured (+) per unit of operation of processing unit (u) in mode (m) in refinery region (r). The (u) index includes the utility manufacturing units.

$Q_{p,r}$ is the volume of spec product (p) manufactured at refinery region (r). This column exists only when product (p) is a spec blend.

$A_{l,p,r}$ is the quantity of utility (l) consumed per unit of spec product (p) manufactured at refinery region (r).

$H_{p,h,r}$ is the volume of product (p) manufactured by recipe blend (h) at refinery region (r). This column exists only when product (p) is a spec blend.

$A_{l,h,r}$ is the quantity of utility (l) consumed per unit of recipe product (h) manufactured at refinery region (r).

       I.e., for each utility at each refinery region, the quantity purchased plus the amount manufactured must equal the consumption.

26. Constrain each processing unit throughput to maximum capacity at each refinery region:

$$\Sigma_m R_{u,r,m} - K_{u,r} - A_{u,r} * (L_{u,r} + E_{u,r}) \;\; = \;\; 0 \quad \forall \;\; r, u$$

where:

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$K_{u,r}$ is the base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded rather than fixed. See note below.

$A_{u,r}$ is the stream factor for processing unit (u) at refinery region (r) defined as the ratio of calendar day capacity to stream day capacity.

$L_{u,r}$ is the cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is, of course, fixed.

$E_{u,r}$ is the stream day capacity added during this simulated period for processing unit (u) at refinery region (r). This column is generally upper bounded.

       I.e., the activity of a particular processing unit must be limited to the maximum operating capacity.

       Note: By making this row fixed with the base capacity upper bounded, the processing throughput is calculated as $K_{u,r} + A_{u,r} * (L_{u,r} + E_{u,r})$. Of course, in a model lacking capacity expansion capability, the capacity constraint row is commonly constructed as throughput and is equal to or less than a right-hand-side capacity value so that the throughput is merely the row activity.

27. Balance each intermediate refinery stream at each refinery region:

$$\Sigma_u \Sigma_m R_{u,r,m} * A_{i,u,r,m} + \Sigma_s (Tx_{s,i,r} - Tx_{i,s,r}) - \Sigma_p G_{i,p,r} - \Sigma_p \Sigma_h H_{p,h,r} * A_{i,h} = 0 \qquad \forall \quad i, r$$

where:

$i \in s$ i.e., the intermediate streams are a subset of all refinery streams.

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{i,u,r,m}$ is the volume fraction of intermediate stream (i) created (or consumed if the sign is negative) per unit of manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r) for processing unit (u) at refinery region (r).

$Tx_{s,i,r}$ is the volume of stream (s) transferred to intermediate stream (i) at refinery region (r).

$Tx_{i,s,r}$ is the volume of intermediate stream (i) transferred to stream (s) at refinery region (r).

$G_{i,p,r}$ is the volume of intermediate stream (i) blended into spec blended product (p) at refinery region (r).

$H_{p,h,r}$ is the volume of product (p) manufactured according to recipe (h) at refinery region (r).

$A_{i,h}$ is the volume fraction of intermediate stream (i) consumed per unit volume of product manufactured according to recipe (h) at refinery region (r).

         I.e., at each refinery region, each intermediate stream must be volume balanced so that the amount manufactured plus the amount transferred from higher quality streams must equal the volumes consumed by manufacturing processes, the amount that may be transferred to other lower quality streams plus the volumes blended into spec and recipe products.

28. Constrain qualities of spec blended products:

$$\Sigma_i G_{i,p,r} * A_{y,i,p} - Q_{i,r} * A_{y,p,r} \quad \le, \ge, = \quad 0 \qquad \forall \quad y, p, r$$

where:

$G_{i,p,r}$ is the volume of intermediate stream (i) blended into spec-blended product (p) at refinery region (r).

$A_{y,i,p}$ is the blend value of property (y) for spec product (p) of stream (i).

$Q_{p,r}$ is the total volume of spec-blended product (p) manufactured at refinery region (r).

$A_{y,p,r}$ is the constraining value of property (y) that spec product (p) must adhere to; e.g., an octane number, at refinery region (r).

Note: The row type varies depending upon whether the blend specification quality is a maximum, minimum, or fixed value.

i.e., for each spec for each product at each refinery region, the aggregate spec value of the product determined by volume weighting the spec properties of the consumed blending stocks must not violate the specification limit.

29. Sum oxygen percentage contribution by oxygenates blended to reformulated gasoline

$$\Sigma_{OX} G_{OX,RFG,r} * PO_{OX} + H_{ETH,RFG,r} * PO_{ETH} * F_{ETHRFG} + H_{ETH,RFH,r} * PO_{ETH} * F_{ETHRFH} = ZOX_r$$

where:
$G_{OX,RFG,r}$ is the volume of oxygenate stream (OX) blended to RFG in region (r).
PO_{OX} is the percentage oxygen in oxygenate stream (OX). This group includes MTBE, TAM, and THM from methanol and ETB, TAE, and THE from ethanol. Also included is the ethanol splash blended.
$H_{ETH,RFG,r}$ is the volume of RFG splash blended with ethanol in region r.
PO_{ETH} is the percentage oxygen in ethanol
F_{ETHRFG} is the fraction of ethanol in RFG for 2.0% min oxygen (= 5.8%).
$H_{ETH,RFH,r}$ is the volume of RFH splash blended with ethanol in region r.
F_{ETHRFH} is the fraction of ethanol in RFH for 2.7% min oxygen (= 7.8%).
ZOX_r is the total volume in units of percent oxygen-barrels of RFG.

30. Sum oxygen percentage contribution by renewable oxygenates blended to RFG.

$$\Sigma_{OE} G_{OE,RFG,r} *PO_{OE} +H_{ETH,RFG,r} *PO_{ETH} *F_{ETHRFG} +H_{ETH,RFH,r} *PO_{ETH} *F_{ETHRFH} \geq L*ZOX_r$$

where, in addition to the terms defined in equation 29:

$G_{OE,RFG,r}$ is the volume of renewable oxygenate stream (OE) blended to RFG in region (r).
PO_{OE} is the percentage oxygen in oxygenate stream (OE). This group includes ETB, TAE, and THE from ethanol. Also included is the ethanol splash blended.
L is the volume fraction of the oxygen that must come from renewable oxygenates, i.e., ethanol, ethylbenzene (ETB) and ethyl ethers (TAE and THE).

31. Calculate refinery consumption of natural gas supply by summing volumes processed for each refinery region:

$$\Sigma_p N_r NGRFN_p - U_r NGF = 0$$

where:

$N_r NGRFN_p$ is the volume of natural gas consumed in refinery region (r) at supply price delta (p).
$U_r NGF$ is the total volume of natural gas consumed in refinery region r.

32. Place an upper bound on each natural gas supply step volume:

$$N_r NGRFN_p \quad \leq \quad NG_p \, max$$

where:

$N_r NGRFN_p$ is the volume of natural gas allowed on step p in region (r) at cost a cost delta.

$NG_p \, max$ is the maximum volume of natural gas supply allowed, based on an input value. Note that step N1 has a minimum lower bound volume.

33. Calculate Alaskan crude export volumes:

$$\Sigma_q \, NZAMHP_q \; + \; \Sigma_q \, NZAMHN_q \; - \; ZZAMHTOT \; = \; 0$$

where:

$\Sigma_q \, NZAMHP_q$ Volume at price increment q of Alaskan Crude (AMH) exports.
$\Sigma_q \, NZAMHN_q$ Volume at price discount q of Alaskan Crude (AMH) exports.

34. Place an upper bound on each Alaskan crude supply step volume:

$$NZAMHx_q \quad \leq \quad NZAMHx_q \, max$$

where:

$NZAMHx_q$ Volume at price increment/discount q of Alaskan Crude (AMH) exports.

$NZAMHx_q \, max$ is the maximum volume of crude export allowed, based on an input value.

35. In addition to the above, several non-constraining rows exist merely as a convenience to sum over certain columns via the row activity parameter.

B.6 Row and Column Cross References

The PMM LP matrix is generated from a program written in the FORTRAN language using callable subroutines from OML. The correspondence between the rows and the column symbols in the preceding matrix description and the generated matrix names of PMM are shown in Table B4.

Table B4. Column Cross References

Column Notation	Matrix Name
$B_{a,d,q}$	C(d)(a)R(q)
$D_{p,d}$	D(d)(p)S1
$Dn_{p,d,q}$	D(d)(p)N(q)
$Dp_{p,d,q}$	D(d)(p)P(q)
$E_{u,r}$	E(r)(u)INV
$G_{i,p,r}$	B(r)(p)(i) & F(r)(p(i)
$H_{p,h,r}$	X(r)(h)(p)
$H_{p,h,d}$	X(d)(h)(p)
$I_{p,d}$	I(d)(p)Z9
$I_{p,r,q}$	I(r)(p)R(q)
$K_{u,r}$	K(r)(u)CAP
$L_{u,r}$	L(r)(u)BLD
M_r	G(r)METDEM
Mt	D@METS1
$O_{c,v,b}$	O@CRDEXP
P_b	P(b)DCRQ1
$Pi_{c,r,q}$	P(r)F(c)Q(q)
$Q_{p,r}$	Q(r)(p)
$Ra_{c,v,r}$	R(r)ACU(v)(c)

Column Notation	Matrix Name
$R_{u,r,m}$	R(r)(u)(m)
Tu	T@TOTUNF
$T_{i,r}$	T(r)UNF(i)
$Tx_{s,p,r}$	T(r)(s)(p)
$Tx_{p,p',r}$	T(r)(p)(p')
$Tx_{s,s',r}$	T(r)(s)(s')
$U_{l,r}$	U(r)(l)
Vcj	VTVC(m)CP
V_{pc}	VTVP(m)CP
$Vcts$	VTPCGAC
$Vcp_{b,r}$	VTPC(b)(m)(r)
$Vpp_{r,d,m}$	VPP(r)(d)(m)
$Vtpl_{r,d,m}$	VTPL(r)(m)(d)
$W_{a,r,d,m}$	W(r)(a)(m)(d)
$W_{a,d,r,m}$	W(d)(a)(m)(r)
$W_{p,r,d,m}$	W(r)(p)(m)(d)
$W_{p,d,d',m}$	W((d)(p)(m)(d')
$X_{p,d}$	D(d)(p)Z9
$Y_{c,v,b,r,m}$	Y(b)(v)(c)(m)(r)
$Y_{c,v,r,r',m}$	Y(r)(v)(c)(m)(r')

Column Notation	Matrix Name
Zt	Z@TOTCRD
ZET_d	Z(d)ETHTAX
ZOX_r	Z(r)RFGOXY
$N_rNGFRFN$	N(r)NGFRFN
U_rNGF	U(r)NGF
$NZAMHP_q$	NZAMHP(q)
$NZAMHN_q$	NZAMHN(q)
ZZAMHTOT	ZZAMHTOT
Z_rFLO_u	Z(r)FLO(u)

Table B5. Row Cross References

Row Number	Matrix Name
1	Z@IRACN
2	Z@IRACX
3	Z@CRDTOT
4	A@PRDIMP
5	D@MET
6	A@INVST
7	A(r)INVST
8	F@TOTCRD
9	F(r)UNF(i)
10	D(d)(a)
11	D(d)(p)
12	D(d)(p')
13	M(d)(p)
14	C(b)(v)
15	TVC(m)CP
16	TVP(m)CP
17	TPCGAC
18	TPC(b)(m)(r)
19	TPP(r)(m)(d)
20	TPL(r)(m)(d)
21	P(r)(e), Z(r)CAP(u)
22	C(r)(v)(c)
23	C(r)F(c)
24	M(r)(p)
25	U(r)(l)
26	L(r)(u)CAP
27	B(r)(i)
28	Q(r)(p)(y)
29	S(r)RFGOXY
30	Q(r)RFGREN
31	Z(r)NGFSUM
32	N(r)NGFRFN(q)
33	ZZAMHSUM
34	NZAMHN/P(q)

APPENDIX C

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APPENDIX C Bibliography

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47.   Also see citations in Appendix A.

APPENDIX D

Model Abstract

APPENDIX D Model Abstract

D.1 Model Name:

Petroleum Market Model

D.2 Model Acronym:

PMM

D.3 Description:

The Petroleum Market Model is a simulation of the U.S. petroleum industry. It includes 12 domestic crude oil production regions, 5 refining centers with full processing representations and capacity expansion capability and gas plant liquid production, and 9 marketing regions. The heart of the model is a linear program optimization which ensures a rational economic simulation of decisions of petroleum sourcing, resource allocations, and the calculation of marginal price basis for the products. Eighteen refined products are manufactured, imported, and marketed. Seven of these products are specification blended, while the remaining 11 are recipe blended. Capacitated transportation systems are included to represent existing intra-U.S. crude oil and product shipments (LPG, clean, dirty) via pipeline, marine tanker, barge, and truck/rail tankers. The export and import of crude oil and refined products is also simulated. All imports are purchased in accordance with import supply curves. Domestic manufacture of methanol is represented as though the processing plants were a part of the refinery complexes whereas ethanol sources are treated as merchant. Transportation is allowed for ethanol shipments to the demand region terminals for splash blending.

The program is written in FORTRAN which includes callable subroutines allowing full communication with the LP portion of the model which is in the form of an MPS resident file.

D.4 Purpose of the Model:

The PMM models domestic petroleum refining activities, the marketing of petroleum products to consumption regions, the production of natural gas liquids in gas processing plants, and domestic methanol production. The purpose of the PMM is to project petroleum product prices, refining activities, and movements of petroleum into the United States and among domestic regions. In addition, the model contains adequate structure and is sufficiently flexible to examine the impact of a wide variety of petroleum-related issues and policy options, in order to foster understanding of the petroleum refining and marketing industry as well as determine the effects of certain policies and regulations.

The PMM projects sources of supply for meeting petroleum product demand. The sources of supply include crude oil, both domestic and imported; other inputs including alcohols and ethers; natural gas plant liquids production; petroleum product imports; and refinery processing gain. In addition, the PMM estimates domestic refinery capacity expansion and fuel consumption. Product prices are estimated at the Census division level and much of the refining activity information is at the Petroleum Administration for Defense (PAD) District level.

D.5 Most Recent Model Update:

October 1995

D.6 Part of Another Model?

National Energy Modeling System (NEMS)

D.7 Model Interfaces:

Receives information from the International, Natural Gas Transmission and Distribution, Oil and Gas Supply, Renewable Fuels, Electricity Market, Residential, Commercial, Industrial, and Transportation Models. Delivers information to each of the models listed above plus the Macroeconomic Model.

D.8 Official Model Representative:

Bruce Bawks
Office of Integrated Analysis and Forecasting
Oil and Gas Analysis Branch
(202) 586-6579

D.9 Documentation:

EIA Model Documentation: Petroleum Market Model of the National Energy Modeling System (NEMS), December 1995. (DOE/EIA-M059).

D.10 Archive Media and Installation Manual

Archived as part of the NEMS production runs.

D.11 Energy System Described:

Petroleum refining industry and refined products market.

D.12 Coverage:

Geographic: Twelve domestic crude oil production regions (East Coast, Gulf Coast, Mid-Continent, Permian Basin, Rocky Mountain, West Coast, Atlantic Offshore, Gulf Offshore, Pacific Offshore, Alaska South, Alaska North, Alaska Offshore); five refining regions (PAD Districts I-V); nine market regions, the Census divisions (New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific)

Time Unit/Frequency: Annual, 1990 through 2015

Products: LPG, traditional motor gasoline, traditional high oxygen motor gasoline, reformulated motor gasoline, reformulated high oxygen motor gasoline, M85, E85, jet fuel, distillate fuel oil, highway diesel, low-sulfur residual fuel oil, high-sulfur residual fuel oil, petrochemical feedstocks, asphalt/road oil, marketable coke, still gas, other.

Refinery Processes: crude distillation, vacuum distillation, delayed coker, fluid coker, visbreaker, fluid catalytic cracker, hydrocracker-dist, hydrocracker-resid, solvent deasphalter, resid desulfurizer, FCC feed hydrofiner, distillate HDS, naphtha hydrotreater, catalytic reformer-450 psi, catalytic reformer-200 psi, alkylation plant, catalytic polymerization, pen/hex isomerization, butane isomerization, etherification, butanes splitter, dimersol, butylene isomerization, naphtha splitter, C2-C5 dehydrogenator, hydrogen plant, sulfur plant, aromatics recovery plant, lube + wax plants, FCC gasoline splitter, gas/H2 splitter, stream transfers, fuel system, steam production, power generation

Crude Oil: Alaska low sulfur light, Alaska mid sulfur heavy, domestic low sulfur light, domestic mid sulfur heavy, domestic high sulfur light, domestic high sulfur heavy, domestic high sulfur very heavy, imported low sulfur light, imported mid sulfur heavy, imported high sulfur light, imported high sulfur heavy, imported high sulfur very heavy.

Transportation Modes: Jones Act dirty marine tanker, Jones clean marine tanker, LPG marine tanker, import tankers, clean barge, dirty barge, LPG pipeline, clean pipelines, dirty pipelines, rail/truck tankers. These cover all significant U.S. links.

D.13 Modeling Features:

Model Structure: FORTRAN callable subroutines which update the linear programming matrix, re-optimize, extract and post-process the solution results, update system variables, and produce reports.

Model Technique: Optimization of linear programming representation of refinery processing and transportation which relates the various economic parameters and structural capabilities with resource constraints to produce the required product at minimum cost, thereby producing the marginal product prices in a manner that accounts for the major factors applicable in a market economy.

Special Features: Choice of imports or domestic production of products is modeled, capacity expansion is determined endogenously, product prices include fixed and environmental costs, oxygenated and reformulated gasolines and low-sulfur diesel fuel are explicitly modeled.

D.14 Non-DOE Input Sources:

Information Resources Inc. (IRI), WORLD model data, National Petroleum Council, ICF Resources

D.15 DOE Input Sources:

Forms:

EIA-14   Refiners' Monthly Cost Report
EIA-182   Domestic Crude Oil First Purchase
EIA-782A   Monthly Petroleum Product Sales
EIA-782B   Reseller/Retailer's Monthly Petroleum Product Sales
EIA-782C   Monthly Petroleum Products Sold into States for Consumption
EIA-810   Monthly Refinery Report
EIA-811   Monthly Bulk Terminal Report
EIA-812   Monthly Product Pipeline Report
EIA-813   Monthly Crude Oil Report
EIA-814   Monthly Imports
EIA-817   Monthly Tanker and Barge Movement
EIA-820   Annual Refinery Report
EIA-826   Monthly Electric Utility Sales
EIA-856   Monthly Foreign Crude Oil Acquisition
EIA-867   Annual Nonutility Power Producer Report

In addition to the above, information is obtained from several Energy Information Administration formal publications: *Petroleum Supply Annual*, *Petroleum Supply Monthly*, *Petroleum Marketing Annual*, *Petroleum Marketing Monthly*, *Fuel Oil and Kerosene Sales*, *Natural Gas Annual*, *Natural Gas Monthly*, *Annual Energy Review*, *Monthly Energy Review*, *State Energy Data Report*, *State Energy Price and Expenditure Report*.

D.16 Computing Environment:

Hardware: RS 6000 POWER server 590
Operating System: AIX version 3
Software: AIX FORTRAN, OML
Memory Requirement: 4,000K
Storage Requirement: 34.7 MB
Estimated Run Time: 2,200 seconds in a full NEMS run (26 years)
Special Features: None.

D.17 Independent Expert Reviews Conducted:

Independent reviews of the Component Design Report of the PMM were conducted by:

A.S. Manne, ASM Consulting Services, July 1992
A.S. Manne, ASM Consulting Services, September 1992

D.18 Status of Evaluation Efforts by Sponsor:

None.

APPENDIX E

Data Quality

APPENDIX E. Data Quality

E.1 Quality of Distribution Cost Data

Costs related to distributing petroleum products to end-users are incorporated by adding fixed transportation markups to the wholesale prices which include the variable and fixed refinery costs. Transportation markups for petroleum products are estimated as the average annual difference between retail and wholesale prices over the years 1984 through 1994[1]. The differences are based on **wholesale prices** in the producing Census division and **end-use prices** (which do not include taxes) in the consuming Census division.   See Appendix F for a discussion of programs and input files used in estimating these markups.

Annual **wholesale prices** for all petroleum products are aggregated from state-level prices from the EIA-782A. The estimation and reliability of the EIA-782A data is discussed in the *Petroleum Marketing Annual 1994* (DOE/EIA-0487(94)). See Table E1 for inputs and sources.

With the exception of gasoline, non-utility distillate fuel, and jet fuel, **sectoral end-user prices** through 1992 are aggregated from prices from the State Energy Price and Expenditures Report 1992 (SEPER). The methodology behind these state-level sectoral prices are discussed in the *State Energy Price and Expenditures Report 1992* (DOE/EIA-0376(92)). One area of concern is the SEPER methodology for residual fuel transportation prices where the vessel bunkering prices are tied to State electric utility prices. This methodology is questionable because most utility residual fuel use is on the East Coast whereas vessel bunkering is concentrated on the Gulf and West Coasts.

Gasoline, jet fuel, and non-utility distillate prices are estimated as weighted averages using end-user prices from EIA-782A and sectoral consumption from the *State Energy Data Report* (DOE/EIA-0214(92)) (SEDS).

Due to a two-year lag in the publication of the SEPER data, end-use price estimates for 1991 and 1992 are calculated using the same data series and methodology described in SEPER. The SEPER methodology uses prices from EIA-782A, FERC-423, EIA-759, and weights them with consumption volumes from SEDS. Refer to SEDS for a discussion of the reliability of consumption data and to Electric Power Annual 1994 (DOE/EIA-0348(94)) for a discussion or the reliability of electric utilities data from FERC-423 and EIA-759. Table E1 shows the data series used in the estimation of end-use prices.

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[1] Transportation markups for kerosene are based on the difference between end-user kerosene prices and wholesale distillate prices.

Table E1. Sources of Markup Inputs

Products	Sectors	Data Series Inputs
Distillate	CM, IN, RS, TR	EIA-782A, SEDS
Jet Fuel	TR	EIA-782A, SEDS
Motor Gasoline	CM, IN, TR	EIA-782A, SEDS
Asphalt and Road Oil	IN	SEPER, EIA-782A, SEDS
Kerosene	CM, IN, RS	SEPER, EIA-782A, SEDS
Liquified Petroleum Gases	CM, IN, RS, TR	SEPER, EIA-782A, SEDS
Low Sulfur Residual Fuel	CM, IN	SEPER, EIA-782A, SEDS
High Sulfur Residual Fuel	TR	SEPER, EIA-782A, SEDS
Distillate	EU	SEPER, EIA-759, FERC-423
Low Sulfur Residual Fuel	EU	SEPER, EIA-759, FERC-423
High Sulfur Residual Fuel	EU	SEPER, EIA-759, FERC-423

E.2 Quality of Tax Data

In the PMM, State and Federal taxes are added to the prices of gasoline, and distillate fuel, liquefied petroleum gas (LPG), jet fuel, ethanol and methanol in the transportation sector.   State taxes are held constant in real terms while Federal taxes are deflated in each forecast year. The tax methodology was adopted starting with AEO95 because a tax trend analysis indicated that State taxes keep pace with inflation while Federal taxes do not.

The State taxes are added as Census division weighted averages which are based on the most recently-available State taxes. State taxes for LPGs, jet fuel, ethanol, and methanol are taken from The Clean Fuels Report, April 1995, published by J.E. Sinor Consultants. State and Federal taxes for gasoline and

transportation distillate are based on data from the Federal Highway Administration, but are modified to include other known changes to State taxes. The quality of the State level tax data is unknown but deemed reliable. Federal taxes, which were increased by 4.3 per gallon in 1993, are widely published, and deemed highly reliable.

See Appendix F for a description of programs and input files used in the estimation of historical taxes and taxes used in the price projections.

E.3 PMM Critical Variables

The PMM contains numerous variables and parameters. Some variables have greater impact on model results than others. The following is a list of variables that we believe has a high degree of influence on PMM results. It is provided to help users understand the critical factors affecting the PMM.

- World oil price
- Product demands
- Imported crude supply curves
- Imported product supply curves
- Domestic crude production
- Prices and available supplies of methanol, ethanol, MTBE, and other ethers
- Investment cost for capacity expansion
- Market shares for gasoline and distillate types
- NGL supply volumes

Most of these variables are provided by other models in the NEMS system. The investment cost and market share data are developed offline and read in to the PMM.

Tests on some of these variables are discussed in a separate appendix to this documentation, titled *Documentation of the Petroleum Market Model, Appendix: Model Developer's Report*. In an earlier effort, a detailed calibration was made, using the same refinery model technology database as in PMM, compared against the EIA Petroleum Supply Annual (PSA) for 1989.[2] This comparison indicated that the validation was quite good with total crude volumes from the model only 0.48 percent above actual PSA values and total production just 0.28 percent higher. A more complete comparison, including assumptions, can be found in the cited reference.

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[2]"U.S. Detailed Refinery Model," Letter of October 20, 1993, from Martin Tallett of ENSYS to G. H. Harp of EIA.

APPENDIX F

Estimation Methodologies

APPENDIX F. Estimation Methodologies

F.1 Refinery Investment Recovery Thresholds

The calculation methodology for the capital investment recovery threshold values have been taken from a standard refinery industry reference.[1] The inside battery limits (ISBL) investment cost and labor costs for most of the processing unit types were obtained from a study by Bonner and Moore Associates.[2] The data for typical unit sizes and stream factors as well as supplementary investment and labor was obtained from the World Oil Refining, Logistics, and Distribution (WORLD) model.[3] A basic premise used in the PMM application is that the investment recovery value at the end of project life (PL) will equal site decommissioning cost, an expectation that seems to be widely shared in the petroleum industry.

The inside battery limits cost per barrel investment cost at the Gulf Coast (P) for each refinery process modeled was obtained from the cited data sources. The total investment cost (INV) was then calculated using the referenced methodology. Finally, the capital recovery threshold for each process was calculated.

Given that a Gulf Coast plant and equipment battery limits cost for an expansion of processing plant type I is P_i dollars per barrel per day of stream day capacity (This is assumed to include required storage facilities but not necessarily all mandated environmental systems.), then the nominal total plant and equipment cost at some arbitrary location would be

$$NTPE_i = P_i(1+U)(1+O)$$

(1)

where   U = Utilities cost multiplier
                O = Offsites multiplier

With construction occurring over a 3-year period at a constant rate, the present value of the nominal total plant and equipment is

$$PVNTPE_i = \frac{NTPE_i}{3} \Sigma_{j=1}^{3}(1+DEF_i)^j$$

(2)

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[1]J.H. Gary and G.E. Handwerk, *Petroleum Refining: Technology and Economics* (New York: Marcel Dekker, 1975), Chapters 13 and 14.

[2]Bonner & Moore Associates, Inc., *A Capital Expansion Methodology Review of the Department of Energy's Petroleum Market Model*, prepared for the United States Department of Energy, Contract No. EI-94-25066 (Houston, TX, July 1994).

[3]Ensys Energy & Systems, Inc., *WORLD Reference Manual*, a reference for use by the analyst and management prepared for the United States Department of Energy, Contract No. DE-AC-01-87FE-61299 (Washington, D.C., September 1992).

where DEF = inflation rate during construction

The final land, plant, and equipment cost is

$$FLPE_i = PVNTPE_i(1+S)(1+C)$$ **(3)**

where   S = Special costs multiplier (includes land)
C = Contingency cost multiplier

The total investment is

$$INV_i = (1+W) * FLPE_i$$ **(4)**

where   W = Working capital multiplier

A multiplier called the plant depreciation factor or PDF, is used in the investment recovery calculations. It is merely the ratio of depreciable investment to total investment. More specifically, the numerator of the PDF is total investment less land, working capital, and supplies. The total Gulf Coast investment cost and depreciable investment fraction (PDF) as well as the fixed costs are presented in Table F4. The location factors, taken from working papers developed for the 1993 NPC refinery study, are presented in Table F2. In order to do this, several premises have been set in accordance with Table F1. The multipliers in Table F1 were obtained from the Gary and Handwerk reference. The variability of these factors is unknown. The INV values were pre-calculated in a worksheet so the recovery factors could be placed in the FORTRAN code while maintaining flexibility in changing the key volatile parameters such as required return on investment. The investment data are used for two different purposes in PMM: (1) the negative of the sum of the recovery factor and the fixed cost are entered into the objective row of the unit expansion vectors of the PMM LP to provide an investment decision criteria; i.e., the investment will occur to the extent that it is economic and (2) the basic investment cost (INV) multiplied by the location factor (L) and any appropriate environment factor is what must be multiplied by the LP expansion vector activity with the resulting products summed to provide entries for the CAPEXP matrix, i.e. the capital expenditure table, of the NEMS FORTRAN common block.

Table F1. Investment Multiplier Values

Multiplier	Value
U	0.075
O	0.15
DEF	0.03
C	0.15
S	0.04
W	0.10

The capital recovery threshold is calculated from:

$$CRT_{i,j} = \frac{INV_i \times (L_j + E) \times (U_{R,PL} - PDF_i \times \frac{TR_j}{PL \times 365})}{(1 - TR_j)}$$ (5)

where,

$CRT_{i,j} =$ The daily investment recovery required for processing unit type I at location j, $/bbl

$INV_i =$ The investment required for processing unit type I on the Gulf Coast, $/bbl

$L_j =$ Location factor for PAD District j

$E =$ Investment factor for environmental capital expenditure

$PDF_i =$ Plant depreciation factor (fraction of investment that may be depreciated) for processing unit type I

$TR_j =$ Effective combined income tax rate in PAD District j

$R =$ Investment return rate, fraction

$PL =$ Plant life, years

Table F2. Location Index (J) and Location Factors

PAD District	Location Factor
I	1.2
II	1.2
III	1.0
IV	1.2
V	1.2

when R > 0, then

$$U_{R,PL} = \frac{R}{365 \times (1 - (1 + \frac{R}{365})^{-PL \times 365})} \tag{6}$$

otherwise,

$$U_{R,PL} = \frac{1}{PL \times 365} \tag{7}$$

Also,

$$TR_j = TRF + TRS_j - TRFxTRS_j$$

where

$TRF =$ Federal income tax rate

$TRS_j =$ Average state income tax rate for PAD District j, weighted by crude oil charge

Note that an investment tax credit can be added to this investment model by decreasing the INV by the applicable fraction.

The reader may verify his understanding of the investment equations from a simple example. Calculating the capital recovery required to expand the crude oil distillation tower capacity in PAD District III by one barrel per day for a 15 percent return over a 15-year plant life with a combined income tax rate of 44.2 percent with no allowance for collateral environmental cost,

$CRT_{ACU,I} = \$0.48/\text{day}.$

Refinery Unit Fixed Cost Factor

The fixed cost which, in conjunction with the capital recovery threshold forms the threshold for expansion investment decisions, for processing unit type I is calculated from:

$$FC_i = \frac{1}{365}[B_i + PVNTPE_i \sum_{j=1}^{6} F_j]$$

(8)

where
> B = Operations labor, $/year/BBL/day
> the 6 "F" multipliers are shown in Table F3.

Table F3. Fixed Cost Multiplier Values

Multiplier	Value
1, Insurance	0.005
2, Local tax rate	0.01
3, Maintenance	0.04
4, Supplies	0.002
5, Overhead	0.015
6, Environment	0.02

The labor charge, B, and the overhead multiplier is taken from the WORLD model. The first 4 multipliers was obtained from the Gary and Handwerk reference. The environment base multiplier results from analyst judgement. The 1993 NPC study estimates the new environmental refinery operation and maintenance cost as about one third of base operations and maintenance over the 1991-1995 time period. Gary and Handwerk estimate the maintenance factor to vary between 3% and 8%, 4% was used because the trend is for refineries to increase operating efficiency over time. Variability of the other factors is unknown.

Table F4. Refinery Investment Recovery Data
($1991)

Processing Unit	Unit Index	INV (Dollars per bbl/d)	PDF	Fixed Cost ($/bbl)
Crude oil tower	ACU	$673	0.760	$0.14
Vacuum unit	VCU	$1,067	0.760	$0.21
Solvent deasphalting	SDA	$2,275	0.760	$0.46
Delayed coker	KRD	$5,135	0.760	$0.99
Fluid/flexicoker	KRF	$6,559	0.760	$1.28
Visbreaker/TCC	VBR	$1,657	0.760	$0.34
Naphtha hydrotreater	NDS	$1,312	0.760	$0.28
Distillate desulfurizer	DDS	$1,933	0.760	$0.41
FCC feed hydrofiner	FDS	$2,349	0.760	$0.47
Residuum desulfurizer	RDS	$5,394	0.760	$1.11
Gas oil hydrocracker	HCR	$6,512	0.760	$1.33
Residuum hydrocracker	HCV	$8,702	0.760	$1.74
Naphtha hydrotreater	HCN	$3,990	0.760	$0.81
Lube and wax units	LUB	$16,109	0.760	$3.21
Gas oil dewaxer	DEW	$1,613	0.760	$0.34
Prefrac hi density ATF	JFP	$2,584	0.760	$0.88
Hi density ATF HD unit	HDN	$17,819	0.760	$3.63
HP Semi regen REFORMER	RFH	$2,157	0.760	$0.49
LP Cyclic reformer	RFL	$2,661	0.760	$0.59
LP Continuous reformer	RFC	$3,164	0.760	$0.68
Naphtha splitter	SPL	$863	0.760	$0.17
C3/C4 dehydrogenation	OLE	$13,232	0.760	$2.73
Fluid cat cracker	FCC	$4,358	0.760	$0.88
FCC fractionation	FGS	$690	0.760	$0.13
Alkylation unit	ALK	$7,150	0.760	$1.54
Polymerization unit	CPL	$2,244	0.760	$0.49
Dimersol unit	DIM	$3,107	0.760	$0.65
Aromatics recovery	ARP	$3,625	0.760	$0.78
Pen/Hex Isomerization	PHI	$4,315	0.760	$1.14
Butane isomerization	C4I	$6,213	0.760	$1.68
Total recycle isom	TRI	$6,725	0.760	$1.37
Cyclar unit	CYC	$12,797	0.760	$2.49

Processing Unit	Unit Index	INV (Dollars per bbl/d)	PDF	Fixed Cost ($/bbl)
Etherol unit	ETH	$8,054	0.760	$1.78
H2 Steam ref bfoe/d	H2P	$32,779	0.760	$6.56
H2 Partial Ox bfoe/d	H2X	$32,634	0.760	$6.31
Sulfur, S tons/day	SUL	$200	0.760	$0.04
Steam gener, lbs/hr	STG	$72	0.760	$0.01
Power generation, MKW	KWG	$9	0.760	$0.00
M Dist Furfural trting	FEX	$2,053	0.760	$0.41
M Dist deep hydrotrt	DHT	$2,851	0.760	$0.56
Methanol unit	MOH	$30,611	0.760	$3.41

F.2 Gas Plant Models

The gas plant models for each PAD District is maintained on the spreadsheet 'NGL.WK1' maintained within EIA by the Oil and Gas Analysis Branch. These models require gas plant wet gas volumes as input. In order to accommodate the information available, dry gas production volume, and permit gas plant activity to be driven by dry natural gas demand, factors are applied to the dry gas demand volumes to calculate imputed volumes of processed wet gas. In PADD V, the PMM models only the California gas plants. Although Alaska produces and processes a considerable volume of natural gas, it is nearly all used for reinjection with some NGL dumped into the crude pipeline with the exception of modest volumes of southern Alaska production. The southern Alaska production does have a local NGL market with much of the dry gas shipped out as LNG. In any case, the PAD District V refinery industry is virtually unaffected by Alaska NGL production. Thus, the PMM aggregate gas plant includes California only. Gas residue volumes are not available to the PMM but total dry gas volumes by PAD District are. This information is in the NEMS common block region. Specifically, the total dry gas volumes are available in:

Common block: NGTDMOUT

Variable matrix: PRNG_PADD(PADD,YEAR), BCF

Description: Total dry gas produced including plant fuel and lease fuel (P&L) for PAD
                         District 'PADD' in year 'YEAR' excluding Alaska.

Each of the five values must be multiplied by a factor to obtain an estimate of the corresponding wet gas that is processed by the gas plants; i.e. the total dry gas volumes are multiplied by the ratio of processed wet gas to total dry gas production. These ratios are derived from 1993 data[4] so that data variability is unknown. The five multipliers are shown in Table F5.

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[4]Energy Information Administration, *Natural Gas Annual 1993*, DOE/EIA-0131(93), (Washington, DC, October 1994).

Table F5. Total Dry Gas Multiplier

PAD District	Multiplier
I	0.4536
II	0.7659
III	0.7572
IV	1.0136
CA	0.7745

The multiplier for PAD District I is low because relatively little of the modest PAD District I gas production is processed beyond field decontamination. The multiplier is high for PADD IV because a great deal of Utah gas production is reinjected for field pressure maintenance. This reinjected gas is not counted in total dry gas production.

The NGL extraction is allowed to occur at a minimum, maximum, or average level. Complete ethane rejection is allowed with a processing credit for each barrel rejected. Propane rejection occurs in U.S. gas plants but to an unknown extent. The model allows propane rejection up to one fourth of the propane volume. The basic model structure is devised from the Pace Consultants annual petrochemical report[5] . The liquids extraction data have been calculated by averaging actual liquid extraction volumes from the 4-year period 1990 - 1993[6] as well as obtaining minimum and maximum values. The coefficients were then normalized. The minimum and maximum values seem to suggest the variability of the data but the reader is cautioned that statistically based models, as opposed to engineering models, may understate processing flexibility. Furthermore, the gas business is not statistical. It is driven by technology and ecomomics, i.e. history is suspect as a basis for such values.. The model for PAD District III is shown in the following table. Models for the other PAD Districts are similar except the extraction coefficients differ.

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[5]Pace Petrochemical Service, *Annual Issue*, (Houston, TX, September 1989).

[6]Energy Information Administration, *Natural Gas Annual 1991*, DOE/EIA-0131(91), (Washington, DC, October 1992) and similarly, the Natural Gas Annuals for 1986-1990.

Table F6. Gas Plant Model for PAD District III

	MIN	MAX	AVG	ETH	PRO	Row Type	R HS
Wet Nat. Gas (MMcf)	-1.000	-1.000	-1.000			=	0
Dry Gas (MMcf)	0.945	0.938	0.941	0.002	0.002	=	+
Ethane (bbl)	14.070	14.332	14.562	-1.000			
Propane (bbl)	11.165	11.628	11.782		-1.000		
I-Butane (bbl)	4.375	4.776	4.693				
N-Butane (bbl)	2.506	4.409	3.349				
Nat. Gasoline (bbl)	7.025	7.310	7.286				
Volume Loss (MMcf)	-39.058	-42.394	-41.613	0.998	0.998		
Fuel (MMcfl)	-0.037	-0.040	-0.040				
Oper. Cost ($)	-115.07	-124.82	-122.51				
Oper. Cost ($/bbl)				5.88	2.94		
Capacity limit (bbl/d)					1.000	≤	+

The above table differs from the implemented model in three respects. Propane rejection is controlled via column limit in the LP rather than as a row limit and the operating costs are merely entered into the objective function row rather than occupying two rows as the above depiction suggests. Of course these things are shown in the above form for the sake of clarity. The major difference is that the wet gas balance row is an equal zero row in the LP representation. There is a column representing pseudo purchases of wet gas with a plus one in the wet gas balance row and minus the forecasted gas price in the objective function row. Of course, this column is fixed at the determined level of processed wet gas.

F.3 Chemical Industry Demand for Methanol

Since the PMM includes methanol plant models in each PAD District representing all U.S. methanol capacity, U.S. chemical industry demand (demand other than for MTBE/TAME feedstock and neat fuel) is a required input. The Pace Consultants make long range forecasts of the chemical industry demand[7] . Their forecast is:

Table F7. Chemical Industry Demand for Methanol

Year	Demand (Mbbl/d)	Year	Demand (Mbbl/d)
1990	66.7	2003	89.4
1991	73.7	2004	93.4
1992	72.0	2005	97.6
1993	73.4	2006	102.0
1994	74.8	2007	106.6
1995	76.6	2008	111.4
1996	78.0	2009	116.4
1997	79.5	2010	121.6
1998	81.0	2011	127.1
1999	82.6	2012	132.8
2000	84.2	2013	138.8
2001	85.8	2014	145.0
2002	87.6	2015	151.6

The methanol plant model in each PAD District is represented by a single column activity that consumes natural gas and produces methanol. Two additional transportation activities allow the methanol produced to be transported to the refining region for production of MTBE/TAME and/or splash blending in gasoline or sent to meet the national demand for methanol by chemical plants. The model also allows capacity expansion of the methanol plant.

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[7]Pace Petrochemical Service, *Annual Issue*, (Houston, TX, October 1992).

F.4 Estimation of Refinery Fixed Costs

The marginal prices computed in the PMM by the use of the Simplex algorithm cannot be used directly to determine the wholesale (refinery gate) price because they do not include the fixed costs of operating the refinery. The marginal prices do include the raw material and variable unit operating costs and will reflect the relative costs of producing each product.

A methodology was developed to allocate fixed refinery costs to the marginal prices of light products (LPG, gasoline, kerosine, jet fuel, No. 2 heating oil, and low sulfur highway diesel) thus including fixed costs in the prices reported at the refinery gate. The heavy products (residual oil, petrochemical feedstocks, asphalt, and other) are priced at their marginal cost due to competition from other fuels. Fixed refinery costs in each PAD District are estimated as the sum of fixed operating costs, return on assets, and environmental costs associated with controlling pollution at refineries (Table F8). The average annual cost is applied to all years and is recovered in the prices of light products only. These costs do not vary in the present model, but further analysis will be performed to determine the variability of these costs.

Table F8. Refinery Fixed Costs, by PAD District

(1987 $/bbl)

	PAD District I	PAD District II	PAD District III	PAD District IV	PAD District V
Operating Costs	2.64	1.70	2.01	1.66	2.53
Return On Assets	0.24	0.14	0.21	0.18	0.23
Annual Environmental Cost	0.47	0.48	0.38	0.70	0.53
Total	**3.35**	**2.38**	**2.60**	**2.54**	**3.29**

The methodology for allocating costs among light products is based on the concept of marginal cost and was developed from a similar approach used by the Gas Research Institute (GRI).[8] The steps used are as follows:

    (1)   Determine the fixed costs for each PAD District which include payroll, maintenance, depreciation, and other fixed operating expenses.

    (2)   Determine a fair return (profit) on assets.

    (3)   Determine the environmental investment and operating costs.

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[8]Gas Research Institute, "U.S. Refining Model Methodology", (May 1991).

(4)   The total costs to be recovered are the sum of (1), (2), and (3).
(5)   Determine the marginal revenue from the LP solution that will recover the marginal cost (the product of the marginal price of each product times the production volume).
(6)   Calculate ratios that will apportion the fixed costs to the light products marginal prices.
(7)   Use the ratios from (6) to scale the marginal prices to refinery gate wholesale prices.

Equations: First, marginal revenue is determined for each refining region R:

$$REVLP(LP)_R = VALUE(LP)_R * VOLUME(LP)_R$$
$$REVHP(HP)_R = VALUE(HP)_R * VOLUME(HP)_R$$

where:

VALUE(LP)   is the marginal price for each light product (LP) that <u>will</u> bear the fixed cost

VALUE(HP)   is the marginal price for each heavy product (HP) that <u>will not</u> bear the fixed cost

VOLUME(LP)   is the production volume for each light product

VOLUME(HP)   is the production volume for each heavy product

$TOTREV_R$ $= REVLP(LP)_R + REVHP(HP)_R$

Second, the total revenue required, including the fixed costs, FIXCOST is determined:

$$NTOTREV_R = REVLP(LP)_R + REVHP(HP)_R + (FIXCOST_R * VOLUME)$$
$$NLTREV_R = NTOTREV_R - REVHP(HP)_R$$

The last step is to calculate the refinery gate price for each light product

$$GATEPR(LP)_R = (NLTREV_R/REVLP(LP)_R) * VALUE(LP)_R$$

Refinery Fixed Operating Costs

The fixed operating cost values were developed from information published by the National Petroleum Council based on a 1984 survey of U.S. refineries [9] and are summarized in Table F9. The published values were adjusted to 1987 dollars based on the Nelson Investment Index. The original NPC data included refineries of different complexities from simple to deep conversion in each PAD District. Volume weighted costs were developed based on capacities in each PAD District.

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[9]National Petroleum Council, *U.S. Petroleum Refining*, (October 1986).

Table F9. Fixed Operating Costs by PAD District
(1987 $/bbl except where noted)

Operating Cost Items	PAD District I	PAD District II	PAD District III	PAD District IV	PAD District V
Payroll, etc.	1.03	0.70	0.70	0.68	0.77
Contract Maintenance	0.28	0.14	0.15	0.12	0.22
Maintenance Materials	0.32	0.19	0.21	0.17	0.19
Depreciation	0.45	0.29	0.42	0.22	0.43
Other Operating Expenses	0.56	0.39	0.53	0.48	0.91
Subtotal, $/bbl	**2.64**	**1.70**	**2.01**	**1.66**	**2.53**
Nelson Complexity Factor	9.62	8.97	10.19	6.77	8.61
Crude Oil Charge (Mbbl/cd)	1594	3198	7168	456	2897
Number of Refineries	23	36	64	14	44

Refinery Return on Assets

The use of a return on assets (ROA) is an attempt to include a fair return on investment as part of the refinery cost structure. Estimates of gross fixed assets by refinery type and PAD District were obtained from the NPC study previously cited. The level of return on assets was set at 4 percent. This return is based on a simple average of the net income to total assets for major energy producers for the years 1989, 1990, and 1991 reported by EIA in 1992.[10] By comparison, the Standard & Poor's 400 ROA is 3.9 percent. In Table F10, the Gross Fixed Assets are expressed in $/bbl/d of distillation capacity and the resulting per barrel cost at a rate of 4 percent are shown for each PAD District.

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[10]Energy Information Administration, *Performance Profiles of Major Energy Producers, 1991*, DOE/EIA-0206(91), (Washington, D.C., December 1992).

Table F10. Return on Assets, by PAD District

	PAD District I	PAD District II	PAD District III	PAD District IV	PAD District V
Gross Fixed Assets (1987 $/bbl/d)	2183	1280	1925	1687	2091
ROA at 4 Percent (1987 $/bbl)	**0.24**	**0.14**	**0.21**	**0.18**	**0.23**

Refinery Environmental Costs

Refinery source costs are expenditures incurred to satisfy regulations related to air and water pollutants, solid waste management, and health and safety controls at refineries. Related costs are based on estimates of capital investment, one-time, and operation and maintenance expenses provided in the 1993 National Petroleum Council Study.[11]

The NPC Study provides PAD District level estimates of capital, one-time, and operating and maintenance expenses over three time periods: 1991-1995, 1996-2000, and 2000-2010. Operation and maintenance expenses existing prior to 1996 are not used as they are already reflected in the fixed operating cost estimates. The NPC estimates were converted to an annual average cost per barrel of distillation capacity for inclusion as a refinery fixed cost (Table F8).

The underlying NPC analysis reflects the actions described below:

Air related costs include attainment of ambient air quality standards (Title I of the Clean Air Act Amendments), hazardous air pollutants (Title III, MACT standards), and permits (Title V)[12].

Water related costs include technology required to satisfy toxicity requirements of the National Pollution Discharge Elimination System (NPDES) authorized by the Clean Water Act. Costs for additional measures to protect groundwater are also assumed[13].

Solid waste related costs include remediation of contaminated soil at refineries sites, recovery and monitoring wells, the listing of additional refinery wastes as hazardous, the closing of unlined impoundments, and an assumed phased replacement of half the tanks over 40 years of age[14].

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[11]National Petroleum Council, *U.S. Petroleum Refining - Meeting Requirements for Cleaner Fuels and Refineries,* Volume I (Washington, DC, August 1993).

[12]Ibid, Section V-9-12.

[13]Ibid, Section V-13.

[14]Ibid, Section V-16.

Safety and health related costs includes an assumed phase-out of hydrofluoric alkylation (hf) plants due to the classification of hf as a highly hazardous material. Small costs associated with implementing process hazards analysis are also contained in the NPC estimates[15].

For comparative purposes NPC's estimated capital and OTE costs aggregated over 1991-2010 results in total environmental investments of $43.5 billion. The NPC sum can be compared to estimated investments published by the API[16], by adding the API estimates for individual legislation that are consistent with NPC. The NPC total falls in the middle of the range of API investments of $19.4 to $60.0 billion.

F.5 Estimation of Distribution Costs

Costs related to distributing petroleum products to end-users are incorporated by adding fixed transportation markups to the wholesale prices which include the variable and fixed refinery costs. Transportation markups for petroleum products are estimated as the average annual difference between retail and wholesale prices over the years 1984 through 1994. The differences are based on wholesale prices in the producing Census division and end-use prices (which do not include taxes) in the consuming Census division. Wholesale prices are aggregated from State-level prices from the EIA-782A. Sectoral end-user prices are aggregated from State-level prices from the State Energy Price and Expenditures Report (SEPER) 1992. End-use prices after 1992 are estimated according to the SEPER's methodology. Computer programs and data files used to estimate transportation markups are discussed below.

Data-Reading Programs

The following programs access EIA survey data and should be updated each year. Member names of SAS data sets are given in parenthesis.

Program: **CN6007.PRJ.NEMS.MARKUP.WHOLSALE**

Files Read: CN6007.BBM.A.SASDB.STATE.AB
                                 (IMPSTATA)
                  CN6007.BBM.A.SASDB.STATE.AB9495
                                 (IMP94A)

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[15]Ibid, Section V-19.

[16]The sum of the initial cost estimates in *Costs to the Petroleum Industry of Major New and Future Federal Government Environmental Requirements*, American Petroleum Institute, Discussion Paper #070, (Washington, D.C., October 1991), Tables ES-1 and ES-2. Aggregate estimates exclude product specification and off-site costs, and utilized minimum RCRA reauthorization.

CN6007.PRJ.NEMS.MARKUP.SASDB
    (REGIONS)
    (WHOLSALE)

This program reads a databases containing State-level refiner wholesale prices from the EIA-782A. A separate file is read for data prior to 1994 because the 782 data was kept in a different data system. Wholesale prices for asphalt and road oil, distillate fuel, gasoline, jet fuel, kerosene, liquefied petroleum gases, and residual fuel oil are aggregated into Census division prices (cents/gallon) and output to the NEMS database for other markup programs to access.

Program: **CN6007.PRJ.NEMS.MARKUP.EIA782.READ**

Files Read: CN6007.BBM.A.SASDB.STATE.AB9495
    (IMP94B)
    CN6007.PRJ.NEMS.MARKUP.SASDB
    (REGIONS)
    (PRODE)

This program updates retail prices on the NEMS database using the most recent data from the EIA-782A contained in IMP94B. The State-level prices for gasoline, distillate, kerosene, jet fuel, high and low sulfur residual fuel, and liquefied petroleum gases for the most recent 2 years, 1993 and 1994, are aggregated into regional prices and added to data for previous years (using PRODE). The program is updated by revising files and incrementing YEAR in line 82. Contact the Petroleum Marketing Division of the Office of Oil and Gas concerning the EIA-782 data which is available in March.

Program: **CN6007.PRJ.NEMS.MARKUP.GDP87**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
    (GDP87)

This program updates the GDP deflators in the NEMS database. Program should be rerun after adding most recent year's deflator.

Program: **CN6007.PRJ.NEMS.MARKUP.CONFAC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB

(CONVER84 through CONVER93)

This program provides annual conversion factors for each product. Factors for the most recent year of the SEPER's should be added to the data. These conversion factors are accessed by the SEPER.READ programs. The lpg factor is updated based on the upcoming SEDS (information available in April).

Program: **CN6007.PRJ.NEMS.MARKUP.SEPER.READ90**

Files Read: CN6356.PRJ.SEPER90.SAS.DATA
                        CN6007.PRJ.NEMS.MARKUP.SASDB
                                 (CONVER84 through CONVER93)
                                 (STATE84 through STATE93)

This program reads State-level prices by sector from SEPER-1993 and puts them into the NEMS database. Prices are accessed for the following products:

       gasoline (mg)
       distillate (df)
       kerosene (ks)
       residual fuel (rf)
       liquefied petroleum gases (lg)
       jet fuel (jf)
       asphalt and road oil (ar)
       petrochemical feedstocks (fs)
       naphtha feedstocks (fn)
       other feedstocks (fo)

The program is set up to read only one year of data at a time. The data is available in September. The program should be rerun for historical years back to 1984 since historical data are sometimes revised in SEPER's. Each year's data can be updated by uncommenting the appropriate line between 15 and 21. The price series is read from the SEPER's database with 1984 prices at location 211 and consecutive years at intervals at 14 (1985 at 225, and so on). The appropriate lines should also be uncommented between 38 and 44 and between 61 and 67.

Program: **CN6007.PRJ.NEMS.MARKUP.READ.F759**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB

<div align="center">

(REGIONS)

(E759Y85 through E759Y93)

CN6944.PRJ.F759.MASTER94

</div>

This program reads monthly volumes of distillate, low and high sulfur residual fuel consumed by electric utilities from EIA-759. The volumes are by State and are in gallons. The program annualizes the volumes and assigns them to Census divisions.

Program: **CN6007.PRJ.NEMS.MARKUP.F423.READ**

Files Read: CN6501.PRJ.F423.EXTR1984.REVGAS
                        CN6501.PRJ.F423.EXTR1985.REVGAS
                        CN6501.PRJ.F423.EXTR1986.REVGAS
                        CN6501.PRJ.F423.EXTR1987.REVGAS
                        CN6501.PRJ.F423.EXTR1988.DATA
                        CN6501.PRJ.F423.EXTR1989.DATA
                        CN6501.PRJ.F423.EXTR1990.DATA
                        CN6501.PRJ.F423.EXTR1991.DATA
                        CN6501.PRJ.F423.EXTR1992.DATA
                        CN6501.PRJ.F423.EXTR1993.FINAL
                        CN6501.PRJ.F423.EXTR1994.FINAL
                        CN6007.PRJ.NEMS.MARKUP.SASDB
                            (EUSTATE)
                            (UTDIV)

This program reads State-level quantities and costs of distillate, and high and low sulfur residual fuel consumed by electric utilities from FERC Form 423. The quantities and costs are converted to a trillion Btu basis and assigned to Census divisions.

Program: **CN6007.PRJ.NEMS.MARKUP.ARVOL**

Files Read: CN6356.PRJ.SEDS.PUBLIC93.DATA
                        CN6007.PRJ.NEMS.MARKUP.SASDB
                            (ARVOL84 through ARVOL93)

This program reads industrial asphalt and road oil volumes from SEDS. The program is updated by accessing the most recent SEDS file and adding another output file similar to ARVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **CN6007.PRJ.NEMS.MARKUP.KEROVOL**

Files Read: CN6356.PRJ.SEDS.PUBLIC93.DATA
                         CN6007.PRJ.NEMS.MARKUP.SASDB
                               (KERVOL84 through KERVOL93)

This program reads kerosene consumption in the residential, commercial, and industrial sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to KERVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **CN6007.PRJ.NEMS.MARKUP.GASVOL**

Files Read: CN6356.PRJ.SEDS.PUBLIC93.DATA
                         CN6007.PRJ.NEMS.MARKUP.SASDB
                               (GASVOL84 through GASVOL93)

This program reads gasoline consumption in the transportation, commercial, and industrial sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to GASVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **CN6007.PRJ.NEMS.MARKUP.LPGVOL**

Files Read: CN6356.PRJ.SEDS.PUBLIC93.DATA
                         CN6007.PRJ.NEMS.MARKUP.SASDB
                               (LPGVOL84 through LPGVOL93)

This program reads gasoline consumption in the transportation, residential, and commercial sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to LPGVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **CN6007.PRJ.NEMS.MARKUP.RSVOL**

Files Read: CN6356.PRJ.SEDS.PUBLIC93.DATA
                             CN6007.PRJ.NEMS.MARKUP.SASDB
                                 (RSVOL84 through RSVOL93)

This program reads gasoline consumption in the commercial, industrial, and transportation sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to RSVOL93. The location of the volume should be incremented by 14 (@329+14).

Markup Estimating Programs

All "CALC" programs calculate markups as the difference between a products retail and wholesale price in each Census division and sector. The estimated markups are output to CN6007.PRJ.NEMS.MARKUP.SASDB in 1987 dollars per trillion Btu. The output file from each program contains the variables PRODPMM, SECTOR, CENDIV, MEAN, AND STDERR.

Census Division "99" represents national data and Sector "ZZ" represents all sectors. The following table describes the source programs for petroleum product markups:

Table F11. Markups Output

Products	Sectors	Markup Program	File Name on MARKUP.SASDB
DS	CM, IN, RS, TR, ZZ	PMM.CALC	MARKPMM
JF	TR, ZZ	PMM.CALC	MARKPMM
MG	CM, IN, TR, ZZ	PMM.CALC	MARKPMM
AR	IN, ZZ	ASRO.CALC	MARKAR
KS	CM, IN, RS, ZZ	KERO.CALC	MARKOTH1
LG	CM, IN, RS, TR, ZZ	LPG.CALC	MARKLPG
RL	CM, IN	RESID.CALC	MARKRL
RH	TR	RHTR.CALC	MARKRH
DS	EU	ELECUTIL.CALC	MARKELEC
RL	EU	ELECUTIL.CALC	MARKELEC
RH	EU	ELECUTIL.CALC	MARKELEC

Program: **CN6007.PRJ.NEMS.MARKUP.PMM.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
                        (PRODE)
                        (WHOLSALE)
                        (GDP87)
                        (GASVOL84 through GASVOL93)
                        (CONVER84 through CONVER93)
                        (RGAL82)
                        (MGBTU)
                        (MARKPMM)

This program uses retail gasoline, distillate, and jet fuel prices and volumes originating from the EIA-782A. Commercial and industrial gasoline prices are estimated by weighting the EIA-782 end-user (transportation) prices with SEDS volumes for these two sectors. Commercial and industrial gasoline volumes for 1993 are used to represent 1994, since SEDS stops with 1993 data. Distillate and gasoline markups are estimated as

the average annual difference between end-use and wholesale prices for the years 1984 forward. Due to a break in the data trend, jet fuel markups are based on data starting in 1986.

To update: After updating "data" programs, revise this program to utilize more recent SEDS volumes by adding another data set that reads GASVOL92. Use CONVER92 and increment all year dependent formulas by first changing "93's" to "94's", "92's" to "93's", and "91's" to "92's".

Program: **CN6007.PRJ.NEMS.MARKUP.ASRO.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
                        (PRODE)
                        (WHOLSALE)
                        (STATE84 through STATE92)
                        (PRODE)
                        (ARVOL93)
                        (GDP87)
                        (CONVER84 through CONVER93)
                        (RGAL82)
                        (ARBTU)
                        (MARKAR)

This program uses State-level asphalt and road oil prices to the industrial sector from SEPER's through 1992. End-use prices for 1993 and 1994 are estimated using the 1993 and 1994 changes in the EIA-782 high sulfur residual fuel prices. Prices for each Census division are calculated using 1993 volumes from the SEDS. Estimates for 1994 are weighted using 1993 volumes. Markups are estimated as the average annual difference between end-use and wholesale prices for the years 1984 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE93, use ARVOL94 and CONVER94, and increment all year dependent formulas by first changing "93's" to "94's", "92's" to "93's", and "91's" to "92's".

Program: **CN6007.PRJ.NEMS.MARKUP.KERO.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
                        (PRODE)
                        (WHOLSALE)
                        (STATE84 through STATE92)

(PRODE)
(KEROVOL93)
(GDP87)
(CONVER93)
(KEROGAL)
(KEROBTU)
(MARKOTH1)

This program uses State-level kerosene prices to the residential, commercial, and industrial sectors from SEPER's through 1992. End-use prices for 1993 and 1994 are estimated using the 1993 and 1994 changes in the EIA-782 distillate prices. Prices for each Census division are calculated using 1993 volumes from the SEDS. End-use price estimates for 1994 are weighted using 1993 volumes. Markups are estimated as the average annual difference between kerosene end-use and distillate wholesale prices for the years 1984 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE93, use KERVOL94 and CONVER94, and increment all year dependent formulas by first changing "93's" to "94's", "92's" to "93's", and "91's" to "92's".

Program: **CN6007.PRJ.NEMS.MARKUP.RESID.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE92)
(RSVOL93)
(GDP87)
(CONVER84 through CONVER93)
(RSGAL)
(RSBTU)
(MARKRL)

This program uses State-level residual fuel prices to the commercial, and industrial sectors from SEPERS through 1992. End-use prices for 1993 and 1994 are estimated using the 1993 and 1994 changes in the EIA-782 low sulfur residual fuel prices. Commercial and industrial prices for each Census division are calculated using 1991 volumes from SEDS. Price estimates for 1993 are weighted using 1993 volumes. Residential prices are estimated using 1993 and 1994 EIA-782 consumption volumes. Markups are estimated as the

average annual difference between low sulfur end-use prices and aggregate residual fuel wholesale prices for the years 1984 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE93, use RSVOL94 and CONVER94, and increment all year dependent formulas by first changing "93's" to "94's", "92's" to "93's", and "91's" to "92's".

Program: **CN6007.PRJ.NEMS.MARKUP.RHTR.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
                                  (PRODE)
                                  (WHOLSALE)
                                  (STATE84 through STATE92)
                                  (PRODE)
                                  (REGIONS)
                                  (EUSTATE)
                                  (RSVOL93)
                                  (GDP87)
                                  (CONVER93)
                                  (RSTRGAL)
                                  (RSTRBTU)
                                  (MARKRHTR)

This program uses State-level residual fuel prices to the transportation sector from SEPERS through 1992. End-use prices for 1993 and 1994 are estimated using average residual fuel prices to electric utilities according to SEPER's methodology. The average Census division prices to utilities are multiplied by the ratio of national high sulfur price from the EIA-782 to the national residual fuel price to utilities. Prices for each Census division are calculated using 1993 volumes from SEDS. End-use price estimates for 1994 are weighted using 1993 volumes. Markups are estimated as the average annual difference between high sulfur end-use prices and aggregate residual fuel wholesale prices for the years 1987 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE93, use RSVOL94 and CONVER94, and increment all year dependent formulas by first changing "93's" to "94's", "92's" to "93's", and "91's" to "92's".

Program: **CN6007.PRJ.NEMS.MARKUP.LPG.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB

                               (PRODE)
                               (WHOLSALE)
                               (STATE84 through STATE92)
                               (PRODE)
                               (REGIONS)
                               (LPGVOL93)
                               (GDP87)
                               (CONVER93)
                               (LPGGAL)
                               (LPGBTU)
                               (MARKLG)

This program uses State-level SEPER's prices for liquefied petroleum gases to the commercial, industrial, transportation, and residential sectors through 1992. Commercial, industrial, and transportation prices for 1993 are the EIA-782 average end-user prices weighted by the sectoral volumes from SEDS 1993. Residential prices for 1993 are the 1992 SEPER's prices multiplied by a 782 PADD level growth rate. The 1994 prices for all sector's are the 782 sectoral prices, because the 782 began carrying sectoral data in 1994. Markups are estimated as the average annual difference between end-user lpg prices and wholesale prices for the years 1985 forward. The average residential markups exclude 1989 data because of the price spike related to a heating oil crisis that winter.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE93, use LPGVOL94 and CONVER94. Since sectoral 782 prices are available starting in 1994, remove the sections estimating the weighted average prices based on 782 average end-user prices, and residential price growth rates. Increment all year dependent formulas by first changing "93's" to "94's", "92's" to "93's", and "91's" to "92's".

Program: **CN6007.PRJ.NEMS.MARKUP.ELECUTIL.CALC**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB

                               (PRODE)
                               (WHOLSALE)
                               (STATE84 through STATE92)
                               (PRODE)
                               (REGIONS)
                               (UTDIV)
                               (E759Y84 through E759Y94)

(GDP87)
                        (CONVER84 through CONVER93)
                        (EURFRGAL)
                        (EURFBTU)
                        (MARKELEC)

This program uses State-level SEPER's prices for distillate, high sulfur, and low sulfur residual fuel to electric utilities through 1992. End-use prices for 1993 and 1994 are estimated using SEPER's methodology. The program breaks residual fuel consumption from the EIA-759 into high and low sulfur using a high/low sulfur breakout estimated from the FERC Form 423. The estimated high and low sulfur residual fuel volumes are used to estimate weighted average prices to the utility sector.

Markups are estimated as the average annual difference between prices to utilities and wholesale prices for the years 1984 forward. The average markup for high sulfur residual fuel in Census division 8 excludes all years but 1990 because of an anomalous trend.

To update: After updating "data" programs, revise this program to utilize more recent data. Add
                datasets CONVER94, and E759Y95.

Program: **CN6007.PRJ.NEMS.MARKUP.CREATE.FLATFILE**

Files Read: CN6007.PRJ.NEMS.MARKUP.SASDB
                        (MARKPMM)
                        (MARKLPG)
                        (MARKRL)
                        (MARKRHTR)
                        (MARKOTH1)
                        (MARKAR)
                        (MARKELEC)
                CN6005.PRJ.PMM.MU1PRDS.BASE.D0525951
                CN6005.PRJ.NEMS.MARKUP.DOL94.D0525951

This program pulls together the markups for each product, transposes the data and outputs it to a file used by NEMS. Converts the markups into 1994 dollars and outputs to a file.

To update: Update the GDP deflator, GDPDEF94.

F.6 Estimation of Taxes

In the PMM, taxes are added to the prices of gasoline, transportation distillate fuel, transportation liquefied petroleum gas, and jet fuel. Taxes are also estimated for M85 (transportation methanol) and E85 (transportation ethanol). Weighted averages of the most recently-available State and Federal taxes are developed for each Census division. The State taxes are fixed in real terms; the Federal taxes decline at the rate of inflation (i.e., Federal taxes are fixed in nominal terms). Historical values are also calculated for gasoline and transportation distillate and added to historical end-use prices excluding taxes in order to develop a series with taxes included. The State taxes, by sector, product, and year, are contained in following file which resides in the default input directory:

MU2PRDS

The Federal taxes are read into the PMM from file

QDCRDCF

and are updated each forecast year by deflating the current value by the rate of inflation for that forecast year.

The following section traces the development of the taxes and lists the files used to produce both historical and forecast values. The historical data are developed on a monthly basis by State, then aggregated to volume-weighted annual averages by Census division. The outputs specified are members of the following SAS database unless otherwise stated:

CN6007.BBM.NEMS.TAX.SASDB

Program: **CN6007.BBM.NEMS.TAX.Dyymm**

Inputs: semi-annual tax information from the Federal Highway Administration and other sources

Outputs: STyymmS
STyymmM
where yymm refers to years 84 through 94, and months 01 and 07 (except for 1990 when the months are 01 and 08)

State-level taxes are obtained from the Federal Highway Administration on a semi-annual basis (usually reflecting taxes as of January 1 and July 1), supplemented by information from the *Petroleum Marketing Monthly*, Highway Users Federation, and other sources. These data are entered into the above program.

We assume that taxes remain at the same level for the 6 months following each semi-annual report, unless information on effective dates of tax changes is provided. Thus, the tax level reported for say, 9207, is kept at the same amount for 9208-9212. The file STyymmS contains data for 1 month, while the file STyymmM reproduces the results for the subsequent 6 months, taking into account tax changes to the extent that they are known.

Program: **CN6007.BBM.NEMS.TAX.CALC94**
                     CN6007.BBM.NEMS.TAX.CALC94.CURRENT

(Old Versions):   **CN6007.BBM.NEMS.TAX.CALC93**
                     CN6007.BBM.NEMS.TAX.CALC93.CURRENT

Inputs: STyymmM for years 1984 to current
                     IMPSTATB, a file containing State-level refiner and marketer prices for petroleum products
                     IMPSTATA, a file containing State-level sales of petroleum products, which are used as weights in calculating weighted averages
                     REGIONS, maps States to Census divisions
                     GDP87, GDP deflators for conversion to constant dollars

Outputs: STGAS_MO
                     STDES_MO

The CALC program pulls together the monthly tax information and calculates Federal, State, and total taxes by month and State in cents per gallon and dollars per million Btu for both nominal and constant 1987 dollars. Sales volumes and regional designations are added to facilitate volume weighting across time and regions as required. Gasoline and diesel files are calculated and output separately. The programs were adjusted to incorporate changes in the EIA-782 database starting with the 1994 data.

Program: **CN6007.BBM.NEMS.TAX.YRREG**
(Old version):   **CN6007.BBM.NEMS.TAX.YRREG93**

Inputs: STGAS_MO

STDES_MO

Outputs: STGAS_YR
                    STDES_YR
                    CDGAS_YR
                    CDDES_YR

The YRREG program takes the State monthly tax files created in the CALC program and develops weighted average annual taxes by State, then averages across Census divisions and outputs annual average taxes by Census division. The Census division annual averages are used to develop historical end-use prices including taxes by adding the calculated taxes to ex-tax prices from the *Petroleum Marketing Monthly*. The program was adjusted to incorporate changes in the EIA-782 database starting with the 1994 data.

Program: **CN6007.BBM.NEMS.TAX.FORECAST**

Inputs: STGAS_MO
                    STDES_MO
                    STGAS_YR
                    STDES_YR

Outputs: GASCAST
                    DIESCAST

The FORECAST program uses the latest tax information, combined with the most recent year of sales data, and develops Census division weighted-average taxes which are used for the forecast. The latest tax information is in the file:

CN6007.BBM.NEMS.TAX.DCURR

The outputs include both nominal, constant 1987, and constant 1994 dollar denominations for both cents per gallon and dollars per million Btu.

CN6007.BBM.NEMS.TAX.FORECAST.E85
CN6007.BBM.NEMS.TAX.FORECAST.JET
CN6007.BBM.NEMS.TAX.FORECAST.LPG
CN6007.BBM.NEMS.TAX.FORECAST.M85

F.7 Gasoline Specifications

The PMM models the production and distribution of four different types of gasoline: traditional, oxygenated, reformulated, and reformulated/high-oxygen. The following specifications are included in PMM to differentiate between traditional and reformulated gasoline blends: octane, oxygen content, Reid vapor pressure (Rvp), benzene content, aromatics content, sulfur content, olefin content, and percent distillate at three temperatures.

Starting in 1998 the specifications for traditional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline". These specifications prevent the quality of traditional gasoline from eroding overtime which is the intent of the EPA's "antidumping" requirements.

Oxygenated gasoline which has been required during wintertime in many U.S. cities since October of 1992 requires a oxygen content of 2.7 percent by weight. There will be some overlap of areas that already require oxygenated gasoline and those that will require reformulated gasoline in the future. In those areas, reformulated-high oxygen gasoline containing 2.7 percent oxygen will be required. Oxygenated gasoline is assumed to have specifications identical to traditional gasoline with the exception of a higher oxygen requirement. Similarly, the oxygen requirement is assumed to be the only difference between the reformulated/high oxygen and reformulated gasoline blends.

Beginning in 1995, many areas of the country will require reformulated gasoline. Between 1995 and 1997 the Environmental Protection Agency (EPA) will certify reformulated gasoline according to either the "simple" or "complex" models. The PMM assumes that reformulated gasoline during this time period will meet the EPA's "simple model" definition which allows no lead content, limits benzene content to 1.0 percent and aromatics content to 25 percent by volume, requires an oxygen content of 2.0 percent by weight, and caps nitrogen oxide emissions at a baseline level. Beginning in 1998 the EPA will only certify reformulated gasoline using the "complex model" which allows refiners to specify reformulated gasoline based emissions reductions from their companies 1990 baseline, or the EPA's 1990 baseline. The PMM uses a set of specifications that meet the "complex model" requirements but does not attempt to determine the optimal specifications that meet the "complex model" (Table 13). Specifications such as Rvp, aromatics, sulfur and olefin content change in the year 2000 , reflecting further emissions reductions required by CAAA90.

The CAAA90 provided for special treatment of California that would allow different specifications for oxygenated and reformulated gasoline in that State. In 1992, California requested a waiver from the wintertime oxygen requirements of 2.7 percent, reducing the requirement to a range of 1.8 to 2.2 percent. The PMM assumes that PAD District V refiners must meet the California specifications. Therefore, for 1993-1994, the specifications for oxygenated gasoline in PAD District V meet a 2.0-percent standard.

Starting in 1996, the specifications for reformulated gasoline in PAD District V are the same as California standards.

Annual Average Rvp Methodology

The annual average Rvp limits are derived based on existing summertime requirements and estimated wintertime levels. The assumed summer and winter Rvp specifications are annualized in spreadsheet RVP.wk1 by using summer and winter weights provided by the EPA.[17] To reflect pipeline requirements which are tighter than EPA limits, the specifications used in PMM (Table F12.) are 0.3 psi below the weighted annual specifications. Since the cost of reducing Rvp may not be linear, the PMM could be used in the future to test for the appropriate Rvp to represent the annual average.

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[17]The summer weight of 0.396 and winter weight of 0.604 were provided by Dave Korrotney of EPA (313-668-5507).

Table F12. Estimated Annual Reid Vapor Pressure

Gasoline Market/Type		Weighted Annual	Annual Rvp in PMM
PADD I-IV			
Traditional/Oxygenated		10.5	10.2
1995-1997 Reformulated/Reformulated-	High Oxygen	10.0	9.7
1998-1999 Reformulated/Reformulated-	High Oxygen	9.8	9.5
2000-forward Reformulated/Reformulated-	High Oxygen	9.4	9.1
PADD V			
Traditional		9.5	9.2
Reformulated (CARB)		9.0	8.7

The lower Rvp specifications in PAD District V reflect more stringent California limits which are imposed statewide.

Complex Model Standards for Motor Gasoline

The Environmental Protection Agency (EPA) has promulgated new regulations for reformulated motor gasoline that are designed to lower vehicle emission pollutants as required by the amended Clean Air Act of 1990[18]. The reformulated gasolines are designed to reduce vehicle emissions of toxic and ozone-forming

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[18]Federal Register, Environmental Protection Agency, <u>Regulation of Fuels and Fuel Additives;Standards for Reformulated and Conventional Gasoline; Final Rule</u>, Part II, 40 CFR Part 80, (Washington, DC, 16 February 1994)

compounds. Reformulated gasoline must be sold in certain regions where there are summertime ozone problems as well as in areas which opt into the program. Traditional gasoline may be sold elsewhere but it must not be more polluting than it was in 1990. These areas are discussed elsewhere in the documentation. Although The EPA has established some conventionally treated specifications, namely minimum oxygen content and maximum benzene content, the new conceptual aspect of the emission standards is that the reformulated gasoline must be blended in such a way that it meets maximum allowable emissions of volatile organic compounds (VOCs), nitrous oxides (NO_x), and toxics. These new motor gasoline standards are calculated by complex formulae based upon key properties of the gasoline blend. The new regulations cover Phase I (1 January 1995 through 31 December 1999) and Phase II (1 January 2000 and indefinitely afterwards). During Phase I the refiner must certify his reformulated gasoline to meet the new standards but, at his option, he may use a simpler EPA model rather than the complex EPA model until 1 January 1998. The model assumes that the refiners will use the simple model for as long as possible. Thus, Phase I has, in effect, two subphases; Phase Ia applies to 1 January 1995 through 31 December 1997 while Phase Ib applies to 1 January 1998 through 31 December 1999. Also, the refiner may meet the requirements for VOCs and NO_x on either a per gallon basis or on an average basis although some per gallon constraints still apply. The average basis has been incorporated into the model.

The NO_x and toxics emission standards for reformulated gasoline apply year-round whereas the VOCs standards apply only in the summer. The NO_x standard varies depending upon whether the VOCs standards apply, i.e. depending upon whether it is summer or winter. The VOCs standard for the north[19] is different from the VOCs standard applying to the south, greater volatility is allowed in the north. The Complex Model Averaged Standards are shown below in Table F13.

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[19]For the sake of simplicity, we use the terms south and north to refer to EPA regions 1 and 2 respectively. Region 1 is covered by ASTM Class B while Region 2 is covered by Class C.

Table F13. Complex Model Standards

	Phase I 1995 - 1999	Phase II 2000+
VOC Reduction, %		
South	$\geq$ 36.6	$\geq$ 29.0
North	$\geq$ 17.1	$\geq$ 27.4
NO$_x$ Reduction, %		
Summer	$\geq$ 1.5	$\geq$ 6.8
Winter	$\geq$ 1.5	$\geq$ 1.5
Toxics Reduction, %	$\geq$ 16.5	$\geq$ 21.5
Oxygen, wt%	$\geq$ 2.1	$\geq$ 2.1
Benzene, %	$\leq$ 0.95	$\leq$ 0.95

These standards were translated into traditionally configured specifications for blending motor gasoline. First, two winter specifications were developed, one for Phase I and one for Phase II. Of course, the VOCs standard was excluded from consideration. Then four summer specifications were created, a south set and a north set for Phase I and similarly for Phase II.

These sets were developed by use of a spreadsheet, developed by EPA, which calculates the VOCs, NO$_x$, and Toxics of a reformulated gasoline as a function of the 'conventional' properties of the gasoline, i.e. as a function of Rvp, sulfur content, oxygen content, aromatics content, olefins content, benzene content, percent evaporation at 200 degrees Fahrenheit (E200), and percent evaporated at 300 degrees Fahrenheit (E300). The approach was to start with 'best informed guess' properties and use trial and error to gradually expand the allowable property limits. The blend properties cited as typical fuels in an EPA presentation[20] served as the starting values for both Phases I and II. The same starting point was used for both winter and summer. Table F14, following a chart developed by the EPA[21], indicates the directional sensitivities of the properties on the standards. Of course, a more rigorous approach is possible in establishing the specification sets. For instance, one might perform incremental changes over the reformulated gasoline properties followed by

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[20]C.L. Gray, "Reformulated Gasoline Final Rulemaking and Renewable Oxygenate Proposal," Proceedings of The World Conference on Refinery Processing and Reformulated Gasoline, March 22-24, 1994, Information Resources, Inc.

[21]Ibid.

computer runs to establish minimum cost specifications. However, in the event, resources were constrained. The above procedure was used after some discussion.

Table F14. Directional Emission Effects of
Gasoline Property Changes

Property	VOC	NO$_x$	Air Toxics
Rvp ↓	↓ ↓ ↓	−	↓
Sulfur ↓	↓	↓ ↓ ↓	↓ ↓
Aromatics ↓	↓	↓	↓ ↓
Olefins ↓	−	↓	−
E200 ↑	↓	↑	↓
E300 ↑	↓	−	−
Oxygen ↑	−	−	↓ ↓
Benzene ↓	−	−	↓ ↓ ↓

The PMM is an annual model, i.e. it does not have seasonality. A decision was made to develop, for PADDs I-IV, a single reformulated gasoline specification for Phase I simulation and a single specification for Phase II. This required several actions. The two summer sets for Phase I were linearly blended by compositing the projected gasoline sales-weighted south specifications to the appropriately weighted specifications of the north. The resulting two sets of specifications for Phase I, one for summer and one for winter, were then composited after weighting them according to summer sales and winter sales respectively.. The Phase II specifications were collapsed to a single set in the same manner. The composites were calculated in a spreadsheet maintained by the Oil and Gas Analysis Branch. This specification was adapted from the presentation made by Charles L. Gray at the conference cited above. The resulting reformulated gasoline specifications are shown in Table F15. It is, of course, a simple matter to convert the PMM blending stock distillation temperature values as needed.

Table F15. PMM Reformulated Gasoline Specifications

	Phase I PADDs I-IV	Phase II PADDs I-IV
Max Rvp, psia	8.8	8.5
Max S, ppm	305	140
Max Aro, %	26.0	24.5
Max Ole, %	11.0	11.0
Min E200, %	49.0	49.0
Min E300, %	87.0	87.0
Min Oxy, wt%	2.1	2.1
Max Ben, %	0.95	0.95

F.8 Estimation of Gasoline Market Shares

Time series market shares for traditional (TRD), oxygenated (TRH), reformulated (RFG), and reformulated/high oxygen (RFH) gasoline were estimated using a Gasoline Market Share Spreadsheet (GMSS). The estimates are based on the population of control areas (nonattainment areas requiring or assumed to require new types of gasoline) relative to the population of each Census division. Control areas used are based on a list of nonattainment areas put out by the Environmental Protection Agency[22]. Population data are from the 1990 Census, U.S. Bureau of Census.

The ratio of the control area population to the Census division population are used by PMM to disaggregate gasoline demand in that region. The control areas included in each year reflect assumptions about the phase-in of CAAA and State legislation.

MGSHR   is the annual percent of total gasoline demand.

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[22]Environmental Protection Agency, Office of Air Quality Planning and Standards, *Ozone and Carbon Monoxide Areas Designated Nonattainment*, (October 1991, Research Triangle Park, NC).

OXY   ratio of population in carbon monoxide nonattainment areas, requiring oxygenated gasoline.

RFH   ratio of population in areas that are both carbon monoxide and ozone nonattainment, requiring high oxygen reformulated gasoline.

WDEM ratio of wintertime gasoline demand to annual demand in each region (see table). The ratio was estimated using monthly gasoline sales data from the Form EIA-782A for the years 1983 through 1991.

Census Division	1	2	3	4	5	6	7	8	9
WDEM	.22	.48	.09	.06	.13	.11	.22	.30	.46

COPOP population of carbon monoxide nonattainment areas.

COOZ population of areas of overlap for carbon monoxide and severe ozone nonattainment areas.

COOZOPT population of areas in carbon monoxide and less severe ozone nonattainment areas assumed to opt-in to the reformulated gasoline program.

OZ   population in nine severe ozone nonattainment areas where RFG is mandated.

OZOPT population in less severe ozone nonattainment areas assumed to opt-in to the RFG program.

DIV   population of a given Census division.

SPILL "spillover demand" or demand for reformulated fuels outside the boundaries of nonattainment areas. Spillover is assumed to be 5 percent. The spillover assumption was tested between 0 and 10 percent and found to have minimal impact.

Traditional Gasoline Market Shares:

In every year the annual market share of traditional gasoline is calculated by:

$$MGSHR_{TRD,CD} = 1 - MGSHR_{TRH,CD} - MGSHR_{RFG,CD} - MGSHR_{RFH,CD}$$

where

CD	represents a Census division.

Oxygenated Gasoline Market Shares:

In every year the annual market share of oxygenated gasoline is calculated as a percentage of total annual gasoline demand:

$$MGSHR_{TRH,CD} = OXY_{CD} * WDEM_{CD}$$

In most Census divisions the annual market share for oxygenated gasoline from **1995 forward** is calculated as follows:

$$OXY_{CD} = (\sum(COPOP_{CD} - COOZ_{CD} - C00Z0PT_{CD}))/DIV_{CD} * (1 + SPILL)$$

Beginning in 1996, a different estimation for oxygenated gasoline is required in **Census Division 9** due to a statewide mandate of 2.2 percent oxygen in gasoline used in California:

$$OXY_{CD9} = (\sum(COPOP_{CD9} - COOZ_{CD9} - C00Z0PT_{CD9} - COPOP_{CA} - COOZ_{CA} - C00Z0PT_{CA}))/DIV_{CD9}$$

Beginning in 1997, a different estimation for oxygenated gasoline is required in **Census Division 4** due to a statewide mandate of 2.7 percent oxygen in gasoline used in Minnesota:

$$OXY_{CD4} = (MNPOP/DIV_{CD4)} * (1 + SPILL)$$

where

MNPOP	is the population of Minnesota

Reformulated Gasoline (2.0 percent oxygen) Market Shares:

The reformulated gasoline program **begins in 1995**, therefore the market share for reformulated gasoline are estimated as follows:

$$MGSHR_{RFG,CD} = ((\sum(OZ_{CD} + OZOPT_{CD}))/DIV_{CD} * (1 + SPILL)) - MGSHR_{RFH,CD}$$

Beginning in 1996, the reformulated market share in **Census Division 9** has a unique calculation reflecting a statewide requirement for reformulated gasoline in California:

$$\text{MGSHR}_{\text{RFG,CD9}} = \text{CAPOP/DIV}_9 + (\sum(\text{COOZ}_{\text{CD9}} + \text{COOZOPT}_{\text{CD9}}\text{-COOZ}_{\text{CA}} + \text{COOZOPT}_{\text{CA}}))/\text{DIV}_{\text{CD9}} * (1 + \text{SPILL}))$$

Reformulated/High Oxygen Gasoline (2.7 percent oxygen) Market Shares:

Requirements for gasoline that is both reformulated and oxygenated occur during the wintertime in areas that fail to meet both carbon monoxide and ozone standards. **Beginning in 1995**, the market shares are estimated as:

$$\text{MGSHR}_{\text{RFH,CD}} = \text{RFH}_{\text{CD}} * \text{WDEM}_{\text{CD}}$$

where

$$\text{RFH}_{\text{CD}} = (((\sum(\text{COOZ}_{\text{CD}} + \text{COOZOPT}_{\text{CD}}))/\text{DIV}_{\text{CD}}) * (1 + \text{SPILL}))$$

Beginning in 1996, the estimation for the high oxygen/reformulated market share in **Census Division 9** must exclude sales in California because of State legislation:

$$\text{MGSHR}_{\text{RFH,CD9}} = (\sum(\text{COOZ}_{\text{CD9}} + \text{COOZOPT}_{\text{CD9}}\text{-COOZ}_{\text{CA}} - \text{COOZOPT}_{\text{CA}}))/\text{DIV}_{\text{CD9}} * (1 + \text{SPILL}))$$

F.9 Estimation of Low-Sulfur Diesel Market Shares

The CAAA90 mandates the use of low sulfur diesel for on-highway use. Market shares for low-sulfur diesel relative to distillate fuel are estimated based on data from EIA's *Annual Fuel Oil and Kerosene Sales 1992* (DOE/EIA-0535(92)). Since 20 percent of current demand in the transportation sector is off-highway, 80 percent of transportation demand for distillate fuel is assumed to be low-sulfur.

F.10 Low-Sulfur Diesel Specifications

In order to account for diesel desulfurization regulations, low-sulfur diesel is differentiated from other distillates. Specifications for sulfur, aromatics content, and API gravity are included in the PMM. Diesel fuel in Census Divisions 1 through 9 have a maximum sulfur content of 0.05 percent by weight, and a maximum aromatics content of 35 percent, reflecting Federal specifications. The specifications for diesel fuel supplied to Census Division 9 will be updated to reflect the more severe California Air Resources Board requirements.

F.11 Estimation of Regional Conversion Coefficients

Differing regional definitions necessitate the conversions of certain variables from one regional structure to another. Regional conversions are not extensive in the PMM, but are needed for three refinery input prices, refinery fuel consumption, and cogeneration information.

Conversions for Prices of Refinery Inputs

PMM receives prices for refinery inputs of natural gas in other regional configurations and must convert these into PAD District level prices. Due to the proximity of refineries in PAD Districts 2, 3, and 4 to the sources of natural gas supply, prices in these PAD Districts reflect wellhead natural gas prices in the corresponding Oil and Gas Production Regions. PAD Districts 1 and 5 use industrial prices in the corresponding Census divisions in order to capture the additional costs of moving the natural gas to the refineries. Table F16. shows the source of PAD District level natural gas prices:

Table F16. Source of PMM Natural Gas Prices

Correlation of Prices	
PAD District	Input Price
1	Census Division 2 industrial price (PGIIN)
2	Oil and Gas Production Region 3 wellhead price (OGWPRNG)
3	quantity weighted average of Oil and Gas Production Regions 2,4, & 8 wellhead price (OGWPRNG)
4	Oil and Gas Production Region 5 wellhead price (OGWPRNG)
5	Census Division 9 industrial price (PGIIN)

PMM receives prices for refinery inputs of electricity by Census division. PAD District level prices are derived by assuming prices in intersecting Census divisions. Table F17. shows the correlation between PAD District and Census division electricity input prices:

Table F17. Source of PMM Electricity Prices

Correlation of Prices	
PAD District	Input Price
1	Census Division 2 industrial prices (PELIN)
2	Census Division 3 industrial prices (PELIN)
3	Census Division 7 industrial prices (PELIN)
4	Census Division 8 industrial prices (PELIN)
5	Census Division 9 industrial prices (PELIN)

Conversions for Refinery Fuel Consumption

Refinery fuel consumption must be converted from the PAD District to the Census division level. Each eCnsus division consumption number will equal the consumption in the overlapping PAD Districts times a factor. The factors were developed using State-level refinery operating capacity and are shown in Table F18. The factors are interperted as follows: The 0.8434 at the intersection of Census Division 2 and PAD District I indicates that 84.3 percent of the PAD District I refinery fuel consumption is estimated (using refinery operating capacity as estimator) to occur in Census Division 2. These values will change by small amounts as refinery capacities change, but the impact on model results will be small.

Example: Census Division 7 fuel consumption =
(PAD District II consumption * .12) + (PAD District III consumption * .93)

Table F18. PAD District to Census Division Conversion Factors

	1	2	3	4	5	6	7	8	9	SUM
					Census Division					
PAD District 1		0.84			0.16					1.00
PAD District 2			0.60	0.19		0.09	0.12			1.00
PAD District 3						0.07	0.93			1.00
PAD District 4								1.00		1.00
PAD District 5									1.00	1.00

Conversions for Cogeneration

Information including cogeneration levels (RFCGGEN(CD)), cogeneration capacity (RFCGCAP(CD)), refinery fuel consumption (RFCGFUEL(CD)), self-generation (RFCGSELF(CD)), and generation for grid (RFCGGRID(CD)) must also be converted from PAD District level to Census divisions. The same factors and methodology developed for refinery fuel consumption (Table F18) are used to convert the cogeneration data.

Conversion coefficients for refinery fuel consumption and cogeneration information are estimated using &6007PRJ.PMM.CAPACITY.COEFS. An input file named &6007PRJ.PSD.CAPACITY.DATA95 contains refinery capacity data from the 1994 Petroleum Supply Annual (PSA). To update the program, operating capacity data can be pulled from IPS. (Manual updates to the data file can be made using data from Table 36 of the PSA and making some minor adjustments to the program that reads the data.)

F.12 Estimation of Sulfur Dioxide Allowance Equations

Between Oct. 1, 1993, and Dec. 31, 1999, small refineries that produce low sulfur diesel fuel will be eligible to receive allowances for sulfur dioxide emissions through the year 1999[23]. Refiners are not covered under the Acid Rain program but can trade the allowances with electric utilities and other units that must meet Title VI compliance. Allowance trading under the Acid Rain program will begin in 1995.

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[23]Proposed Rules,<u>Federal Register</u>, Vol. 57, No. 130, July 7, 1992, pp. 29960-29961.

In order to be eligible for allowances, small refiners must desulfurize both on- and off- road diesel. A "small refinery" is defined as a refinery or portion of a refinery that has a crude throughput less than 18.25 million barrels (MMbbl) and that is owned by a refiner with a combined throughput less than 50.19 MMbbl. The annual throughput will be measured as of November 15, 1990, according to Form EIA-810[24].

Analysis of the 1990 EIA-810 data indicates distillate production from eligible small refiners represented 12.8 percent of domestic distillate production in 1990. Identification of eligible small refiners and production of distillate was done in program CN6007.SSE.DIESEL.READ, which reads company level data from the EIA-810 data contained in CN6007.SSE.PSD.DIESEL.DATA.

AEO95 assumes that all small refiners desulfurize and produce low sulfur diesel at the national diesel (transportation and off-highway) to normal distillate ratio of 59 percent which correlates with 86,337 allowance requests. The actual number of small refiners that will choose to invest in desulfurization and the amount of the distillate yield at these refineries eligible for allowances (used as motor fuel) is very uncertain. The EPA awards allowances based on the EIA-810 which began differentiating between low sulfur and regular distillate in January 1993 but does not report end-uses. The maximum requests for allowances based on 1990 data and assuming all eligible refiners will produce only low sulfur distillate is 93,930.

Small refiner distillate volumes eligible for allowances can be estimated as:

Possible Allowance Volume (PAV) = total distillate * .128 * .59
$$(MMbbl)$$

The EPA will award allowances based on their estimates of sulfur dioxide reduction resulting from desulfurization. Each unit of low-sulfur diesel produced by eligible refiners will be equated to a .224 percent reduction in sulfur by weight[25]. Reflecting molecular weights, the reduction in sulfur is converted to a reduction in sulfur dioxide by multiplying by 2. One allowance request will be allowed for every ton of reduction in sulfur dioxide. Eligible volumes are converted to weight to estimate sulfur dioxide reduction/allowances as follows:

Possible Allowance Weight (PAW) = PAV * (302/2000 tons/bbl)
$$(MMtons)$$
and

Requested Allowances = PAW * (0.00224 % wt) * 2

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[24]Ibid.

[25]The percent weight .224 represents the difference in sulfur content between high-sulfur(.274 percent weight) and low-sulfur (.05 percent weight) distillates.

Allowances for each refinery will be based on diesel yield as reported on the EIA-810.
A maximum total of 35,000 allowances per year will be available for small refineries. An individual refinery may receive up to 1500 allowances per year. Therefore, sulfur allowances are estimated as the minimum of requested allowances estimated above or 35,000.

Future Methodology:

In January of 1993 the EIA-810 started to differentiate between low sulfur diesel and other distillate. Annual data can be used to calculate the percent of low sulfur diesel produced at small refineries. This percent should replace the 59-percent assumption discussed above.

F.13 Unfinished Oil Imports Methodology

PAD Districts I and III are the primary recipients of unfinished oil imports into the United States. Of the four categories that EIA publishes, light gas oils are practically nil and will not be modeled in PMM.

The Oil Market Module used the most recent known values for imports of unfinished oils, which remained fixed throughout the forecast period. While simplistic, this methodology was difficult to improve on.

In the methodology described below, unfinished oil imports are estimated as a function of crude oil input to refineries. Only six observations were available for this equation (1989 was an outlier and was not used), so this methodology should be reviewed later, possibly re-estimating the equation using quarterly data. Total U.S. unfinished oil imports are estimated from the equation, then the PAD District I and III values are shared out.

> U.S. Unfinished Oil Imports = $\quad$ -2856.7 + (0.2447 * Crude Inputs)
> $\qquad$ t-stats: (-157.5) (8.97)
> $\qquad$ R-squared: $\quad$ .95

> PAD District III Unfinished Oil Imports = U.S. Unfinished Oil Imports * 0.65
> $\qquad$ PAD District III Naphthas = PAD District III Total * 0.24
> $\qquad$ PAD District III Heavy Gas Oils = PAD District III Total * 0.27
> $\qquad$ PAD District III Residuum = PAD District III Total * 0.49

> PAD District I Unfinished Oil Imports = U.S. Unfinished Oil Imports * 0.35
> $\qquad$ PAD District I Naphthas = PAD District I Total * 0.09
> $\qquad$ PAD District I Heavy Gas Oils = PAD District I Total * 0.73
> $\qquad$ PAD District I Residuum = PAD District I Total * 0.18

F.14 Product Pipeline Capacities and Tariffs

Two sources were used to obtain the product pipeline data; (1) The NPC study [26] and (2) The North American Crude Oil Distribution (NACOD) model prepared by ICF for the Office of Strategic Petroleum Reserves (OSPR) during 1990-91. The NACOD data was received in LOTUS.WK3 spreadsheet format from Don Buck of OSPR.

NACOD data for the year 2000 were used for the petroleum product pipeline capacities and tariffs (1991$). The NPC study was used for LPG and NGL pipeline capacity data. The NACOD model defines 15 crude oil demand regions (including Canada and Puerto Rico/Virgin Islands) and the NPC study uses PAD District regions. The links needed for PMM, as shown in Table F19, are based on PAD Districts for refining regions and Census divisions for demands.

Many of the arcs shown in Table F20 and Table F21 represent more than one pipeline. In some cases, we have retained more than one arc from a source to a destination in order to have a better representation of product movements.

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[26]National Petroleum Council, *Petroleum Storage and Distribution, Volume 5, Petroleum Liquids Transportation*, (April 1989).

Table F19. NACOD Regions and NEMS/PMM Census Regions

NACOD Regions		NEMS/PMM Regions	
Code	Locations	Code	Locations
1	New England	1	NE, New England
2	Includes MD,DE	2	MA, excludes MD,DE
3	WV to FL	5	SA, includes MD,DE
4	KS, OK	7	WSC, includes OK,KS
5	PAD District II	3, 4	WNC,ENC, and KY, TN from 6
6	Texas Gulf Coast	7	WSC
7	LA Gulf Coast	7	WSC
8	West Texas, NM	7	WSC, excludes NM
9	AR, No. LA, No. MS, AL	6, 7	ESC,AR,LA,MS,AL
10	PAD District IV, North- ID, MT	8	MNT
11	PAD District IV, South- WY,UT,CO	8	MNT
12	Alaska		
13	Hawaii		
14	PAD District V,	9	PAC, excludes NV,AZ

The product pipeline capacities, excluding LPG/NGL service, are shown in Table F21. The matrix formulation used in PMM allows for separate arcs for product movements. For example, to deliver a barrel of gasoline to Dorsey MD (In Census Region 2) from PAD District III, (Census Region 7), requires flow on the arc from Region 7 to Region 6 (capacity of 2280 Mbbl/cd) at a cost of $0.31/bbl, flow on the arc from Region 6 to Region 5 (capacity of 2526 Mbbl/cd) at a cost of $0.74/bbl, and flow on the arc from Region 5 to Region 2 (capacity of 1392 Mbbl/cd) at a cost of $0.16/bbl. The total tariff is $1.21/bbl or 2.88 cents/gallon.

Table F20. Petroleum Product Pipeline Capacities and Tariffs[1]

Census region			
From	To	Capacity (Mbbl/cd)	Rate (Wt. avg $/bbl)
ENC, 3	MA, 2	157	1.32
ENC, 3	SA, 5	20	1.40
SA, 5	MA, 2	1392	0.16
ESC, 6	SA, 5	2526	0.74
WSC, 7	ENC, 3	328	0.56
WSC, 7	WNC, 4	280	0.86
WSC, 7	WNC, 4	717	0.80
WSC, 7	ESC, 6	2280	0.31
WSC, 7	MNT, 8	81	0.74
WSC, 7	MNT, 8	58	0.73
MNT, 8	WNC, 4	44	0.99
MNT, 8	PAC, 9	73	0.99

[1]Capacities and tariffs from NACOD model.

The LPG/NGL pipelines are shown in Table F21.

Table F21. LPG/NGL Pipelines Capacities and Tariffs[2]

Census Region		Capacity (Mbbl/cd)	Rate (Wt. avg $/bbl)
From	To		
ENC, 3	MA, 2	61	2.18
WNC, 4	ENC, 3	56	0.99 (estimated)
WNC, 4	SA, 5	57	0.99 (estimated)
ESC, 6	SA, 5	109	0.65
WSC, 7	ESC, 6	120	0.28
WSC, 7	WNC, 4	225	0.65
WSC, 7	WNC, 4	65	1.14
WSC, 7	MNT, 8	47	0.84
MNT, 8	WNC, 4	12	1.15

F.15 Cogeneration Methodology

Electricity consumption in the refinery is a function of the throughput of each unit. Sources of electricity consist of refinery power generation, utility purchases, and refinery cogeneration. Power generators and cogenerators are modeled in the PMM Linear Program (LP) as separate units which are allowed to compete along with purchased electricity.

The cogeneration unit in the PMM LP was modeled using historical data as a guideline. Cogeneration activity for each refinery was aggregated to the PADD level for incorporation into the PMM LP. Cogeneration capacity, fuel consumption, and percent sales to the utility grid were estimated from the EIA-867, Annual Nonutility Power Producer Report for 1994. The data covers all of SIC 29, not just SIC 2911. Cogeneration investment and operating costs were derived from the 1980 Office of Technology Assessment (OTA) report "Industrial Cogeneration".

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[2]Capacities from NPC study, tariffs from NACOD model data

Cogeneration capacity (including planned capacity) for each refining region was derived from the EIA-867 historical data base. It should be noted that the capacity provided in the data base is summertime capability and not nameplate capacity. The LP limits utilization to 90 percent of the summertime capability. Cogeneration capacity is allowed to expand when the value received from the additional product exceeds the investment and operating costs of the new unit. The value of adding capacity includes revenues from sales to the utility grid and the displacement of purchases of electricity. Investment costs are derived from the OTA report. The capacity expansion methodology is described in detail in Chapter 4.

Cogeneration fuel consumption was also calculated using the EIA-867 historical data base. It was found that consumption of 1.01 barrels of fuel oil would produce approximately 1000 kwh of electricity and 6530 lbs of steam. Since the LP refinery consumes fuel in barrels of fuel oil equivalent, shares of individual fuels were determined from the historical data and computed post process. The shares are allocated as follows:

Oil	2.10%
Natural Gas	74.15%
Other Gaseous Fuels	23.75%.

In the past, shares of all petroleum based fuels were aggregated under Petroleum Products. This category has now been divided into Oil and Other Gaseous Fuels.

In general, refineries will sell portions of the cogenerated electricity back to the utility grid. However, because of the "all or nothing" nature of an LP, sales to the grid could not be projected. If it is cost effective to sell cogeneration electricity, the LP will sell all of it. Likewise if it is not profitable, it will sell none of it. To model the situation more realistically, sales to the grid were modeled using percentages derived from the historical data base. The percentage of sales to the grid for each refining region (PADD) was calculated from the 1994 data as follows:

REGION	PERCENT SOLD TO GRID
PADD 1	63.24
PADD 2	0.87
PADD 3	5.09
PADD 4	80.78
PADD 5	46.29

The LP is forced to sell electricity back to the grid in these percentages at a price equal to the average price of electricity.

Fixed operating costs are calculated in the model as a function of cogeneration capacity while variable operating costs are determined as a function of electricity generated. The following rates were determined from the OTA report.

Annual Fixed Cost $7.32/kw
Variable Cost $0.00565/kwh

Data from the EIA-867 report was reconfigured using the following SAS program to extract information necessary to the LP.

CN6007.JDI.COGEN.HISTRY94.DATA manipulates the EIA-867 raw data so that all pertinent information for each refinery is contained in one line (SAS observation). The EIA-867 refinery data is aggregated by PADD and census division (CD) for input into the PMM history file. The PMM LP requires data to be sorted by PADD whereas the NEMS model requires cogeneration data be aggregated by CD. The program also calculates fuel allocation shares, and percentage of sales to the utility grid. The results are stored in the SAS database **CN6007.JDI.COGEN.F867.DATA94.SASDB.**

F.16 Natural Gas Plant Fuel Consumption

The consumption of natural gas by natural gas processing plants is modeled as a function of dry gas production. Natural gas consumed at gas processing plants is calculated as a percentage of dry gas production using data from the *Natural Gas Annual 1992*. The ratios are calculated by PAD District, except for PAD District V where Alaska is computed separately from the rest of PAD District V.

PAD District I	1.36
PAD District II	2.50
PAD District III	2.43
PAD District IV	2.61
PAD District V	2.25
ALASKA	8.93

F.17 Alaskan Crude Oil Exports

In November 1995, the ban on exports of Alaskan North Slope (ANS) oil was lifted. Exports could begin by the spring of 1996. The lifting of the ban had been expected for several months and was included in AEO96.

The theory supporting the economic incentives for exporting Alaskan crude is as follows. The current restriction on ANS crude probably results in an undervaluing of ANS crude on the West Coast. The value of

ANS crude on the West Coast would be expected to rise with greater amounts of ANS crude exports. In the Pacific refining regions, the value of ANS crude would decline as larger quantities flowed into the region. At some point, the rising value on the West Coast and the declining value in the Pacific regions would come together and the economic incentive to export ANS would cease.

The PMM does not have refinery representation for foreign regions, but instead relies upon supply curves to represent import availability of both crude oil and petroleum products. Allowing crude exports from Alaska could not be done, therefore, simply by adding a transportation vector from Alaska to the Pacific refining region. Instead, three vectors were added with specified quantities and target prices which represent the value of exporting ANS crude to the Pacific region. If the target price associated with the vector was higher than the value of ANS crude oil in PADD V, then the exports would flow. Since the value of ANS crude in the Pacific region is expected to fall as export flow increases,[3] the target prices declined across the three vectors.

AEO96 Results: The AEO96 incorporates the export of Alaskan North Slope crude oil from the United States starting in 1996. The projections indicate export levels near 200 thousand barrels per day (MBD) in 1996 and 1997, declining to about 140 MBD in 1998. After 1998, ANS exports are not expected until the last four years of the forecast, when moderating product demand and a slight upturn in ANS production levels results in export levels of 20-70 MBD.

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[3] Table 3.1, page 45, U.S. Department of Energy, *Exporting Alaskan North Slope Crude Oil*, DOE/PO-0025 (Washington, D.C., June 1994)

APPENDIX G

Matrix Generator Documentation

APPENDIX G. Matrix Generator Documentation

G.1 Introduction

The purpose of this report is to describe the program which runs the Multi-Refining Model (MRM) (3-regions or 5-regions) and the Enhanced Refinery Model (ERM) (single region); and to provide detail on how it works. The program allows the user to simulate a single region (ERM) or either a 5-region or 3-region (MRM) representation of the entire refining industry in the United States.

The ERM model simulates a single PADD (Petroleum Administration for Defense District) and has no transportation of crude oil to the refinery region nor product from the refinery region. Instead, crude oil is supplied directly to the refinery gate and product demands are satisfied at the refinery gate. The ERM projects petroleum product prices, product demands, crude oils, alcohols, ethers, natural gas and fuel consumption; and capacity expansion in a PADD.

Both the 3-region and 5-region MRMs simulate multiple PADD regions. They both are a collection of ERMs linked by a transportation network. They simulate the entire refining industry in the United States. The MRM simulates the operation of petroleum refineries in the United States, including the supply and transportation of crude oil to refineries, the regional processing of these raw materials into petroleum products, and the distribution of petroleum product to meet regional demands. In addition to the quantities that an ERM produces, the MRM identifies sources of supply for domestic and imported crude oils, alcohols, ethers and natural gas. The main difference between the 3-region and 5-region MRM is in the aggregation of the refineries in the United States and the transportation network. The MRM 5-region simulates five PADD's (I, II, III, IV, and V whose letter codes are E, C, G, M, and W) while the MRM 3-region simulates three PADD's (B, G, and W, where B is a grouping of E, C, and M into the B PADD).

The program generates the matrix for the linear programming model representation of the ERM or MRM, solves it, writes the solution, reports, and packs the matrix for use by the analyst using the ANALYZE software.

G.2 Code

The program is written in Fortran and makes use of the OML (Optimization and Modeling Libraries) to read in the data files, generate the matrix representation of the model, solve the problem, store the solution, and pack the matrix for use with ANALYZE. In addition to the above, the program produces reports.

The program is data driven and the user provides key information such as the model he chooses to run, the location of the input data files, and some other options.

G.2.a Variables and Constraints

The model consists of variables or activities (columns), constraints (rows), and bounds on activities. To each variable and constraint, we associated a unique name. In the naming of the variables and rows, we used indices. The following table displays the index set name and the number of elements in the set and gives a brief description of the set and a partial listing of the set members.

Index	No. of Values	Description	Members
@	1	represents all regions	@
c	2	Constraint type	X: for max N: for min
d	9	Census divisions	1: New England 2: Mid Atlantic 3: East North Central 4: West North Central 5: South Atlantic 6: Est South Central 7: West South Central 8: Mountain 9: Pacific
e	2	Emission source	C: Emission from fuel combustion N: Emission from process unit
m	15	Transportation mode, function of material and means of movement	0: U.S. flag LPG 4: U.S. flag residual oil 5: South Atlantic node 6: East South Central node A: Crude pipeline from G to C B: Barge residual oil I: West Texas to PADD 2 J: U.S. flag light products R: PADD 3 loop to PADD 2 S: PADD 3 capeline to PADD 2 T: Light product pipeline U: LPG, C4, CC5 pipeline V: Barge residual oil X: Local transportation Y: Pipeline PADD C to region 6

Index	No. of Values	Description	Members
o	8	OGSM regions	0: OGSM 1A East Coast 1: OGSM 1B East West part 2: OGSM 2 Gulf Coast 3: OGSM 3 Midcontinent 4: OGSM 4 Permian Basin 5: OGSM 5 Rocky Mountain 6: OGSM 6 West Coast A: OGSM A Alaska North
r	5	Refining regions	E: PADD I C: PADD II G: PADD III M: PADD IV W: PADD V
t	2	Type of transportation	V: Vessel P: Pipeline
x	5	Exporting regions	2: Export cd for PADD I 3: Export cd for PADD II 7: Export cd for PADD III 8: Export cd for PADD IV 9: Export cd for PADD V
Nn	3	Negative shift in demand	N1, N2, N3
On	8	Natural Gas refinery supply steps	N1, N2, N3, N4, P5, P6, P7, P8
Pn	3	Positive shift in demand	P1, P2, P3
qm	10	Quality code for gasoline blending	AR: Aromatics BZ: Benzene E2: E 200 E3: E 300 MO: Motor octane PO: Percent oxygen OL: Olefine RO: Research octane RV: Reid vapor pressure SL: Sulfur
qd	7	Quality code for distillate	AR: Aromatics FL: Flash point FZ: Freezing point GR: Gravity LM: Luminometer number SL: Sulfur VB: Viscosity
Qs	3	Step label for crude oil imports	Q1, Q2, Q3

Index	No. of Values	Description	Members
Rs	9	Step label for product imports	R1, ..., R9,
S1	1	Step label for product demands	S1
SX	1	Product exports	SX
Z9	1	Distress imports and exports	Z9
crt	12	Crude groups by quality and origin	ALL: Alaskan, API 25-66, S<0.5, B<15 AMH: Alaskan, API 21-32, S<1.1, B>15 DLL: Domestic, API 25-66, S<0.5, B<15 DMH: Domestic, API 21-32, S<1.1, B>15 DHL: Domestic, API 29-56, S<1.99, B<15 DHH: Domestic, API 23-35, S<3.0, B>15 DHV: Domestic, API<23, S>0.7, B>15 FLL: Foreign, API 25-66, S<0.5, B<15 FMH: Foreign, API 21-32, S<1.1, B>15 FHL: Foreign API 29-56, S<1.99, B<15 FHH: Foreign, API 23-35, S<3.0, B>15 FHV: Foreign, API<23, S>0.7, B>15
dfo	5	Distillate fuel oil blends	JTA: Jet fuel N2H: Number 2 oil DSL: Low sulfur diesel N6I: Low sulfur resid N6B: High sulfur resid
emu	6	Emission type	CAR: Total carbon CO1: Carbon monoxide CO2: Carbon dioxide NOX: Nitrous oxides SOX: Sulfur oxides VOC: Volatile organic compounds
ist	273	Refinery intermediate streams	LNI: Light naphtha, (175-250) intermediate LNN: Light naphtha, (175-250) naphthenic LNP: Light naphtha, (175-250) paraffinic
mgb	2	Gasoline blends	TRG: Traditional gasoline RFG: Reformulated gasoline
mod	many	Operating mode	C2A: Ethyl alkylate C3A: Propyl alkylate C4A: Butyl alkylate

Index	No. of Values	Description	Members
ncr	10	Non crude purchase	ARB: Atmospheric resid of type B CC3: Propane ETH: Ethanol HGM: Heavy gas oil medium sulfur IC4: Isobutane MET: Methanol MTB: M.T.B.E. NAT: Natural gasoline NC4: Normal butane NPP: Paraffinic naphtha
pol	25	Policy type	LOS: Lost OVC: Other variable cost MSD: Maximum distillation feed, cat cracker MSR: Maximum low sulfur resid, cat cracker SVR: Maximum severity, cat cracker H00: Maximum 100 severity, HP reformer H05: Maximum 105 severity, HP reformer
prd	18	Products	AST: Asphalt COK: Coke DSL: Low sulfur diesel E85: 85% Ethanol and 15% TRG JTA: Jet fuel LPG: Liquefied petroleum gas M85: 85% Methanol and 15% TRG N2H: Number 2 oil N67: Low sulfur resid to utilities N68: High sulfur resid to utilities N6B: High sulfur resid N6I: Low sulfur resid OTH: Other PCF: Petrochemical feed stock RFG: Reformulated gasoline RFH: Reformulated high oxygen gasoline TRG: Traditional gasoline TRH: Traditional high oxygen gasoline
pri	12	Product imports	DSL, JTA, LPG, MET, MTB, N2H, N6B, N6I, OTH, PCF, RFG, TRG
prx	10	Product exports	COK, DSL, JTA, LPG, N2H, N6B, N6I, OTH, PCF, TRG
px9	16	Distress exports	AST, COK, DSL, JTA, LPG, N2H, N67, N68, N6B, N6I, OTH, PCF, RFG, RFH, TRG, TRH

Index	No. of Values	Description	Members
pi9	18	Distress imports	AST, COK, DSL, E85, JTA, LPG, M85, N2H, N67, N68, N6B, N6I, OTH, PCF, RFG, RFH, TRG, TRH
unf	3	Unfinished oil	ARB: Atmospheric residual bottom type B HGM: Heavy gas oil medium sulfur NPP: Medium naphtha paraffin
uns	33	Process unit	ACU: Atmospheric crude distillation See Appendix F for complete list of processes
uuu	3	Utility	KWH: Kilo-watt hour NGF: Natural gas liquids STM: Steam

In the naming of the columns and rows, we are limited to a maximum of eight characters per name. The following two tables give the name of the variable (activity) and the row (constraint) represented.

The general name structure for columns is (v)(r)(abc)(def), where v is key code, r is region code, abc and def are 3 character names.

Name	Activity Represented
B(r)(mgb)(ist)	Blend stream (ist) to gasoline grade (mgb) in (r)
C(d)ETHR(s)	Ethanol supply step (s) in (d)
D(d)(prd)S1	Product (prd) demand in (d)
D(d)(prx)SX	Product (prx) exports from (d)
D(d)(px9)Z9	Distress product (px9) export from (d)
E(r)(uns)INV	Investment in new capacity for process (uns) in (r)
F(r)(dfo)(ist)	Blend stream (ist) to distillate fuel oil (dfo) in (r)
G(r)DGR	Dry gas residue in (r)
G(r)GPL01	Gas plant operations mode 01 in (r)
G(r)(ist)(prd)	Gas plant output transfer of stream (ist) to product (prd) in (r)
G(r)MOH01	Methanol plant operations in (r)
G(r)(ist)RFN	Transfer of gas plant stream (ist) to refinery in (r)
G(r)METDEM	Methanol production from methanol plant in (r)

Name	Activity Represented
G(r)SC2CC1	Shift of ethane to natural gas in gas plant in (r)
G(r)SC3CC1	Shift of propane to natural gas in gas plant in (r)
H(r)(uns)(ist)	Production of process (uns) of stream (ist) at merchant plant in (r)
H(r)(aa)(bb)(ist)*	Transfer from (aa) to (bb) of stream (ist) in (r)
I(d)(pi9)Z9	Distress product (pi9) imports to (d)
I(r)(pri)R(s)	Imported product (pri) step (s) to region (r)
K(r)(uns)CAP	Existing capacity for process (uns) in (r)
L(r)(uns)BLD	Addition to capacity for process (uns) in (r)
N(r)(ncr)	Purchase noncrude and additives (ncr) in (r)
N(r)DGP	Dry gas supply in (r) for ERM
N(r)NGRF(On)	Natural gas to refinery supply step (On) in (r)
NZAMH(On)	Export supply step (on) for Alaskan crude
O@CRDEXP	Alaskan crude exports
O@CRDSPR	SPR fill in US
P(o)DCRQ1	Domestic crude in (o)
P(r)(crt)(Qs)	Supply step (Qs) of imported crude (crt) to (r)
PANGLQ1	Supply of natural gas liquids from Alaska North slope
Q(r)(mgb)	Spec vector, total volume for (mgb) in (r)
Q(r)(dfo)	Spec vector, total volume for (dfo) in (r)
R(r)ACU(crt)	Volume of crude (crt) processed by the ACU unit in (r)
R(r)(uns)(mod)	Refinery process (uns) operation for mode (mod) in (r)
T(r)(ist)(ist)	transfer of stream (ist) to stream (ist) in (r)
T@UNFTOT	Total unfinished oils in US
TAAMHXZ	Volume of AMH crude transported from Alaska to Valdez
T(r)CBNTAX	Carbon tax in (r)
U(r)(uuu)	Utility (uuu) purchased in (r)
VTVC(m)CP	Crude vessel transportation capacity for mode (m)
VTVP(m)CP	Product vessel transportation capacity for mode (m)

Name	Activity Represented
VTPC(r)*(m)(d)	Crude pipeline transportation capacity from (r) to (d) using mode (m)
VTPP(r)*(m)(d)	Product pipeline transportation capacity from (r) to (d) using mode (m)
VTPL(r)*(m)(d)	LPG pipeline transportation capacity from (r) to (d) using mode (m)
W(r)(prd)(m)(d)	Product (prd) transportation from (r) to (d) using mode (m)
W(d)(prd)(m)(r)	Product (prd) transportation from (d) to (r) using mode (m)
X(d)(prd)SPG	Recipe blends of product (prd) for oxygenated fuels and electric utility residual oils in (d)
X(r)(prd)(ist)	Recipe blends of product (prd) from stream (ist) in region (r)
X(d)(ist)(prd)	Splash blending of (prd) from stream (ist) in (d)
Y(o)(crt)(m)(r)	Crude (crt) transportation from (o) to (r) using mode (m)
Y(r)(crt)(m)(r)	Crude (crt) transportation from (r) to (r) using mode (m)

* : (aa), (bb) = MP, GP, RF, where MP = Merchant plant, GP = Gas plant, RF = Refinery

For (ist): first and last character of (ist)

The general name structure for rows is: (v)(r)(abc)(def), where v is key code, r is region code, abc and def are 3 character names.

Name	Constraint Represented
A(d)(prd)	Product demand accounting row in (d) for (prd)
A(d)GO8(xx)	Gasoline blending accounting row in (d) for (xx)
A(d)RFG(xx)	Gasoline blending accounting row in (d) for (xx)
A(d)TRGTRH	Gasoline blending accounting row in (d)
A(x)PRDEXP	Product export accounting row in (x)
A(d)ETHTAX	Ethanol tax accounting row in (d)
A@NLGPRD	NGL accounting row in US
A(r)INVST	Investment accounting row in (r)
A(r)(prd)	Product (prd) refined accounting row in (r)
A(r)CRX(crt)	Crude oil (crt) accounting row in (r)
A@CRDAKA	Alaskan crude oil accounting row in US
A@CRDDCR	Domestic crude oil accounting row in US
A@CRDEXP	Crude oil export accounting row in US
A@CRDFCR	Foreign crude oil accounting row in US
A@CRDL48	Lower 48 crude oil accounting row in US
A@CRDSPR	SPR crude oil accounting row in US
A@CRDTOT	Total crude oil accounting row in US
A(r)ETHRFN	Ethanol to refinery accounting row in (r)
A(r)FUEL	Fuel use accounting row in (r)
A(r)FUM(xx)	FUM accounting row in (r) for (xx)
A(r)FXOC	Fixed cost accounting row in (r)
A(r)G(I)(xxx)	Gasoline blend components accounting row in (r) for (xxx)
A(r)GAIN	Gain accounting row in (r)
B(r)(ist)	Balance for intermediate stream (ist) in (r)
C(o)(crt)	Crude balance for crude type (crt) in (o)
C(r)(crt)	Crude balance for crude type (crt) in (r)

Name	Constraint Represented
D(d)(prd)	Final demand for product (prd) in (d)
E(r)(emu)(e)	Emission of (emu) from source (e) in (r)
F(r)UNF(unf)	Unfinished oil balance for (unf) in (r)
F@TOTCRD	Total crude balance for unfinished oil constraint in US
G(r)(ist)	Gas plant balance for stream (ist) in (r)
G(r)(pol)	Gas plant policy (pol) accounting row in (r)
H(r)(ist)	Merchant oxygenate plant balance row for (ist) in (r)
H(r)FUMCAP	Merchant oxygenate fuel balance row in (r)
H(r)(pol)	Merchant oxygenate plant policy (pol) accounting row in (r)
L(r)(uns)CAP	Process (uns) capacity in (r)
M(r)(prd)	Final product (prd) demand at refinery (r)
O(o)(crt)	Domestic crude oil (crt) accounting in (o)
OBJ	Objective function
P(r)(pol)	Policy (pol) constraint in (r)
P(r)CBNTAX	Carbon tax accounting row in (r)
Q(r)(prd)(qd)(c)	Product (prd) specification for quality (qd) constraint type (c) in (r)
S(r)(mgb)E	Sum row for blending gasolines (mgb) in (r)
S(r)(dfo)E	Sum row for blending fuel oils (dfo) in (r)
S(r)(RFGOXY	Constraint on renewable OXY limits in (r)
T(t)C(m)CP	Crude oil transportation (t) capacity limits for mode (m)
T(t)P(m)CP	Product transportation (t) capacity limits for mode (m)
TPC(r)(m)(d)	Crude transportation capacity balance row
TPL(r)(m)(d)	LPG transportation capacity balance row
TPP(r)(m)(d)	Product transportation capacity balance row
U(r)(uuu)	Utilities (uuu) in region r
Z(r)CAP(uns)	Balance row for total capacity of (uns) in (r)
Z(r)NGFSUM	Sum row for natural gas to refineries in (r)
ZZAMHSUM	Sum row for Alaskan crude export

Name	Constraint Represented
Z@WOP	Current world oil price in value of RHS
Z@CRDTOT	Sum row for total crude in US
Z@YRITER	Iteration year
Z@IRACX	Sum row to force average refinery crude cost within specified range
Z@IRACN	Sum row to force average refinery crude cost within specified range
Z(mmddyy)	Month, day, year of matrix generation

(I) = 01, 02, ... , 12

(xx) = LPG, N2H, N6B, N6I, NGS, OTH, STG

(xxx) = TRG and RFG

There are several other accounting rows.

The following Table gives the dimensions of each model:

Model	Columns		Rows	
	Total	Fixed	Total	Fixed
MRM 5 regions	8413	425	3090	789
MRM 3 regions	5524	316	2109	600
ERM	1335	46	486	124

The general structure for the model is as follow:

MRM Model Block Diagram

	Crude Trans.	Purchases Crude Oil, Other Inputs	Crude Distillation	Other Process Unit Operations	Capacity Expansion	Stream Transfers	Blending	Product Demand	Product Trans.	Row Type	RHS
Objective	-ct	-c	-o	-o	-i			+p	-pt	NC	Max
Crude Oil Balance	+1 +1	+1 +1	-1 -1							EQ	0
Intermediate Stream Balance			+y +y	-1 -1 +y +y		-1 +1 -1 +1	-1 -1			EQ	0
Utilities		+1	-u	-u +1						EQ	0
Policy Constraints				+z -z				+z -z		GE LE	0
Environmental Constraints			+q	+q						GE LE	E
Unit Capacities			+1	+1	-1					LE	K
Quality Specifications							+q +q -Q			GE LE	0
Product Sales						-1	-1	-1 +1 +1 -1		EQ	0
Pipeline/Marine Capacities	+1 +1								+1 +1	LE	C
Bounds	Up/Lo/Fix	Up/Lo/Fix						Lo/Fix			

Legend:
c = crude cost y = yield u = utility consumption K = unit capacity o = operating cost
p = price z = policy ratio q = stream quality ct = crude transportation cost pt = product transportation cost
Q = product specifications C = pipeline/marine capacity E = environmental quality limit i = investment cost

G.2.b Subroutines

The program consists of several subroutines and a main program. The subroutines can be grouped as those that setup the OML environment, read in the data tables, form parts of the matrix representation of the model, solve the model, retrieve needed information for report writing, and write the reports. All the subroutines that generate part of the matrix representation of the model use input from data files in an OML format. These files have a .dat extension. Some subroutines use ASCII files as input and some others don't use any. The following table shows the subroutine names, the input data file names, the purpose of the subroutines, and the model that uses them.

Subroutine	Data file	Purpose	Models
accunit.f	accunit.dat	Represents ACU unit	All
akaexp.f	akaexp.dat	Represents Alaskan exports	MRM 3 and 5
avoids.f	avoids.dat	Represents the avoids	MRM 3 and 5
cogener.f	cogener.dat	Represents the cogeneration	All
crdimprt.f	crdimprt.dat	Represents crude imports	MRM 3 and 5
demand.f	demand.dat	Represents demands	MRM 3 and 5
distblnd.f	distblnd.dat	Represents distillate blending	All
distress.f	distress.dat	Represents the distress imports and exports	MRM 3 and 5
emish.f	emish.dat	Represents emissions	MRM 3 and 5
ermcrude.f	ermcrude.dat	Represents crude inputs	ERM
ermother.f	ermother.dat	Represents non-crude inputs	ERM
ermprod.f	ermprod.dat	Represents product demands	ERM
ethanol.f	ethanol.dat	Represents ethanol supply and prices	MRM 3 and 5
fixcol.f	fixcol.dat	Fixes some columns	All
fuelmix.f	fuelmix.dat	Simulates fuel mixing	All
gasoblnd.f	gasoblnd.dat	Simulates gasoline blending	All
limpol.f	limpol.dat	Puts limits on policy rows	All
lplookup.f		Retrieves solution	MRM 5
main.f	main.dat, paths, mrmparam	Sets up the OML environment, reads in some main data, controls the program, calls subroutines to form matrix, solves problem, stores solution, writes reports, basis and packs matrix.	All
mchproc.f	mchproc.dat	Simulates the merchant plant	MRM 3 and 5
ngprod.f	ngprod.dat	Provides gas supply steps to refinery	MRM 3 and 5
nrfplant.f	nrfplant.dat	Simulates the non refinery plant activities	MRM 3 and 5
output.f		Prints a report	MRM 5

Subroutine	Data file	Purpose	Models
prdexp.f	prdexp.dat	Simulates the product exports	MRM 3 and 5
prdimprt.f	prdimprt.dat	Simulates the product imports	MRM 3 and 5
recipes.f	recipes.dat	Specifies product recipe blends	All
refproc.f	refproc.dat	Simulates the refinery	All
setrows.f	setrows.dat	Sets some rows	All
splash.f	splash.dat	Simulates splash blending	MRM 3 and 5
stream.f	stream.dat	Simulates stream transfers	All
tabread.f		Reads data tables	All
transit3.f	transit.dat	Simulates the product and crude oil transportation for the 3-region representation of MRM	MRM 3
transit5.f	transit.dat	Simulates the product and crude oil transportation for the 5-region representation of MRM	MRM 5
unfinished.f	unfinished.dat	Provide for unfinished oil imports	MRM 3 and 5
utility.f	utility.dat	Simulates utility purchased	MRM 3 and 5
utilitye.f	utility.dat	Simulates utility purchased	ERM

Most of the subroutines that constitute the program generate part of the matrix representation of the model. In the following we will give a representation of the submatrix generated by each subroutine in table form. Columns of the tables correspond to activities (variables) and rows of the table to constraints. The symbols x, -x or +-x represent matrix coefficient.

accunit.f: This subroutine simulates the ACU unit. It creates the following submatrix:

	R(r)ACU(crt)
C(r)(crt)	-x
L(r)ACUCAP	x
A(r)CRDFCR*	x
A@CRDFCR*	x
A(r)CRX(crt)	x
A@CRDTOT	x
Z@CRDTOT	x
F@TOTCRD	x
B(r)(ist)	x
U(r)(uuu)	-x
P(r)(pol)	x

* for (crt) = FLL, FMH, FHL, FHH, and FHV

Bounds: None

akaexp.f: This subroutine simulates the Alaskan exports. It creates the following submatrix:

	NZAMH(i)	ZZAMHTOT	TAAMHXZ	PANGLQ1
OBJ	+-x*	x	-x	-x
CAAMH			-x	
CZAMH		-x	x	
BW(ist)				x
ZZAMHSUM	x	-x		
A@AKAEXP		x		
AANGLPRD				x
A@NGLPRD				x
AWNGLRFN				x

(i) = N1, N2, N3, P4, P5, P6
* : -x if i = N1, N2, N3; x if i = P4, P5, P6

Bounds: PANGLQ1, NZAMH(i)

avoids.f: This subroutine simulates the avoids. It is turned off. It creates the following submatrix:

	D(d)(prd)N(i)	D(d)(prd)P(i)
D(d)(prd)	x	-x
OBJ	-x	-x
A(d)(prd)	-x	x
A@PRDDEM	-x	x
A@AVDNEG	x	
A@AVDPOS		x

(i) = 1, ..., 3

Bounds: D(d)(prd)N(i) and D(d)(prd)P(i)

cogener.f: This subroutine simulates the cogeneration unit. It creates the following submatrix

	E(r)CGNINV	K(r)CGNCAP	L(r)CGNBLD	R(r)CGNCGN	U(r)(uuu)*
B(r)FUL				-x	

	E(r)CGNINV	K(r)CGNCAP	L(r)CGNBLD	R(r)CGNCGN	U(r)(uuu)*
L(r)CGNCAP	x	-x	-x	x	
OBJ	-x		-x	x	-x
P(r)OVC				-x	
U(r)(uuu)				x	
A@FXOC	x		x		
A(r)FXOC	x		x		
A@INVST	x				
A(r)INVST	x				
A@KWHRFN				x	

*: for (uuu) = KWH

crdimprt.f: This subroutine simulates the crude imports into the United States. It creates the following matrix:

	P(r)(crt)Q(s)
C(r)(crt)	x
C(o)(crt)	x
OBJ	-x
A@CRDFCR	x
A(r)CRDFCR	x
Z@IRACN	x
Z@IRACX	x

Bounds: P(r)(crt)Q(s)

demand.f: This subroutine simulates product demands. It creates the following submatrix:

	D(d)(prd)S1	D@METS1
D(d)(prd)	-x	
OBJ	x	
A(d)(prd)	x	
A@METDEM		x
A@PRDDEM	x	
D@MET		-x

Bounds: D@METS1 and D(r)(prd)S1

distblnd.f: This subroutine simulates the distillate blending. It creates the following matrix:

	F(r)(dfo)(ist)	Q(r)(prd)
B(r)(ist)	+-x	
M(r)(prd)		x
Q(r)(prd)(qq)(c)	x	x
S(r)(dfo)E	x	x
A(r)(prd)		x
A@PRDRFN		x

Bounds: None

distress.f: This subroutine simulates product distresses. It creates the following submatrix:

	I(d)(pri)Z9
D(d)(pri)	x
OBJ	-x
A@ZZIMP	x

Bounds: None

domcrude.f: This subroutine simulates domestic crudes. It creates the following submatrix:

	P(o)DCRQ1	PADCRQ1	O@CRDEXP	O@CRDSPR
OBJ	-x	x		
C(o)(crt)	x	x		
CAAMH			-x	
CGFHL				-x
A@CRDDCR	x	x		
A@CRDAKA		x		
A@CRDL48	x			
A@CRDEXP			x	
A@CRDSPR				x
A@CRDFCR				x
Z@IRACN	x			

	P(o)DCRQ1	PADCRQ1	O@CRDEXP	O@CRDSPR
Z@IRACX	x			
O(o)(crt)	x			

(o) : except A

Bounds: P(o)DCRQ1, PADCRQ1, O@CRDEXP, O@CRDSPR

emish.f: This subroutine simulates emissions. It creates the following submatrix:

	K(r)(uns)CAP	R(r)FUM(ist)
E(r)(emu)N	x	
E(r)(emu)C		x

Bounds: None

ermcrude.f: This subroutine simulates domestic crudes for ERM. It creates the following submatrix:

	P(r)(crt)*
C(r)(crt)*	x
OBJ	-x

* (crt) = FHH, FHL, FHV, FLL, FMH

Bounds: P(r)(crt)

ermother.f: This subroutine simulates the non-crude inputs for ERM. It creates the following submatrix:

	N(r)(ist)
B(r)(ist)	x
OBJ	-x
A(r)(ist)	x

Bounds: N(r)(ist)

ermprod.f: This subroutine simulates product demands for ERM. It creates the following submatrix:

	D(r)(prd)S1
M(r)(prd)	-x

	D(r)(prd)S1
OBJ	x

Bounds: D(r)(prd)S1

ethanol.f: This subroutine represents ethanol supply and prices. It creates the following submatrix:

	C(d)ETHR(i)	Z(d)ETHTAX
D(d)ETH	x	
OBJ	-x	x
A(d)ETH	x	
A(d)ETHTAX	x	-x
A@ETHPRD	x	

i = 1, ..., 4

Bounds: C(d)ETHR(i)

fixcols.f: This subroutine fixes some variables or activity. No submatrix is generated

Bounds: R(r)FCC(ist)

fuelmix.f: This subroutine simulates fuel mixing. It creates the following submatrix:

	R(r)FUM(ist)	T(r)CBNTAX	K(r)FUMCAP
B(r)(ist)	-x		
B(r)FUL	x		
L(r)FUMCAP	x		-x
M(r)(prd)	-x		
OBJ		-x	
P(r)CBNTAX	-x	x	
P(r)LOS	x		
A(r)FUM(mod)	x		
A@FUM(mod)	x		
A(r)FUEL			x
A@FUEL			x
A(r)GAIN	x		
A@GAIN	x		

Bounds: None

gasoblnd.f: This subroutine simulates gasoline blending. It creates the following submatrix:

	B(r)(mgb)(ist)	Q(r)(mgb)	Z(r)RFGOXY
B(r)(ist)	-x		
M(r)(prd)		x	
Q(r)RFGREN	x		-x
Q(r)(prd)(qq)(c)	x	-x	
S(r)(mgb)E		-x	
S(r)RFGOXY			-x
U(r)KWH		-x	
A(r)(xxx)(mgb)	x		
A(r)(prd)		x	
A@(xxx)(mgb)	x		
A@PRDRFN		x	

(xxx) = GO1, ..., G12

Bounds: None

lplookup.f: Retrieves solution values and stores them in arrays.

main.f: This subroutine reads in the mrmparam file that has the information relative to the model to run; initializes the OML subroutine library environment; opens the database; specifies a problem in the database for processing; initializes the matrix processing; reads in the path file, the main.dat file that contains some global variables such as the refinery, the exporting, and demand regions code; calls the subroutines that generate the matrix; ends the matrix processing; writes out the MPS file; inserts the advanced basis; solves the matrix; puts the solution in output; writes the optimal basis; prints reports; packs the matrix; and closes the database.

mchproc.f: This subroutine represents the merchant plant. It creates the following submatrix

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	K(r)FUXCAP	H(r)(uns)(ist)
H(r)FUMCAP				x	x
L(r)(uns)CAP	-x	-x	-x		x
OBJ		-x	-x		
A@FXOC		x	x		
A(r)FXOC		x	x		
A@INVST		x			

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	K(r)FUXCAP	H(r)(uns)(ist)
A(r)INVST		x			

mchproc.f (Continued)

	H(r)(uns)(ist)	H(r)KWHMCH	H(r)(aa)(bb)(ist)*	T(r)MCHOVC
H(r)(ist)	+-x		-x	
H(r)(uuu)	+-x			
H(r)(pol)	+-x			
G(r)(ist)			x	
B(r)(ist)			-x	
H(r)KWH		x		
H(r)OVC				x
OBJ		-x	-x	-x

*: first and last character of (ist)
   (aa) and (bb) = MP, GP, RF
   where MP = Merchant plant, GP = Gas plant, and RF = Refinery

Bounds: K(r)(uns)(CAP, E(r)(uns)INV, L(r)(uns)BLD

ngprod.f: This subroutine represents the gas supply steps to refinery. It creates the following submatrix

	N(r)NGRF(ij)*
OBJ	+-x**
N(r)NGRFSUM	x
Z(r)NGFSUM	x

* (ij) = N1, N2, N3, N4, P5, P6, P7, P8
** +x for N1, N2, N3, N4 and -x for P5, P6, P7, P8

Bounds: N(r)NGRF(ij)

nrfplant.f: This subroutine simulates the non refinery plant. It creates the following submatrix:

	G(r)DGR	G(r)GPL01	T(r)GPLOVC	G(r)(xxx)*LPG	G(r)(xxx)**RFN
G(r)OVC	-x		x		
G(r)DGP	x	-x			
G(r)LOS	-x	-x			

	G(r)DGR	G(r)GPL01	T(r)GPLOVC	G(r)(xxx)*LPG	G(r)(xxx)**RFN
G(r)(xxx)		x		-x	x
G(r)CC1	-x				
OBJ			-x	-x	-x
A(r)GPLPG				x	
A(r)NGLRFN					x
A@NGLRFN					x
B(r)(xxx)**					x
M(r)LPG				x	
A(r)NGLPRD				x	x
A@NGLPRD				x	x

nrfplant.f (Continued)

	G(r)SC2CC1	G(r)SC3CC1	N(r)DGP	G(r)METRFN	G(r)METDEM
GGCC1	x	x	x		
GGCC3		-x			
GGLOS	x	x			
GGPGS	-x				
OBJ	x	x		-x	-x
A(r)NGSMER				x	
A@NGSMER				x	
B(r)MET				x	
G(r)MET				-x	-x
D@MET					x

nrfplant.f (Continued)

	E(r)MOHINV	L(r)MOHBLD	K(r)MOHCAP	G(r)MOH01
L(r)MOHCAP	-x	-x	-x	x
G(r)MET				x
G(r)OVC				-x
U(r)NGF				-x
A(r)NGSMET				x
A@NGSMET				x
A@METPRD				x

	E(r)MOHINV	L(r)MOHBLD	K(r)MOHCAP	G(r)MOH01
OBJ	-x	-x		
A(r)INVST	x			
A@INVST	x			
A(r)FXOC	x	x		
A@FXOC	x	x		

(xxx) : PGS, CC3, IC4, NC4, NAT
* : (xxx) except NAT ; **: (xxx) except PGS, CC3

Bounds: G(r)SC3CC1, N(r)DGP, E(r)MOHINV, K(r)MOHCAP

output.f: This subroutine prints reports.

prdexp.f: Simulates product exports. It creates the following submatrix:

	D(z)(prx)*SX	D(z)COKSX	D(z)ASTSX
D(z)(prx)	-x	-x	-x
OBJ	x	x	
A@COKEXP		x	
A(r)PRDEXP	x		x
A@PRDEXP	x		x

*: All (prx) except COK and AST

Bounds: D(z)(prx)SX, except for (prx) = COK

prdimprt.f :   This subroutine simulates product imports. It creates the following submatrix:

	I(r)(pri)*R(s)	I(r)(pri)**R(s)
A@(pri)*IMP	x	
A(r)(pri)*IMP	x	
B(r)(pri)*	x	
A(r)PRDIMP		x
A@PRDIMP		x
M(r)(pri)**		x
OBJ	-x	-x

* : for (pri) = MET and MTB
**: for all (pri) except MET and MTB

Bounds: I(r)(pri)Rn

recipes.f: This subroutine simulates product recipe blending. It creates the following submatrix:

	X(r)(xxx)(yyy)
B(r)(ist)	-x
M(r)(yyy)	x
OBJ	+-x*
U(r)STM	-x**
A(r)(yyy)	x
A(r)PETCOK	x***
A@PETCOK	x***
A@PRDRFN	x

(xxx) = AST, AVG, CKH, CKL, GOP, SUL ; (yyy) = AST, OTH, COK, PCF, SAL
*: -x for (xxx) = AVG; **: for (xxx) = AST and (yyy) = AST; ***: for (yyy) = COK

refproc.f: This subroutine simulates the refinery processes. It creates the following submatrix:

	E(r)(uns)INV	K(r)(uns)CAP	L(r)(uns)BLD	T(r)OVCOBJ	R(r)(uns)(ist)
B(r)(ist)					x
L(r)(uns)CAP	-x	-x	-x		x
U(r)(uuu)					-x
P(r)(pol)				x*	x
OBJ	-x		-x	-x	
A(r)INVST	x				
A@INVST	x				
A(r)FXOC	x		x		
A@FXOC	x		x		
A(r)GAIN					x
A@GAIN					x
A(r)METRFN					x**
A(r)NGSH2P					x***
A@NGSH2P					x***
A@MTBPRD					x****

*: when (pol) = OVC; **: when (uns) = ETH; ***: when (uns) = H2P; ****: when (uns) = ETH and (ist) = MTB

Bounds: K(r)(uns)CAP, E(r)(uns)INV, L(r)(uns)BLD

setrows.f: This subroutine sets the right hand side (rhs) of rows P(r)(xxx), where (xxx) = N6B, N6I, LOS, ...

splash.f: This subroutine simulates splash blending. It creates the following submatrix:

	X(d)ETH(xxx)	X(d)METM85	X(d)(www)SPG	B(r)RFG(sss)	B(r)RFG(rrr)
D(d)(xxx)	x				
D(d)ETH	-x				
D(d)(yyy)	-x				
D(d)M85		x			
D(d)(zzz)		-x			
Q(r)RFG(vvv)	x*				
A(d)G08(xxx)**	x				
A@ETH(xxx)	x				
A@METM85		x			
A(d)RFG(xxx)*	x				
A(d)TRGTRH	x				
D(d)(www)			x		
D(d)(ttt)			-x		
Q(r)RFGREN				x	
S(r)RFGOXY					x

(ttt) = N6B, N6I; (vvv) = REN, OXY; (www) = N67, N68; (xxx) = E85, RFG, RFH, TRH
(yyy) = SSR when (xxx) = RFG, RFH and (yyy) = SST when (xxx) = TRH; (zzz) = MET, TRG
*: (xxx) not equal to E85; **: when (xxx) = RFG and RFH

stream.f: This subroutine simulates stream transfers. It creates the following submatrix:

	T(r)(ist)(ist)
B(r)(ist)	+-x
M(r)(prd)	+-x
A(r)(prd)	x
A@PRDRFN	x

streame.f: This subroutine is almost identical to stream.f, except that it is for ERM.

taberead.f: This subroutine prints the data file names, the number of tables and lists the tables names that are read.

transit5.f: This subroutine simulates the transportation network for MRM 5-region

	Y(o)(crt)(m)(r)	W(s)ETH(r)	W(s)MET(r)	W(s)(prd)(r)	V(xxxxxx)
C(o)(crt)	-x				
C(r)(crt)	+x				
OBJ	-x	-x	-x	-x	
TVC(m)CP	x				
TPC(o)(m)(r)	x				
B(r)ETH		x			
D(s)ETH		-x			
D(r)ETH		x			
A(r)ETHRFN		x			
B(s)MET			-x		
D(r)MET			x		
M(s)(prd)				-x	
M(r)(prd)				x	
TPL(s)(m)(r)				x**	
TPP(s)(m)(r)				x***	
D(r)(prd)				x**	
TVP(m)CP				x	
(xxxxxx)					-x

** for (prd) = LPG and PCF; *** for (prd) different then MET, ETH, LPG, and PCF
(s) : supply regions; (xxxxxx) = TVC5CP, TVPJCP, ...

Bounds: V(xxxxxx)

transit3.f: This subroutine simulates the transportation network for MRM 3-region. Almost identical to transit5.f

unfinish.f: This subroutine simulates the unfinished oil process. It creates the following submatrix:

	T(r)UNF(ist)	T@UNFTOT
B(r)(ist)	x	

	T(r)UNF(ist)	T@UNFTOT
F(r)UNF(ist)	-x	x
OBJ	-x	
A(r)UNF	x	
A@UNFIMP	x	
A(r)UNFIMP	x	
F@TOTCRD		-x

utility.f: This subroutine represents the utility. It creates the following submatrix:

	U(r)(uuu)	R(r)STGBSF	R(r)KWGPGN	K(r)(uuu)CAP	T(r)NGFNGS
U(r)(uuu)	x	-x**	x**		-x***
OBJ	-x	x**	-x**		
A@KWHRFN	x*		x		
L(r)KWGCAP			x		
L(r)STGCAP		x			
L(r)(uuu)CAP				x	
P(r)OVC		-x			
B(r)FUL		x			
B(r)NGS					x
A(r)NGSRFN					x
A@NGFTOT	x***				
A(r)NGFTOT	x***				
Z(r)NGFSUM	-x***				

*: for (uuu) = KWH ; **: for (uuu) = KWH and STM; ***: for (uuu) = NGF

utilitye.f: This subroutine is the same as utility.f, except that it is for ERM.

All the Fortran files are located in /refine/db6/mrm/default/source/

G.2.c Common Blocks

Variables shared by several subroutines are set up in common. There are four files that contain the common blocks used by the program. Some of the files consists of several common blocks.

The following table lists the common block names, gives a brief description and the location of the block.

Common	Description	Location
IPMMREAL	Common for real variables shared by subroutines that generate submatrices	/refine/db6/mrm/default/data/ipmmtest
IPMMINT	Common for integer variables shared by subroutines that generate submatrices	/refine/db6/mrm/default/data/ipmmtest
IPMMCHAR	Common for character variables shared by subroutines that generate submatrices	/refine/db6/mrm/default/data/ipmmtest
LPTAB	Common used for solution retrieval and report writing	/refine/db6/mrm/default/data/lpout
DFINC2	Common for OML database functions	/default/includes/dfinc2
CR	Common for the WHIZ optimizer	/default/includes/wfinc2

A list of the common blocks and the variables that constitute them is given in Appendix D.

G.3 Data

Most of the data that the program uses is provided in files with a .dat extension. There is a one to one correspondence between the Fortran files that form part of the matrix and the .dat data files (ex accunit.f gets its input from accunit.dat) . In each of the .dat file, the data is arranged in an OML format that consists of tables. Each table consists of a table name; row or stub and column or head names; and values at the intersection of rows and columns. In addition there are ASCII files. These ASCII files are for control of the program. The following is the description of each input file.

G.3.a   Data sets

.dat files

accunit.dat

Table Name	Columns	Rows	Description
ACUCUTS	(crt)	(ist)	Crude distillation yield
ACUPOL	OVC, LOS	(crt)	ACU policy table
ACUUTI	(uuu)	(crt)	ACU utility consumption
INVLIM	MAX	(r)	Maximum investment

akaexp.dat

Table name	Columns	Rows	Description
EXPAKA	P, Q	N1, N2, N3, P4, P5, P6	Price and quantity of Alaskan crude exports.
NGLAKA	PER	PGS, CC3, NC4, IC4, and NAT	Yield of NGL
PRQAKA	VOL, TRP, EXPPRC	A	Volume, and transportation and expected cost for Alaskan crude exports

avoids.dat

Table	Columns	Rows	Description
SADELPX	FACTORS	N1, N2, N3, P1, P2, P3	Price differentiate
PRDAVOID	DUMMY	(prd)	Product list
SADELQ	N1, N2, N3, P1, P2, P3	(prd)	Demand shift quality fraction

cogener.dat

Table	Columns	Rows	Description
CGNCAP	CAP, PUL, BLD	(r)	Cogeneration capacity, %utilization and build
CGNINV	INV, FXOC, CAPREC	(r)	Cogeneration investment, fixed cost and capital recovery
CGNPOL	OVC	CGN	Cogeneration policy
CGNREP	CGN	FUL	Cogeneration yields
CGNUTI	(uuu)	(r)	Cogeneration utility usage
SELGEN	SOLD	(r)	% cogeneration sold to grid

crdimprt.dat

Table	Columns	Rows	Description
CRUDETYPE	DUMMY	(crt)*	Foreign crude types
ICR(crt)*r)	C1, Q1, C2, Q2, C3, Q3	(year)	Price and quantity available for crude imports.

*: for (crt) = FLL, FMH, FHL, FHH, FHV (i.e. foreign crudes)

demand.dat

Table	Columns	Rows	Description
CKSMIX	CKL, CKH	OBJ, CKL, CKH, COK	Coke price and conversion factor
PRODLIST	Dummy	(prd)	List of products
(prd)	(d)	(year)	Product (prd) demand
DEMMET	CHEM	(year)	MET demand

distblnd.dat

Table	Columns	Rows	Description
Q(r)DFO	(dfo)	(spec)	Distillate fuel oil blend specs
FN(dfo)	(spec)	(ist)	Component blend stream values

Table	Columns	Rows	Description
BX(dfo)	(spec)	Hydrogen treated component streams	Component blend stream values
BX(dfo)B	Hydrogen treated component streams	H2S, PGT: represents output quantity from hydrogen treated component HH2, FUL: represent required input for hydrogen treated component streams	Yield for hydrogen treated stream
BX(dfo)P	LOS, OVC	Hydrogen treated component streams	Policy coefficient for treated stream
BX(dfo)L	CAP	Hydrogen treated component streams	Capacity coefficient for treated stream
BX(dfo)U	STM, KWH	Hydrogen treated component streams	Utility coefficient for treated stream
BX(dfo)T	Transfer	Hydrogen treated component streams	Transfer of untreated stream to treated
BHDSL	(spec)	Hydrogen treated component streams	Specification
BHDSLT	Transfer	Hydrogen treated component streams	Transfer of untreated DSL stream to severe hydro treated stream
BHDSLB	Hydrogen treated component streams	H2S, PGT: represent output quantity from hydrogen treated component HH2, FUL: represent required input for hydrogen treated component streams	Yield for hydrogen treated stream
BHDSLU	STM, KWH	Hydrogen treated component streams	Utility coefficient for untreated stream
BHDSLP	LOS, OVC	Hydrogen treated component streams	Policy coefficient for untreated stream
BHDSLL	CAP	Hydrogen treated component streams	Capacity coefficient for treated stream

distress.dat

Table	Columns	Rows	Description
ZPX	Value	(prd)	Distress code for pricing

domcrude.dat

Table	Columns	Rows	Description
DCRSHR	(o)	(crt)*	Domestic crude share by OGSM region
CREXP	CRDEXP, CRDSPR	VOL	Crude exports and SPR

*: (crt) except FLL, FMH, FHL, FHH, FHV

emission.dat

Table	Columns	Rows	Description
EMUNS	(e)	Process unit	Emission by process unit
EMFUM	(e)	Fuel stream burned	Emission by fuel burned

ethanol.dat

Table	Columns	Rows	Description
SUPETH(i)*	C1, R1, C2, R2, C3, R3	(year)	Ethanol supply curves
ETHTAX	TAX	(d)	Ethanol taxes

* i = 1, ..., 9

fixcols.dat

Table	Columns	Rows	Description
FIXCOL	R	Dummy	First letter of column to fix
(r)RCOL	FCC	(mod)	Column to fix to zero

fuelmix.dat

Table	Columns	Rows	Description
GROUP	Dummy	Fuel stream	List of fuel stream
MIXINT	LOS	Fuel stream	Fuel mixing
MIXPRD	LOS	N2H, N6I, N6B	Fuel mixing
MIXPOL(r)	PHF, N6B, N6I	H2S, CAP	Fuel mixing policy

gasoblnd.dat

Table	Columns	Rows	Description
Q(r)GSL	TRG, RFG	(spec)	TRG, RFG specs

Table	Columns	Rows	Description
(r)SSR	SSR, RFH	RFG(spec)	Gasoline specs for subspec SSR
(r)SST	SSR, TRH	TRG(spec)	Gasoline specs for subspec SST
GASGROUP	TRG, RFG	Gasoline components	Group of blending streams
GCB	Quality codes	(ist)	Gasoline component volatility values
MCOBV	Octane rating	(ist)	Octane blending numbers
GSLUTI	KWH	(prd)	Gasoline utility
GSPETH	RFGN	RE	Gasoline specs for ETH

limpol.dat

Table	Columns	Rows	Description
UNITPOL	DUMMY	(uns)	List of processes that have a limit on POL
LIM(uns)	(ist)	(r)	Limit on (ist)

main.dat

Table	Columns	Rows	Description
EXPPROD	DUMMY	(prx)	List of product exports
INFACT	LOC, ENV	(r)	Location and environment factors
TRSOVC	OVC	(r)	Conversion factor for operating cost
FORCRD	DUMMY	(crt)*	List of foreign crudes
YRDOLLAR	1991	1987	Conversion factor
ZIRACFAC	Delta	ZIRAC	Range of price differential for IRAC
WOP	WOP	(year)	World oil price
RFNREG	PAD	(r)	List of PADDs
RFNEXP	RFID	Linked list of refinery and export regions	List of exporting regions
DEMNDREG	REGION	List of demand regions	List of demand region
USERYEAR	YEAR	CODE	Year to run model

mchproc.dat

Table	Columns	Rows	Description
MCHINV	INV, FXOC, CAPREC	(uns)	Merchant plant investment, fixed cost and capital recovering

Table	Columns	Rows	Description
(r)CAPMCH	CAP, PUL, BLD	(uns)	Merchant plant processes capacity, % utilization and build.
(uns)POL	(pol)	(ist)	Merchant plant processes policy
(uns)CAP	(uns)CAP	(ist)	Merchant plant process capacity
(uns)REP	(ist)	(ist)	Merchant plant process yields
(uns)UTI	(uuu)	(ist)	Merchant plant process utility usage
TRANSFER	Dummy	GP, MP, RF	Transfer allowed
RFTRANS	MP	(ist)	Refinery transfer to merchant plant
GPTRANS	MP	(ist)	Gas plant transfer to merchant plant
MPTRANS	GP, RF	(ist)	Merchant plant transfer to gas plant and refinery
(r)UAP	CST	(uuu)	Utility purchases

ngprod.dat

Table	Columns	Rows	Description
SPNGF	ALLREG	N1, .., N4, P5, ..., P8	Price steps for gas supply
SQNGF	MAX, MIN	N1, .., N4, P5, ..., P8	Quantity steps for gas supply
SCVAL	(r)	VOL	Volume limits on each step

nrfplant.dat

Table	Columns	Rows	Description
INVMOH	INV, CAPREC, FXOC	MOH	Non refinery plant process investment, capital recovery, and fixed cost.
MOHPLT	(r)	CC1, MET, OVC	Production of methanol
MOHCAP	(r)	CAP	Methanol capacity
GASPLT	(r), 01	(ist)	Yield from gas plant
GASSHFT	SC2, SC3	CC1, LOS, OVC	Shift from ethane and propane to methane
GASCAP	(r), 01	CC1, FAC, CAP, LIM, PCU	Gas plant capacity limits

prdexp.dat

Table	Columns	Rows	Description
(x)PRDEXP	VOL	(prx)	Limit on volume to export

Table	Columns	Rows	Description
EXPLIM	YRPC, FIX	1995	Limit on volume and yearly increase
MULTEXPR	MULT	PRICE	Price for exports as function of imports

prdimprt.dat

Table	Columns	Rows	Description
PRODTYP	DUMMY	(pri)	List of product import
IMPLIM	MAX	@	Maximum imports into USA
IPR(pri)(r)	C1, R1, ..., C3, R3	(year)	Product import supply curve
NEMSRSD	R1B, R1PR	R1, ..., R9	Reside import supply curve

recipes.dat

Table	Columns	Rows	Description
RCP1	Recipe blended products	Component stream	Recipe fraction
RCP2	SPG	KER, JTA, N2H	Composition of kerosene
RCP3	SULSAL	SLP	Sulfur transfer to sales
RCPSALE	PRICE	(ist), OTH, AST, COK	Price for stream
RCPUTI	ASTAST	STM	Stream consumption for asphalt production

refproc.dat

Table	Columns	Rows	Description
(r)CAP	CAP, PUL, BLD	(uns)	CAP, PUL and BLD values
(uns)CAP	(uns)	(mod)	Refinery processes capacity
(uns)POL	(ist)	(pol)	Refinery process policy
(uns)REP	(ist)	(mod)	Refinery process yields
(uns)UTI	(uuu)	(mod)	Refinery process utility usage
INV	INV, FXOC, CAPREC	(uns)	Refinery processes investment, fixed cost and capital recovery

setrows.dat

Table	Columns	Rows	Description

(r)POL	TYPE	(pol)	Row type

splash.dat

Table	Columns	Rows	Description
HOXETH	TRH, RFH, RFG	Gasoline blend stream	Ethanol recipe for splash blending
BLNSP(d)	KER, N67, N68	JTA, N2H, KER, N6I, N6B, N67, N68	Blend composition recipe
BLOX(d)XXX	E85, M85, TRH, RFH, RFG	Gasoline stream	Recipe blend composition
XETH	PO	XETH	Oxygen content of ethanol
SCB	PO	Oxygenate stream	Oxygen content of oxygenates

stream.dat

Table	Columns	Rows	Description
PTP	DUMMY	N6IN6B	Linked list of reside transfer
XSALE	DUMMY	(ist)(prd)	Linked list of stream transfer to products
TRS	DUMMY	(ist)(ist)	Linked list of stream transfer

transit.dat

Table	Columns	Rows	Description
MVCCAP	MAX	TV(t)(m)CP	Marine vessel capacity
BVPCAP	MAX	TVP(m)CP	Marine barge capacity
PLCCAP	MAX	TPC(r)(m)(d)	Pipeline capacity
TPCRLIST	Dummy	(r)*	Crude supply regions for transportation
TPCR(r)*	(crt)**	(XY) where X is mode and Y is refinery region	Crude oil transportation cost from supply region (r)
PLCRLIST	DUMMY	(r)*	List of crude oil supply regions for pipeline
PLCR(r)*	(crt)*	(m)(r)	Crude pipeline transportation cost
BVPR(r)	(prd)	(m)(r)	Product barge/truck transportation cost
TPPR(r)	(prd)	(m)(r)	Product marine transportation cost
TPME(r)	MET	(m)(r)	Methanol transportation cost
TPETLIST	DUMMY	(r)*	List of ethanol supply region for transportation
TPET(r)*	ETH	(m)(r)	Ethanol transportation cost

Table	Columns	Rows	Description
PLPRLIST	DUMMY	(r)*	List linked census divisions for product pipeline from region G to East Coast
PLPR(r)*	(prd)	(m)(r)	Product pipeline transportation cost
PLLG(r)	LPG	(m)(r)	LPG transportation cost

unfinished.dat

Table	Columns	Rows	Description
UNFOIL	E, G, PD	NPP, HGM, ARB	Volume split and price for unfinished oils
UNFEQT	SLOPE, CONST	XYZ	Terms for unfinished oil equation

G.3.b Other input files

1. **mrmparam** file

In the mrmparam, the user chooses the model that he wants to run; the names for the actproblem, solution, path file, basis, mps file, and packed matrix; the model title; and the location and name of the starting basis and optimal basis. The following table lists the information that is to be supplied in the mrmparam file.

Variable name	Variable length	Variable purpose	Restrictions
MODELN	8	Model to be run	MRM5, MRM3, ERM
ACTPROB	8	Act problem	
SOLNAME	8	Solution name	
PATHNF	7	Name of file where data files paths are stored.	
TITLE	40	Problem title	
INBASISN*	40	Location and name of advanced basis	
OUTBASIS	8	Name of optimal basis	
BASISN	8	Basis name	
MPSOUTN**	8	MPS file name	
PAKCN**	8	Packed matrix file name	.PCK extension

*: If no name or a file does not exist, the program will operate without an advanced basis.
**: if "NULL" or "null" is provided, the program will skip the part of the program that generates the file.

The above variables have to be provided in the order they are listed in the above Table and should start at column 18. In the Appendix A we provide an example of an mrmparam file. The mrmparam file has to be in the subdirectory where the model is executed.

2. **path** file:

In this file the user provides the program with the location and name of the data files. The order in which the names appear is important. See Appendix B for an example of a path file. The path file has to be in the directory from which the model is executed. This file format is that of an OML table.

3. **Advanced basis** file:

In this file the user provided an advanced basis to the model. If the user does not provide one or provides one whose name does not coincide with the basis name provided in the mrmparam, the program will not use it.

G.4 Submission of a Run

In order to run the model, one has to first compile and link the different FORTRAN source files to form an executable. Once the executable is created, the user submits a run by providing an mrmparam and a path file. The execution of the program will solve the problem and create:

- An ACTFILE file
- An MPS file
- A SYSPRINT file (solution)
- An out basis file
- A packed matrix file
- Reports (only for MRM5)
     The following are the files created by a run:

	ERM	MRM5	MRM3
ACTFILE	ACTFILE.act	ACTFILE.act	ACTFILE.act
MPS file	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Solution file	SYSPRINT	SYSPRINT	SYSPRINT
Out basis	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Packed matrix	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Report	None	reports5, fort.75	None

The source files that encompass the program are on /refine/db6/mrm/default/source/. They have been compiled and linked to form an executable, mrm, on /refine/db6/mrm/default/. The object files created by the compilation of the source codes are in /refine/db6/mrm/default/lib/. We used a makefile (/refine/db6/mrm/default/makefile) to form the executable.

In refine/db6/mrm/default/, there is an mrmparam file and 3 path files one for each of the models (pathe for ERM, paths5 for 5-region MRM, and paths3 for 3-region MRM). The path file points to the default data that is stored in /refine/db6/mrm/default/data/.

The /refine/db6/mrm/default/data/ directory consists of 3 subdirectories: an mrm5, an mrm3, and an erm subdirectory. Each of these subdirectory contains the default data for the appropriate model.

Runs

1. In order to run the default (no changes)
   a. Copy the **executable**, the **mrmparam** and the appropriate **path files** to your own directory.
   b. Run the executable.

2. If you want to make changes to a data file
   a. Copy the **executable**, the **mrmparam**, the appropriate **path files**, and the **data file** you want to modify to your own directory
   b. Make changes to the data file.
   c. Modify the path file to specify the path of the modified file.
   d. Run the executable.

3. If you want to make changes to a source file
   a. Copy the **makefile**, the **mrmparam**, the **path files**, and the **source file** you want to modify to your own directory.
   b. Make changes to the source file.
   c. Modify the makefile to specify the path of the new modified source file and the path where the new object file is to be stored.
   d. Run the makefile.
   e. Run the executable.

Appendix G-A: Example of an mrmparam file.

```
MODELN          'MRM5       '
ACTPROB         'OMLMRM5'                                    !8
SOLNAM          'MRM5SOL '                                   !8
PATHNF          'paths5 '                                         !7
TITLE           'MRM5,  MULTIPLE REGIONS REFINERY          ' !48
INBASISN        '/refine/db6/mrm/default/data/mrm5/inbasis5        ' !48
OUTBASISN       'outbasis5'
BASISN          'MRM5      '
MPSOUTN         'mrm5mps '
PACKN           'MRM5.PCK '
```

The above mrmparam file will run the 5-region MRM model; the act problem will be "OMLMRM5", the solution name will be "MRM5SOL", the data files path will be read from the file "paths5"; the title of the model will be "MRM5, MULTIPLE REGIONS REFINERY"; the advanced basis will be read from "inbasis5" at " /refine/db6/mrm/default/data/mrm5/"; the optimal basis will be stored in the file "outbasis5"; both the advanced and optimal basis will be named "MRM5"; the mps file will be stored in "mrm5mps"; and the packed matrix in "MRM5.PCK"

Appendix G-B: Example of a path file

```
NAME          PATHDATA
      DATA    Z:PATHNAME
**                    TEXT(6)
accunit       /refine/db6/mrm/default/data/mrm5/accunit.dat
avoids        /refine/db6/mrm/default/data/mrm5/avoids.dat
cogener       /refine/db6/mrm/default/data/mrm5/cogener.dat
crdimprt      /refine/db6/mrm/default/data/mrm5/crdimprt.dat
demand        /refine/db6/mrm/default/data/mrm5/demand.dat
distblnd      /refine/db6/mrm/default/data/mrm5/distblnd.dat
distress      /refine/db6/mrm/default/data/mrm5/distress.dat
domcrude      /refine/db6/mrm/default/data/mrm5/domcrude.dat
emish         /refine/db6/mrm/default/data/mrm5/emish.dat
ethanol       /refine/db6/mrm/default/data/mrm5/ethanol.dat
fixcols       /refine/db6/mrm/default/data/mrm5/fixcols.dat
fuelmix       /refine/db6/mrm/default/data/mrm5/fuelmix.dat
gasoblnd      /refine/db6/mrm/default/data/mrm5/gasoblnd.dat
main          /refine/db6/mrm/default/data/mrm5/main.dat
ngprod        /refine/db6/test/ngprod.dat
nrfplant      /refine/db6/mrm/default/data/mrm5/nrfplant.dat
prdimprt      /refine/db6/mrm/default/data/mrm5/prdimprt.dat
recipes       /refine/db6/mrm/default/data/mrm5/recipes.dat
refproc       /refine/db6/test/refproc.dat
setrows       /refine/db6/mrm/default/data/mrm5/setrows.dat
splash        /refine/db6/mrm/default/data/mrm5/splash.dat
stream        /refine/db6/mrm/default/data/mrm5/stream.dat
transit       /refine/db6/mrm/default/data/mrm5/transit.dat
utility       /refine/db6/mrm/default/data/mrm5/utility.dat
mchproc       /refine/db6/test/mchproc.dat
limpol        /refine/db6/mrm/default/data/mrm5/limpol.dat
unfinished    /refine/db6/mrm/default/data/mrm5/unfinish.dat
prdexp        /refine/db6/mrm/default/data/mrm5/prdexp.dat
akaexp        /refine/db6/mrm/default/data/mrm5/akaexp.dat
ENDATA
```

In this path file all files, except for the ngprod.dat, refproc.dat and mchproc.dat that are located on /refine/db6/test/, are located in /refine/db6/default/data/mrm5/

Appendix G-C:Makefile

```
FLAGS= -c -g -C -qcharlen=16384 -qmaxmem=-1 -qnoprint \
      -qflttrap=zerodivide -qsave
INC= -I/refine/db6/mrm/default/ -I/default/includes
LIBS= -lwhiz -ldb -lutil -L/usr/lpp/MPS/oml/lib
DIR= /default/objects/
SIR= /refine/db6/mrm/default/source/
LIR= /refine/db6/mrm/default/lib/
OBJS= $(LIR)main.o \
      $(LIR)akaexp.o \
      $(LIR)prdexp.o \
      $(LIR)unfinished.o \
      $(LIR)lplookup.o \
      $(LIR)output.o \
      $(LIR)ermcrude.o \
      $(LIR)ermother.o \
      $(LIR)ermprod.o \
      $(LIR)tabread.o \
      $(LIR)limpol.o \
      $(LIR)mchproc.o \
      $(LIR)crdimprt.o \
      $(LIR)accunit.o \
      $(LIR)refproc.o \
      $(LIR)nrfplant.o \
      $(LIR)stream.o \
      $(LIR)distblnd.o \
      $(LIR)gasoblnd.o \
      $(LIR)domcrude.o \
      $(LIR)demand.o \
      $(LIR)utility.o \
      $(LIR)utilitye.o \
      $(LIR)cogener.o \
      $(LIR)fuelmix.o \
      $(LIR)recipes.o \
      $(LIR)ethanol.o \
      $(LIR)ngprod.o \
      $(LIR)setrows.o \
      $(LIR)fixcols.o \
      $(LIR)transit3.o \
      $(LIR)transit5.o \
      $(LIR)prdimprt.o \
      $(LIR)splash.o \
      $(LIR)distress.o \
      $(LIR)avoids.o \
      $(DIR)omlanal.v1.4.o \
      $(LIR)emish.o

mrm: $(OBJS)
    xlf -o mrm -g -C $(OBJS) $(LIBS) -bloadmap:loadmap

$(LIR)main.o: $(SIR)main.f
    xlf $(FLAGS) -o $(LIR)main.o $(INC) $(SIR)main.f
$(LIR)akaexp.o: $(SIR)akaexp.f
    xlf $(FLAGS) -o $(LIR)akaexp.o $(INC) $(SIR)akaexp.f
```

```
$(LIR)prdexp.o: $(SIR)prdexp.f
     xlf $(FLAGS) -o $(LIR)prdexp.o $(INC) $(SIR)prdexp.f
$(LIR)unfinished.o: $(SIR)unfinished.f
     xlf $(FLAGS) -o $(LIR)unfinished.o $(INC) $(SIR)unfinished.f
$(LIR)lplookup.o: $(SIR)lplookup.f
     xlf $(FLAGS) -o $(LIR)lplookup.o $(INC) $(SIR)lplookup.f
$(LIR)output.o: $(SIR)output.f
     xlf $(FLAGS) -o $(LIR)output.o $(INC) $(SIR)output.f
$(LIR)limpol.o: $(SIR)limpol.f
     xlf $(FLAGS) -o $(LIR)limpol.o $(INC) $(SIR)limpol.f
$(LIR)tabread.o: $(SIR)tabread.f
     xlf $(FLAGS) -o $(LIR)tabread.o $(INC) $(SIR)tabread.f
$(LIR)mchproc.o: $(SIR)mchproc.f
     xlf $(FLAGS) -o $(LIR)mchproc.o $(INC) $(SIR)mchproc.f
$(LIR)ermcrude.o: $(SIR)ermcrude.f
     xlf $(FLAGS) -o $(LIR)ermcrude.o $(INC) $(SIR)ermcrude.f
$(LIR)ermother.o: $(SIR)ermother.f
     xlf $(FLAGS) -o $(LIR)ermother.o $(INC) $(SIR)ermother.f
$(LIR)ermprod.o: $(SIR)ermprod.f
     xlf $(FLAGS) -o $(LIR)ermprod.o $(INC) $(SIR)ermprod.f
$(LIR)crdimprt.o: $(SIR)crdimprt.f
     xlf $(FLAGS) -o $(LIR)crdimprt.o $(INC) $(SIR)crdimprt.f
$(LIR)accunit.o: $(SIR)accunit.f
     xlf $(FLAGS) -o $(LIR)accunit.o $(INC) $(SIR)accunit.f
$(LIR)refproc.o: $(SIR)refproc.f
     xlf $(FLAGS) -o $(LIR)refproc.o $(INC) $(SIR)refproc.f
$(LIR)nrfplant.o: $(SIR)nrfplant.f
     xlf $(FLAGS) -o $(LIR)nrfplant.o $(INC) $(SIR)nrfplant.f
$(LIR)stream.o: $(SIR)stream.f
     xlf $(FLAGS) -o $(LIR)stream.o $(INC) $(SIR)stream.f
$(LIR)distblnd.o: $(SIR)distblnd.f
     xlf $(FLAGS) -o $(LIR)distblnd.o $(INC) $(SIR)distblnd.f
$(LIR)gasoblnd.o: $(SIR)gasoblnd.f
     xlf $(FLAGS) -o $(LIR)gasoblnd.o $(INC) $(SIR)gasoblnd.f
$(LIR)domcrude.o: $(SIR)domcrude.f
     xlf $(FLAGS) -o $(LIR)domcrude.o $(INC) $(SIR)domcrude.f
$(LIR)demand.o: $(SIR)demand.f
     xlf $(FLAGS) -o $(LIR)demand.o $(INC) $(SIR)demand.f
$(LIR)utility.o: $(SIR)utility.f
     xlf $(FLAGS) -o $(LIR)utility.o $(INC) $(SIR)utility.f
$(LIR)utilitye.o: $(SIR)utilitye.f
     xlf $(FLAGS) -o $(LIR)utilitye.o $(INC) $(SIR)utilitye.f
$(LIR)cogener.o: $(SIR)cogener.f
     xlf $(FLAGS) -o $(LIR)cogener.o $(INC) $(SIR)cogener.f
$(LIR)fuelmix.o: $(SIR)fuelmix.f
     xlf $(FLAGS) -o $(LIR)fuelmix.o $(INC) $(SIR)fuelmix.f
$(LIR)recipes.o: $(SIR)recipes.f
     xlf $(FLAGS) -o $(LIR)recipes.o $(INC) $(SIR)recipes.f
$(LIR)ethanol.o: $(SIR)ethanol.f
     xlf $(FLAGS) -o $(LIR)ethanol.o $(INC) $(SIR)ethanol.f
$(LIR)ngprod.o: $(SIR)ngprod.f
     xlf $(FLAGS) -o $(LIR)ngprod.o $(INC) $(SIR)ngprod.f
$(LIR)setrows.o: $(SIR)setrows.f
     xlf $(FLAGS) -o $(LIR)setrows.o $(INC) $(SIR)setrows.f
$(LIR)fixcols.o: $(SIR)fixcols.f
     xlf $(FLAGS) -o $(LIR)fixcols.o $(INC) $(SIR)fixcols.f
$(LIR)transit3.o: $(SIR)transit3.f
     xlf $(FLAGS) -o $(LIR)transit3.o $(INC) $(SIR)transit3.f
$(LIR)transit5.o: $(SIR)transit5.f
     xlf $(FLAGS) -o $(LIR)transit5.o $(INC) $(SIR)transit5.f
```

```
$(LIR)prdimprt.o: $(SIR)prdimprt.f
    xlf $(FLAGS) -o $(LIR)prdimprt.o $(INC) $(SIR)prdimprt.f
$(LIR)splash.o: $(SIR)splash.f
    xlf $(FLAGS) -o $(LIR)splash.o $(INC) $(SIR)splash.f
$(LIR)distress.o: $(SIR)distress.f
    xlf $(FLAGS) -o $(LIR)distress.o $(INC) $(SIR)distress.f
$(LIR)avoids.o: $(SIR)avoids.f
    xlf $(FLAGS) -o $(LIR)avoids.o $(INC) $(SIR)avoids.f
$(LIR)emish.o  : $(SIR)emish.f
    xlf $(FLAGS) -o $(LIR)emish.o $(INC) $(SIR)emish.f
```

Appendix G-D: Common Blocks

File: ipmmtest

C $Header: /default/includes/RCS/ipmmtest,v 1.6.1.11 1995/07/17 19:59:11 db6 Exp $
```
   COMMON /IPMMREAL/MAX, MIN, VALUE, INFINITY,
   +      WOP,
   +      REALURYR, YRDOLLAR, ENV, LOC, OVCOST
   REAL*8     MAX(1000)
   REAL*8     MIN(1000)
   REAL*8     VALUE(1000)
   REAL*8     INFINITY
   REAL*8     WOP(26)
   REAL*8     REALURYR
   REAL*8     YRDOLLAR
   REAL*8     ENV(5)
   REAL*8     LOC(5)
   REAL*8     OVCOST(5)
   COMMON /IPMMINT/COUNT, DUMMY,
   +      I, IRET, IROWS, J, JCOLS, K, KROWS, NUMREG,EXPREGSS,
   +      USERYEAR, DMDREG, NUMYRS, DBPROBG, COMTAB1, COMTAB2
   INTEGER*4   COUNT
   INTEGER*4   DUMMY
   INTEGER*4   I
   INTEGER*4   IRET
   INTEGER*4   IROWS
   INTEGER*4   J
   INTEGER*4   JCOLS
   INTEGER*4   K
   INTEGER*4   KROWS
   INTEGER*4   NUMREG
   INTEGER*4   EXPREGSS
   INTEGER*4   USERYEAR
   INTEGER*4   DMDREG
   INTEGER*4   NUMYRS
   INTEGER*4   DBPROBG(22)
   INTEGER*4   COMTAB1(13)
   INTEGER*4   COMTAB2(13)
   COMMON /IPMMCHAR/HEAD, STUB, PROCESS, BND, CNAME,
   +   DECKNAME, LRNAME, OBJ, RHS, RNAME, RCHAR5, REGION,
   +   EXPREG, DEMNDREG, DEMNDPAD, PATH, FRCRD, EXPRD
   CHARACTER*8  HEAD(1000)
   CHARACTER*8  STUB(1000)
   CHARACTER*8  PROCESS(1000)
   CHARACTER*8  BND
   CHARACTER*8  CNAME
   CHARACTER*8  DECKNAME
   CHARACTER*8  LRNAME
   CHARACTER*8  OBJ
   CHARACTER*8  RHS
   CHARACTER*8  RNAME
   CHARACTER*5  RCHAR5
   CHARACTER*1  REGION(5)
   CHARACTER*2  EXPREG(5)
   CHARACTER*1  DEMNDREG(9)
   CHARACTER*1  DEMNDPAD(9)
```

```
     CHARACTER*48 PATH(40)
     CHARACTER*8 FRCRD(5)
     CHARACTER*8 EXPRD(11)
```

File: lpout

Common block used for report writing

```
C  LPOUT COMMON BLOCK FOR USE IN OML MATRIX SOLUTION
                            !
     REAL        PRDPRC(9,18)
     REAL        BASECAP(5,27)
     REAL        BASEUTL(5,27)
     REAL        INVCAP(5,27)
     REAL        INVUTL(5,27)
     REAL        TOTCAP(5,27)
     REAL        TOTUTL(5,27)
     REAL        TOTSUP(6)
     REAL        PUTL(5,27)
     REAL        RFCRDCR(6)
     REAL        RFCRDAKA(6)
     REAL        RFCRDL48(6)
     REAL        RFQICRD(6)
     REAL        RFIMCR(6)
     REAL        RFQISPR(6)
     REAL        RFIMTP(6)
     REAL        RFQEXCRD(6)
     REAL        RFPQNGL(6)
     REAL        RFQNGLRF(6)
     REAL        NGLRF(6)
     REAL        NGLMK(6)
     REAL        RFQPRCG(6)
     REAL        RFPQIPRDT(6)
     REAL        RFPQUFC(6)
     REAL        RFQEXPRDT(6)
     REAL        RFQPRDDM(11)
     REAL        QCDUPD(6)
     REAL        RFQDINPOT(6)
     REAL        RFETHD(6)
     REAL        RFMTBI(6)
     REAL        RFMETI(6)
     REAL        RFMETD(6)
     REAL        RFMETCHM(6)
     REAL        RFMETM85(6)
     REAL        RFMETETH(6)
     REAL        RFETHE85(6)
     REAL        RFETHETB(6)
     REAL        RFETHMGS(6)
     REAL        RFCRDOTH(6)
     REAL        OTHOXY(6)
     REAL        QPRDIMD(11,23)
     REAL        QPRDEXD(6,23)
     COMMON/LPTAB/PRDPRC,BASECAP,BASEUTL,INVCAP,INVUTL,TOTCAP,
    +TOTUTL,PUTL,RFCRDDCR,RFCrtAKA,RFCrtL48,RFQICRD,RFIMCR,
    +RFQEXCRD,RFPQNGL,RFQNGLRF,NGLRF,NGLMK,RFQPRCG,RFPQIPRDT,
    +RFPQUFC,RFQEXPRDT,RFQPRDDM,QCDUPD,RFQDINPOT,RFETHD,RFMTBI,
    +RFMETI,RFMETD,RFMETCHM,RFMETM85,RFMETETH,RFETHE85,TOTSUP,
    +RFQISPR,RFIMTP,RFETHETB,RFETHMGS,OTHOXY,QPRDIMD,QPRDEXD,
    +RFCRDOTH
```

File: DFINC2

Common block used for OML database functions

```
C  $Header: /default/includes/RCS/dfinc2,v 1.1 1995/03/14 16:22:27 dln Exp $
C
C    DATABASE.FH    FORTRAN FUNCTION DECLARATIONS
C
C$INCLUDE DWCPRAG.FH
C
      INTEGER DFINIT
      INTEGER DFOPEN
      INTEGER DFEND
      INTEGER DFCLOSE
      INTEGER DFDEL
      INTEGER DFLIST
C
      INTEGER DFPINIT
      INTEGER DFPDEL
      INTEGER DFPCPY
      INTEGER DFPLIST
      INTEGER DFPTDEL
      INTEGER DFPTCPY
      INTEGER DFPMDEL
      INTEGER DFPMCPY
      INTEGER DFPSDEL
      INTEGER DFPSCPY
      INTEGER DFPRTBI
C
      INTEGER DFTINIT
      INTEGER DFTNEW
      INTEGER DFTDIM
      INTEGER DFTDEL
      INTEGER DFTCPY
      INTEGER DFTSNDX
      INTEGER DFTHNDX
      INTEGER DFTNDX
      INTEGER DFTGET
      INTEGER DFTPUT
      INTEGER DFTSADD
      INTEGER DFTHADD
      INTEGER DFTSDEL
      INTEGER DFTHDEL
      INTEGER DFTDISP
C
      INTEGER DFMINIT
      INTEGER DFMEND
      INTEGER DFMSTAT
      INTEGER DFMCRTP
      INTEGER DFMCRSC
      INTEGER DFMCCSC
      INTEGER DFMCVAL
      INTEGER DFMMVAL
      INTEGER DFMCRHS
      INTEGER DFMCRNG
      INTEGER DFMCBND
      INTEGER DFMRRTY
      INTEGER DFMRRSC
      INTEGER DFMRCSC
```

```
      INTEGER DFMRVAL
      INTEGER DFMRRHS
      INTEGER DFMRRNG
      INTEGER DFMRBND
      INTEGER DFMIROW
      INTEGER DFMICOL
      INTEGER DFMIRHS
      INTEGER DFMIRNG
      INTEGER DFMIBND
      INTEGER DFMNROW
      INTEGER DFMNCOL
      INTEGER DFMNRHS
      INTEGER DFMNRNG
      INTEGER DFMNBND
      INTEGER DFMLROW
      INTEGER DFMLCOL
      INTEGER DFMLRHS
      INTEGER DFMLRNG
      INTEGER DFMLBND
      INTEGER DFMLVAL
      INTEGER DFMTAB
C
      INTEGER DFSINIT
      INTEGER DFSROW
      INTEGER DFSCOL
C
      INTEGER DFNCMP
C
```

File: WFINC2

Common block used for the WHIZ optimizer

```
C  $Header: /default/includes/RCS/wfinc2,v 1.1 1995/03/14 16:22:45 dln Exp $
C
C      WHIZ.FH
C
C THIS FILE DEFINES A COMMON AREA NAMED WCR AND SUPPLIES THE TYPES FOR
C ALL OF THE VARIABLES IN THE CR USED BY OML OPTIMIZATION.
C IT ALSO SUPPLIES DECLARATIONS FOR THE INTEGER WF... FUNCTIONS.
C
C$INCLUDE WWCPRAG.FH
C     USE _WCR FOR WATCOM
C      COMMON  /_WCR/
C     USE WCR OTHERWISE (E.G., 370)
      COMMON  /WCR/
     *  XNAME, XCORE, XCORELEN,
     *  XACTCASE, XACTFILE, XACTPROB, XBOUND, XCHOBJ, XCHRHS, XCMASK,
     *  XDATA, XINSERT, XLOADB, XMINMAX, XOBJ., XPUNCH, XRANGE, XRHS,
     *  XRMASK, XRNGFILE, XRNGPRNT, XSAVEB, XSOLFILE, XSOLPRNT,
     *  XSOLSTAT, XEPS, XFUNCT, XINTGOAL, XMAXVAR, XPARAM, XPENCOST,
     *  XPHI, XRSTOP, XSIF, XSSCALE, XTHETA, XTOLCHK,
     *  XTOLCHZR, XTOLCKRW, XTOLCLRT, XTOLDJ, XTOLERR,
     *  XTOLFSTM, XTOLINV, XTOLLMAX, XTOLPERT, XTOLPIV, XTOLREL,
     *  XTOLRMAX, XTOLRWRT, XTOLUREL, XTOLV, XTOLZE, XZERO,
     *  XCHECKSW, XCLOCKSW, XCOMPERR, XCOMPSW, XCRASHSW,
     *  XCYCLESW, XDEGEND, XDEGMAX, XDEMAND, XDETAIL,
     *  XDOATTN, XDODELTM, XDOFEAS, XDOFREQ1, XDONFS, XDOUNB,
     *  XDUAL, XEQUIL, XFEAS, XFREQINV, XFREQLOG, XFREQSAV,
```

```
     *  XFREQSUM, XINVERT, XITERNO, XJ, XLUDENSE,
     *  XLUFILL, XLUINV, XM, XMAJERR,
     *  XMAXITER, XMAXPASS, XMAXTIME, XMINERR, XNEGDJ,
     *  XNIF, XNOWT, XRUNMODE, XRYANOSB, XSCALESW, XSCRNSW,
     *  XSLPNZ, XTIMESAV, XTRACE, XTRAN, XUNBDNDX, XUSEFREE
C
     CHARACTER*8 XNAME
     INTEGER     XCORE
     INTEGER     XCORELEN
C
     CHARACTER*8 XACTCASE
     CHARACTER*8 XACTFILE
     CHARACTER*8 XACTPROB
     CHARACTER*8 XBOUND
     CHARACTER*8 XCHOBJ
     CHARACTER*8 XCHRHS
     CHARACTER*8 XCMASK
     CHARACTER*8 XDATA
     CHARACTER*8 XINSERT
     CHARACTER*8 XLOADB
     CHARACTER*8 XMINMAX
     CHARACTER*8 XOBJ
     CHARACTER*8 XPUNCH
     CHARACTER*8 XRANGE
     CHARACTER*8 XRHS
     CHARACTER*8 XRMASK
     CHARACTER*8 XRNGFILE
     CHARACTER*8 XRNGPRNT
     CHARACTER*8 XSAVEB
     CHARACTER*8 XSOLFILE
     CHARACTER*8 XSOLPRNT
     CHARACTER*8 XSOLSTAT
     REAL*8      XEPS
     REAL*8      XFUNCT
     REAL*8      XINTGOAL
     REAL*8      XMAXVAR
     REAL*8      XPARAM
     REAL*8      XPENCOST
     REAL*8      XPHI
     REAL*8      XRSTOP
     REAL*8      XSIF
     REAL*8      XSSCALE
     REAL*8      XTHETA
     REAL*8      XTOLCHK
     REAL*8      XTOLCHZR
     REAL*8      XTOLCKRW
     REAL*8      XTOLCLRT
     REAL*8      XTOLDJ
     REAL*8      XTOLERR
     REAL*8      XTOLFSTM
     REAL*8      XTOLINV
     REAL*8      XTOLLMAX
     REAL*8      XTOLPERT
     REAL*8      XTOLPIV
     REAL*8      XTOLREL
     REAL*8      XTOLRMAX
     REAL*8      XTOLRWRT
     REAL*8      XTOLUREL
     REAL*8      XTOLV
     REAL*8      XTOLZE
```

```
      REAL*8    XZERO
      INTEGER   XCHECKSW
      INTEGER   XCLOCKSW
      INTEGER   XCOMPERR
      INTEGER   XCOMPSW
      INTEGER   XCRASHSW
      INTEGER   XCYCLESW
      INTEGER   XDEGEND
      INTEGER   XDEGMAX
      INTEGER   XDEMAND
      INTEGER   XDETAIL
      INTEGER   XDOATTN
      INTEGER   XDODELTM
      INTEGER   XDOFEAS
      INTEGER   XDOFREQ1
      INTEGER   XDONFS
      INTEGER   XDOUNB
      INTEGER   XDUAL
      INTEGER   XEQUIL
      INTEGER   XFEAS
      INTEGER   XFREQINV
      INTEGER   XFREQLOG
      INTEGER   XFREQSAV
      INTEGER   XFREQSUM
      INTEGER   XINVERT
      INTEGER   XITERNO
      INTEGER   XJ
      INTEGER   XLUDENSE
      INTEGER   XLUFILL
      INTEGER   XLUINV
      INTEGER   XM
      INTEGER   XMAJERR
      INTEGER   XMAXITER
      INTEGER   XMAXPASS
      INTEGER   XMAXTIME
      INTEGER   XMINERR
      INTEGER   XNEGDJ
      INTEGER   XNIF
      INTEGER   XNOWT
      INTEGER   XRUNMODE
      INTEGER   XRYANOSB
      INTEGER   XSCALESW
      INTEGER   XSCRNSW
      INTEGER   XSLPNZ
      INTEGER   XTIMESAV
      INTEGER   XTRACE
      INTEGER   XTRAN
      INTEGER   XUNBDNDX
      INTEGER   XUSEFREE
C
      INTEGER   WFINIT
      INTEGER   WFDEF
      INTEGER   WFSET
      INTEGER   WFMPSIN
      INTEGER   WFMPSOU
      INTEGER   WFLOAD
      INTEGER   WFOPT
      INTEGER   WFEND
C
      INTEGER   WFCVAL
```

```
      INTEGER    WFCRHS
      INTEGER    WFCRNG
      INTEGER    WFCBND
C
      INTEGER    WFRVAL
      INTEGER    WFRRHS
      INTEGER    WFRRNG
      INTEGER    WFRBND
C
      INTEGER    WFRNAME
      INTEGER    WFCNAME
      INTEGER    WFRMASK
      INTEGER    WFCMASK
      INTEGER    WFSROW
      INTEGER    WFSCOL
      INTEGER    WFRROW
      INTEGER    WFRCOL
C
      INTEGER    WFRLVAL
      INTEGER    WFRLIST
      INTEGER    WFCLIST
      INTEGER    WFSPRT
      INTEGER    WFSFILE
      INTEGER    WFRCORD
      INTEGER    WFRPRT
      INTEGER    WFRFILE
C
      INTEGER    WFSAVEB
      INTEGER    WFLOADB
      INTEGER    WFPUNCH
      INTEGER    WFINSRT
C
      INTEGER    WFMGDMP
      INTEGER    WFMGLOD
      INTEGER    WFCRGET
      INTEGER    WFCRPUT
C
```

Appendix G-E: Refinery Processes

Refinery Process	Abbreviation
Atmospheric crude distillation	ACU
Alkylation	ALK
Alkynax	ALM*
Aromatic recovery	ARP
Polymerization	CPL
Cyclar	CYC
Butane isomerization	C4I
Butane splitter	C4S**
Akylation feed butene isomerizer	C4T*
Butane isomerization	C4X***
C2E to C4E dimerization	C24*
Distillate desulfurizer	DDS
Mid-distillate deep hydrotreater	DHT
Dimersol	DIM
Gas oil dewaxer	DEW
Di-isopropyl ether	DIP*
Etherol	ETH
Cryogenic C2 fractionation	ETS*
Etherrol unit	ETX***
FCC feed hydrofiner	FDS
Fluid cat cracker	FCC
Mid-distillate furfural treating	FEX
Fuel plant	FUM**
Fuel plant	FUX***
Gas oil hydrocraker	HCR
Residum hydrocracker	HCV
Naphta hydrocracker	HCN
High density jet fuel hydrotreating	HDN

Refinery Process	Abbreviation
Hydogen/fuel gas reformer hydrogen	HLO**
H2-stream reformer	H2P
H2-partial oxidizer	H2X
Hydrogeneration normal pentenes/hexenes	H56*
High density jet fuel prefactionation	JFP
Recut for JTA	JPS**
Delayed-coker	KRD
Fluid/flexi-coker	KRF
Power generation	KWG**
Lub and wax	LUB
Naphta hydrotreater	NDS
C2-C5 dehydrogenation	OLE*
C2-C5 dehydrogenation	OLX***
Pentane/hexane isomerization	PHI
Residuum desulfurizer	RDS
HP semi-regenerative reformer	RFH
LP cyclic reformer	RFL
LP continuous reformer	RFC
Solvent deasphalting	SDA
Sulfur, short tons/day	SUL
Naphta splitter	SPL
Steam generation, lbs/hr	STG**
Steam generation, lbs/hr	STX***
Thermal cracker C2-C4 feed	TCG*
Thermal craker naphta feed	TCN*
Thermal craker gas oil feed	TCV*
Total recycle isomerization	TRI*
Vaccum distillation	VCU
Visbreaker/thermal craker	VBR

* : Processes involved in reformulated gasoline manufacturing
**: Utilities and pseudo-units
***: Processes represented in OXY-Refineries

APPENDIX H

Historical Data Processing

APPENDIX H-1. Historical Data Processing

Data Dump Programs:

1) CN6007.PRJ.NEMS.MARKUP.PRICE.HISTFILE: reads markup files and creates &PRJ.PRICE.HIST.SASDB:PBTU9094.

2) CN6007.PRJ.NEMS.READ.SEDS: reads SEDS sectoral consumption data and the total consumption number from the most recent PSA and puts the data into CN6007.PRJ.HISTORY.SASDB:SEDS.

3) Manually update CN6007.PRJ.FUELUSED from fuel consumption data in Table 47. of the PSA.

4) (Manually update CN6007.PRJ.ELCG.FLATFILE.DATA(NGPFUEL) (Bruce).

5) Manually update CN6007.PRJ.ELCG.FLATFILE.DATA(MSPRICE) using estimates from PFPRICES.WK4.

6) CN6007.PRJ.ELCG.FLATFILE.DATA:MBL,CRDWHPR,CRPRODAY (bbl/day) updated by Ted.

7) CN6007.PRJ.COGEN.F867.SASDB:D0629941 updated by cogen program.

Data Processing Files:

1) CN6007.PRJ.PMM.PROCESS.PSADATA - loads &prj.ogirs.data(a compacted version of psa.data94,which is a dump from OGIRS) and saves into &prj.history.sas.psadata.psdata. This part should be commented out after running for the first time each year. The following sections read, transpose, and put required data into SASDB. See attachment for list of missing OGIRS data.

  Input files: CN6007.PRJ.HISTORY.SAS.PSADATA:PSDATA
  Output file: CN6007.PRJ.PMM.HISTORY.DATA.SASDB:PSDATA

2) CN6007.PRJ.PROCESS.NGPFUEL - reads natural gas plant fuel data, transposes and puts in SASDB

  Input files: CN6007.PRJ.ELCG.FLATFILE.DATA(NGPFUEL) manually updated by Bruce

  Output file: CN6007.PRJ.FUELUSE.HIST.SASDB:NGPFUEL includes PADD Year Volume

3) CN6007.PRJ.PMM.PROCESS.RFFUEL - reads refinery fuel consumption data, puts in SASDB

  Input files: CN6007.PRJ.FUELUSED manually updated

and CN6007.PRJ.MISCELL.SASDB:BTU1

Output file: CN6007.PRJ.FUELUSE.HIST.SASDB:RFFUELCD   in BTU's

4) CN6007.PRJ.PMM.PROCESS.CRUDE1 - reads wellhead prices by OGSM region

CN6007.PRJ.PMM.PROCESS.CRUDE2 - reads conventional and conventional/EOR production by OGSM region

Input files: CN6007.PRJ.ELCG.FLATFILE.DATA(CRDPRODAY)
(CRDWHPR)
Output file: CN6007.PRJ.PRODTN.HIST.SASDB:CRDOGSM
CN6007.PRJ.PRICES.HIST.SASDB:CRDPRIC

5) CN6007.PRJ.PMM.PROCESS.COGEN - reads cogen, capacity, and fuel use by Census Division. Transposes for regional headings and puts in SASDB

Input files: CN6007.PRJ.COGEN.F867.SASDB.D0629941

Output file: CN6007.PRJ.PMM.HISTORY.DATA.SASDB:COGEN

6) CN6007.PRJ.PMM.PROCESS.PRCDATA - reads prices and petrochemical prices, transposes for regional headings and puts in SASDB. Data set "test1" must be updated for current year for CD4 and CD8.

Input files: CN6007.PRJ.PRICES.HIST.SASDB:PBTU9094
CN6007.PRJ.ELCG.FLATFILE.DATA(MSPRICE)

Output file: CN6007.PRJ.PRICES.HIST.SASDB:PRDPRIC

7) CN6007.PRJ.PMM.PROCESS.DEMAND - reads sectoral demand from SEDS, estimates most recent year's sectoral demand by using current PSA total demand times the sector ratios. Type in PSA total product supplied number from Table 3.

Input files: CN6007.PRJ.HISTORY.SASDB:SEDS

Output File: CN6007.PRJ.PRODTN.HIST.SASDB:DEMAND

8) CN6007.PRJ.PMM.PROCESS.MISCELL - includes data for miscellaneous inputs, to be manually updated each year.

Output file: CN6007.PRJ.PMM.MISCELL.SASDB:MISCELL

Creating PMM Flatfile:

9) CN6007.PRJ.PMM.MAKE.HIST.FLATFILE - reads SASDBs and puts them in flatfile

Input files: CN6007.PRJ.PMM.HISTORY.DATA.SASDB:PSDATA
                CN6007.PRJ.FUELUSE.HIST.SASDB:NGPFUEL
                CN6007.PRJ.FUELUSE.HIST.SASDB:RFFUELCD
                CN6007.PRJ.PRODTN.HIST.SASDB:CRDOGSM
                CN6007.PRJ.PRODTN.HIST.SASDB:DEMAND
                CN6007.PRJ.PRICES.HIST.SASDB:CRDPRIC
                CN6007.PRJ.PMM.HISTORY.DATA.SASDB:COGEN
                CN6007.PRJ.PRICES.HIST.SASDB:PRDPRIC
                CN6007.PRJ.PMM.MISCELL.SASDB:MISCELL
Output file: CN6007.PRJ.RFHIST6
**   lrecl=100

Petrochemical Feedstocks

from SEPER APPENDIX

p naptha= 1.23* WOP
other = 1.607 * WOP

use 92 prices and volumes for weighted average pf price.

pfprices.wk4

Items Missing form OGIRS dump 6/30/95:

mpule by PADD are 0 in 19990 and missing in 1994
mcrexp3 observation missing in 1990
mcrexp4 observation is missing 1993 and 1994
mupwxus missing in 1991
mupwxus incorrect in 1992
mupsgus missing in 1992
mrpsgus missing in 1992
molex by PADD are missing in 1990
molexp4 missing in 1993

Appendix H-2. Processing Data for STEO Years

The *Short-Term Energy Outlook* (STEO) published by the Energy Information Administration provides quarterly projections two years into the future. Since the STEO is EIA's official forecast during this period, the Petroleum Market Model was set up to produce numbers that very closely match the STEO when a switch in the PMM is turned on. The information in this section describes the programs that are used to generate this data for the PMM. The data is then added to the input file that contains the history data described in Appendix H-1.

The files below are on mainframe account 6007, BBM, unless otherwise stated. Input data are read from and output data are written to
      &BBM6007.NEMSSTEO.COMP.SASDB
unless otherwise indicated. Files 1 and 2 only need to be updated once a year when new historical price and supply data are available. The other files can be updated with data from any STEO projection. Note that some files produce output for other files, so the order of execution is important. For example, program 5 inputs data from programs 2 and 4.

1. NEMS.CREATE.PRBTU.HISTMARG

This file calculates differentials that are used to estimated regional prices from U.S. average STEO prices. Differentials are also calculated from crude oil prices for those fuels that STEO does not price.

2. NEMSSTEO.HISTFACT

This file calculates factors from petroleum supply data which are used to apportion U.S. data to the PADD level.
      Output: SUPPFACT

3. NEMSSTEO.PRICE.DATA

STEO prices are typed in to this program and the differentials from file 1 are input, then regional PMM product prices are estimated.

      Input files: CDSPRD88
                         RCSPRD88
                         RFSPRD88
      Output files: PRICES
                         RRAC87

4. NEMSSTEO.READ.STEODB.OTHINP

This program reads in data from the STEO database and outputs data needed for later processing.

Input files: ALLBBB (from &PRJ6489.STIFSIII.monyy.SASDATA)

Output files: CAPUTIL (STEO capacity and utilization rates)
                  OTHIMP (imports of unfinished oils, ethers, and gasoline blending components)
                  OTHINPUT (other input data)

5. NEMSSTEO.SUPPLY.PUBDATA

In this file, supply data are typed in from the STEO publication.

Input files: SUPPFACT
                  OTHIMP
                  CAPUTIL
Output files: USSUP
                  CRUDEINP
                  CRDPROD
                  PADSUP

6. NEMSSTEO.READ.STEODB.PRODSUP

This program uses data from the STEO database and file 5, and develops product supplied data for the PMM.

Input files: ALLBBB (from &PRJ6489.STIFSIII.monyy.SASDATA)
                  USSUP

Output files: PRODSUP
                  PRODSECT

7. NEMSSTEO.READ.STEODB.REFPROD

This program uses data from the STEO database and file 2, and develops refinery production numbers.

Input files: ALLBBB (from &PRJ6489.STIFSIII.monyy.SASDATA)
                  SUPPFACT
Output: REFPROD

8. NEMSSTEO.RFFUEL

This program estimates refinery fuel consumption based on historical values and STEO crude input estimates.

Input: CRUDEINP
                  RFFUELCD (from &PRJ6007.FUELUSE.HIST.SASDB)
Output: FUELUSE

9. NEMSSTEO.WELLPR

This file estimates regional crude wellhead prices based on wellhead price equations in the PMM provided by the Oil and Gas Supply Team and STEO's world oil price projections.

       Input: RRAC87
       Output: WELLREG

10. NEMSSTEO.ALLDATA

This program reads in all the relevant data created by the previous programs, drops the last historical year,[1] and writes out the data needed to input into the PMM history file.

Input:	Output:
PADSUP	SPADSUP
REFPRD	SREFPRD
USSUP	SUSSUP
OTHINPUT	SOTHINP
PRODSUP	SPRODSUP
PRODSECT	SPRDSECT
FUELUSE	SFUELUSE
PRICES	SPRICES
WELLREG	SWELLREG
CRDPROD	SCRDPROD

The output data from file 10 are read in the program
        &PRJ6007.PMM.MAKE.HIST.FLATFILE
which produces a file containing PMM output data for the history and STEO years.

---

[1]The last historical year was included to provide a check that the estimates for the forecast years were reasonable.