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Part 1 of 2

EIA Model Documentation

PETROLEUM MARKET MODEL OF THE NATIONAL ENERGY MODELING SYSTEM

Part 1

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Oil and Gas Analysis Branch
Energy Supply and Conversion Division
Office of Integrated Analysis and Forecasting
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DISCLAIMER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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). This volume documents the version of the PMM used for the *Annual Energy Outlook 1998* (AEO98) and thus supersedes all previous versions of the documentation.

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 for AEO98. 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; Appendix H, Historical Data Processing; and Appendix I, Biofuels Supply Submodule.

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, domestic crude oil production levels, 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.

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

The PMM is comprised of three geographical regions, defined using the five Petroleum Administration for Defense (PAD) Districts. Individual refineries in PADD I are aggregated into one refinery representation for region 1. Region 2 is an aggregate of all refineries operating in PADD's II, III, and IV. PADD V refineries are represented by a single refinery in region 3. 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 2020.

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 Biofuels Supply Submodule(Appendix I). 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.

- Domestic crude oil production levels from the Oil and Gas Supply Model. 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.

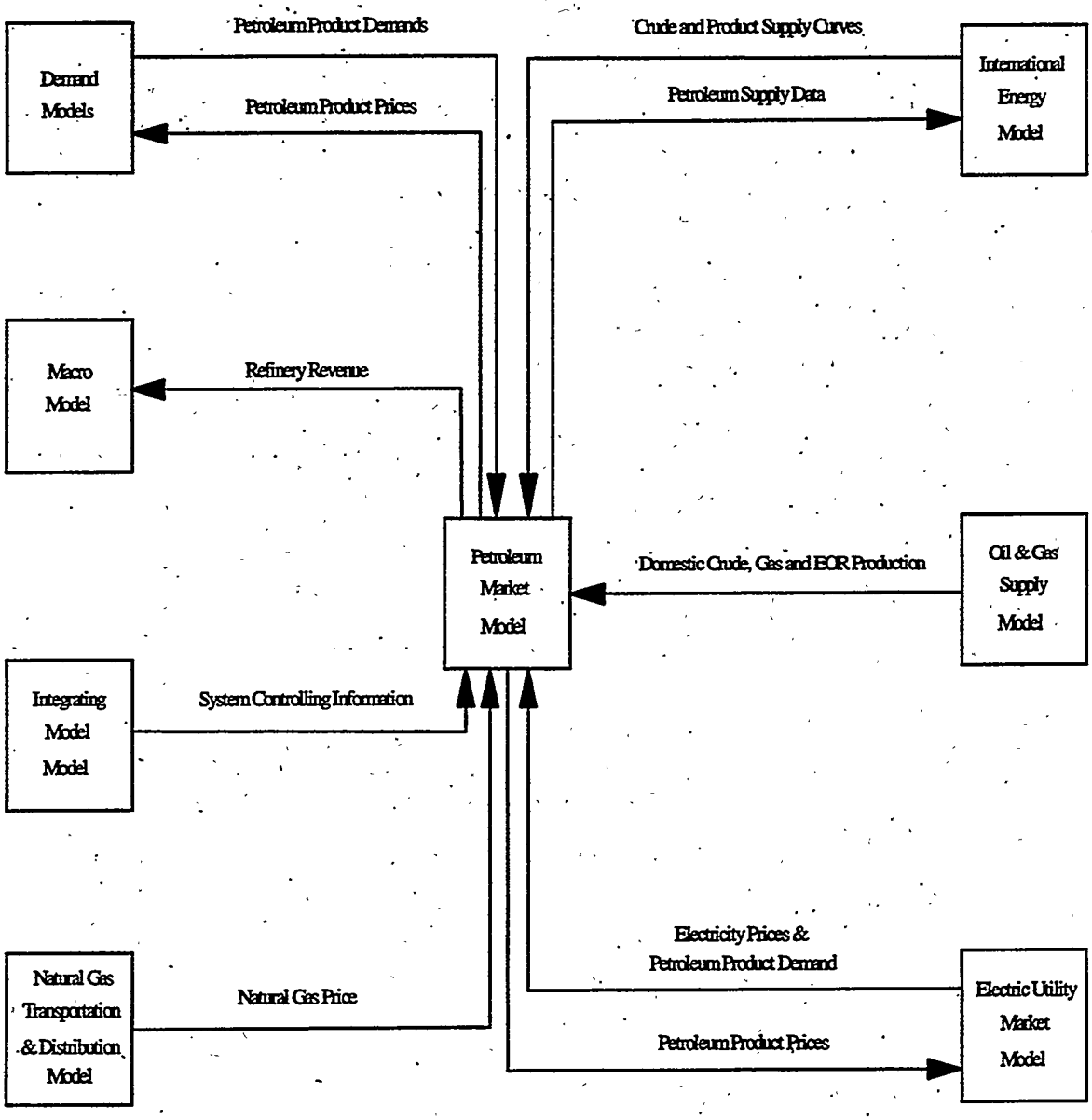
- Fuel consumption from refineries. This information is passed on to the Industrial Model for inclusion in the industrial sector totals. In addition, refinery cogeneration capacity and generation levels are also sent to the Industrial Model.

- 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



3. Model Overview and Rationale

3.1 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 three refining regions. The first region consists of Petroleum Administration for Defense (PAD) District I; the second of PAD's II, III, and IV; and the third of PAD V. Each model region represents an aggregation of the individual refineries in the region. 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 three representations together 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.

The three region linear program formulation is new for AEO98. Previous versions of the PMM utilized a five region linear program, with each region representing a PAD District. In an effort to reduce the size and run time of the PMM, the number of refining regions was reduced from five to three. The regions were formulated to maximize analytical relevance. Region 1 remains unchanged as a representation of PAD District I. PAD District I is maintained as a separate refining region because of its unique product import characteristics. PAD Districts II, III, IV were consolidated to form Region 2, and PAD District V is modeled in Region 3. PAD District V remains a separate refining region because of the stricter blending requirements of California gasolines.

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.

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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).

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 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.

The PMM represents three refining regions. The first region consisting of PAD I; the second of PAD's II, III, and IV; and the third of PAD V. Each refining region 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 and the 1997 Tax Payer Relief 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 Specifications

The PMM models the production and distribution of three different types of gasoline: traditional, oxygenated, and reformulated. 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, olefin content, and the percent evaporated at 200 and 300 degrees Fahrenheit (E200 and E300).

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 an oxygen content of 2.7 percent by weight. Oxygenated gasoline is assumed to have specifications identical to traditional gasoline with the exception of a higher oxygen requirement. Some areas that require oxygenated gasoline will also require reformulated gasoline. For the sake of simplicity, the areas of overlap are assumed to require gasoline meeting the reformulated specifications.

Reformulated gasoline has been required in many areas of the U.S. since January 1995. 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." In 2000 the Complex Model will be tightened to require further emissions reductions. The tighter requirements are reflected by adjustments to specifications such as Rvp, aromatics, sulfur, and olefin content in the model year 2000.

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 all West Coast refiners must meet the California specifications. The specifications for reformulated gasoline in PAD V are the 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, and reformulated gasolines by applying assumptions about the annual market shares for each type. Annual assumptions for each region account for the seasonal and city-by-city nature of the regulations. The market shares are assumed to remain constant at the 1996 level, with minor adjustments reflecting known changes in in oxygenated or reformulated gasoline programs. The Census Division 4 market shares are adjusted to reflect the statewide and year-round requirement for oxygenated gasoline in Minnesota beginning in 1997. The Census Division 8 market shares reflect the 1997 opt-in of Phoenix, Arizona to the Federal reformulated gasoline program.

Although the shares are assumed to remain constant, the PMM structure allows for them to change over time based alternative assumptions about the market penetration of new fuels. This allows for flexibility to analyze the impact of differing market share assumptions and to adjust the assumptions over time based on updated information about announced participation in the oxygenated and reformulated gasoline programs.

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 1996* (online: http://www.eia.doe.gov/oil_gas/fok/1996/fokframe96.html, November 3, 1997). 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. Environmental costs associated with controlling pollution at refineries[2] are reflected as fixed costs. 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

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[2]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).

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 prices. The costs for kerosene are the average difference between end-use prices of kerosene and wholesale distillate prices. End-use prices also include a variable which calibrates model results to historical levels. The calibration variable is specified by product and region.

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 represents three refining regions. The first refining region includes only Petroleum Administration for Defense (PAD) district I, while the second , includes PADs II, II, and IV, and the third includes PAD V. Individual refineries are aggregated into one linear programming representation for each region. In order to interact with other NEMS modules with different regional representations, certain PMM inputs and outputs are converted from a PMM region to a non-PMM 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 from historical data for each region. Expansion of the atmospheric cracking unit is limited to 1.1 million barrels per day in each refining region.

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 1997 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 2000, the PMM looks ahead and determines the optimal capacities given the demands and prices existing in the 2001 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 2001, 25 percent in 2002, and 25 percent in 2003. At the end of 2003, 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 and the 1997 Tax Payer Relief 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. The tax has been in effect since October 1, 1993 for all fuels but jet fuel. Onset of the jet fuel tax was delayed until 1996.

The Tax Payer Relief Act of 1997 reduced excise taxes on liquefied petroleum gases and methanol produced from natural gas. The reductions set taxes on these products equal to the Federal gasoline tax in terms of energy content (in Btu's).

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.[3] Starting in 1995, gasoline sold in 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 1998 reformulated gasoline will be required to meet a performance based definition, "the Complex Model". In 200 the performance measures will become more stringent.

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.

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.[4] 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.

3.4.1 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.

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

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

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 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.

3.4.2 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.[5]

3.4.3 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.[6]

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.

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[5]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).

[6]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).

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).

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,[7] although increasing the range and number of the modes can respond in part to this criticism.

3.4.4 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. In 1997 the PMM was reduced from a five region (PAD) representation to a three region representation. The condensed regionality achieved more rapid execution times while still providing the capability for regional analysis.

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

4. Model Structure

During each NEMS iterative solution, product demand quantities and other variables supplied by the other NEMS demand and supply models are used to update the PMM linear program (LP) matrix. An optimal solution is obtained from the updated LP 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 LP 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 LP matrix of the PMM. Appendix G documents the LP matrix generator source code and data tables.

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. Additionally the REFINE calls the Ethanol subroutine, which provides the PMM with supply curves for ethanol. The Ethanol subroutine is documented in Appendix I.

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 depending on the type of NEMS iteration as follows:

- **(Setup)** If the history switch is on and it is the first year and first iteration, historical values are read from an input file and the PMM LP matrix is loaded into memory to await processing in the PMM base year.

[1]Mathematical Programming System format.

- **(History Year)** 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 system operations. No operations are performed because all historical data were retrieved and variables were updated on the first iteration of the first year.

- **(Iterative NEMS Solution)** 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.

- **(Reporting/Capacity Expansion)** 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.

- **(Prebase Year Capacity Expansion)** 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 1996 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 1997, capacity expansion is done in three year increments. The PMM looks ahead and determines the optimal capacities given the estimated demands and prices expected in the 2000 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 1998, 25 percent in 1999 and 25 percent in 2000. At the end of 2000 the cycle begins anew.

Figure 4.1 PMM Flow Diagram

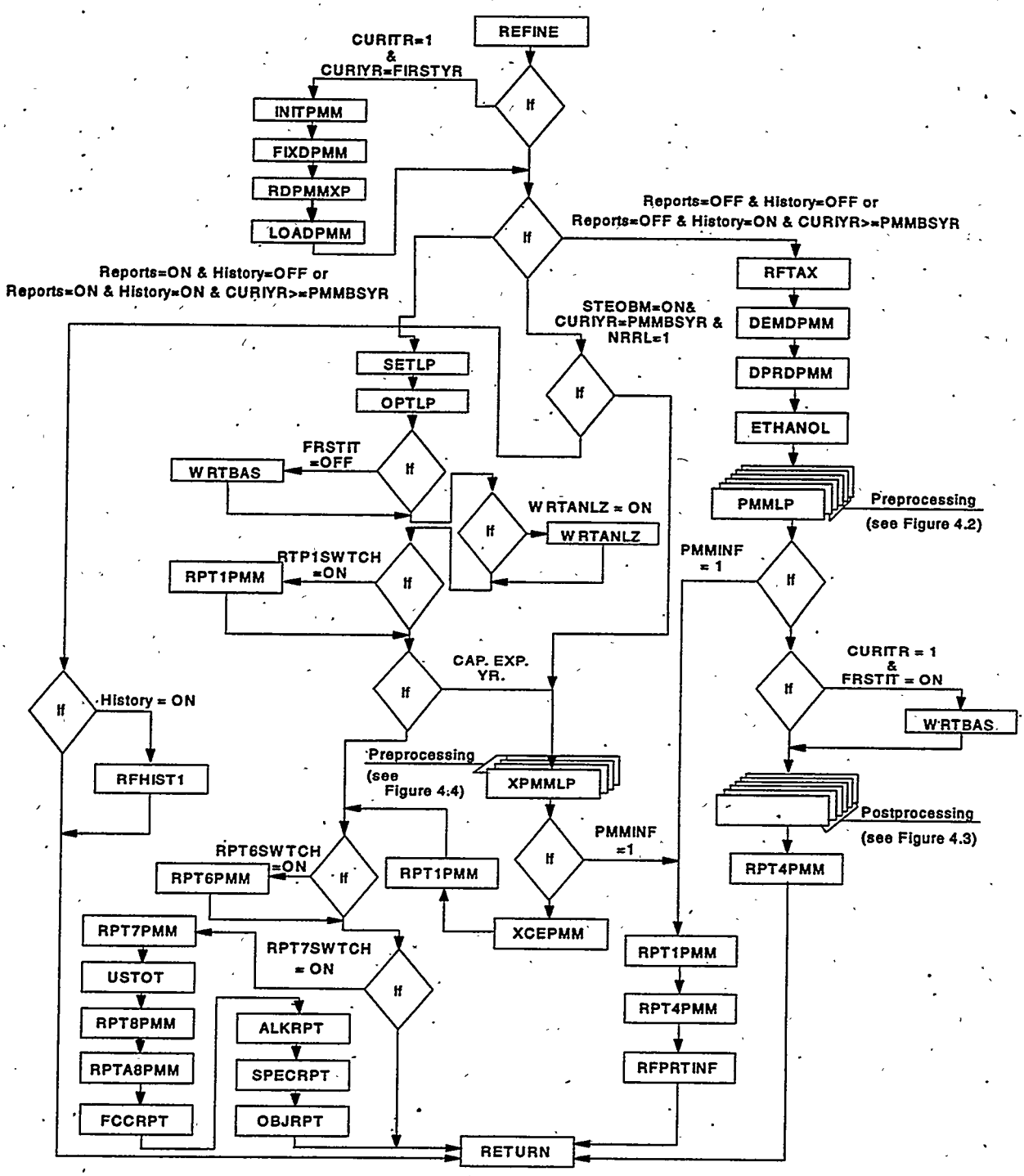


Figure 4.2 Matrix Preprocessing Subroutines

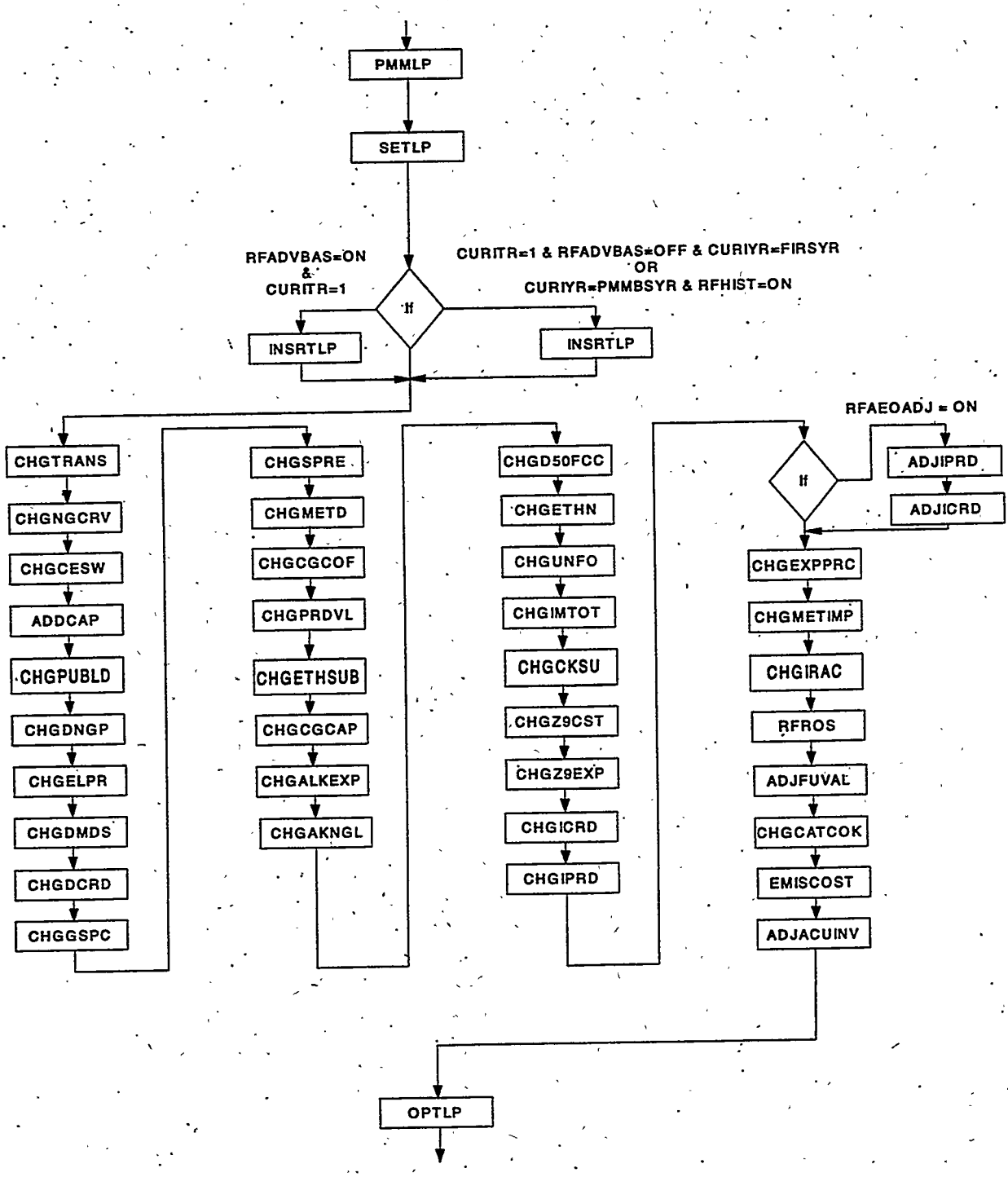


Figure 4.3 Matrix Postprocessing Subroutines

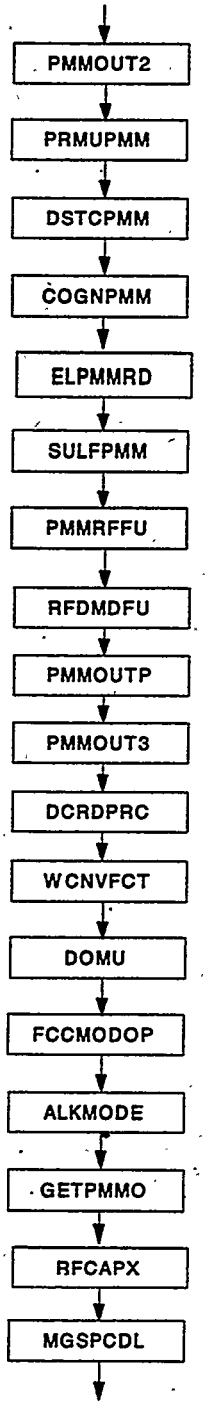
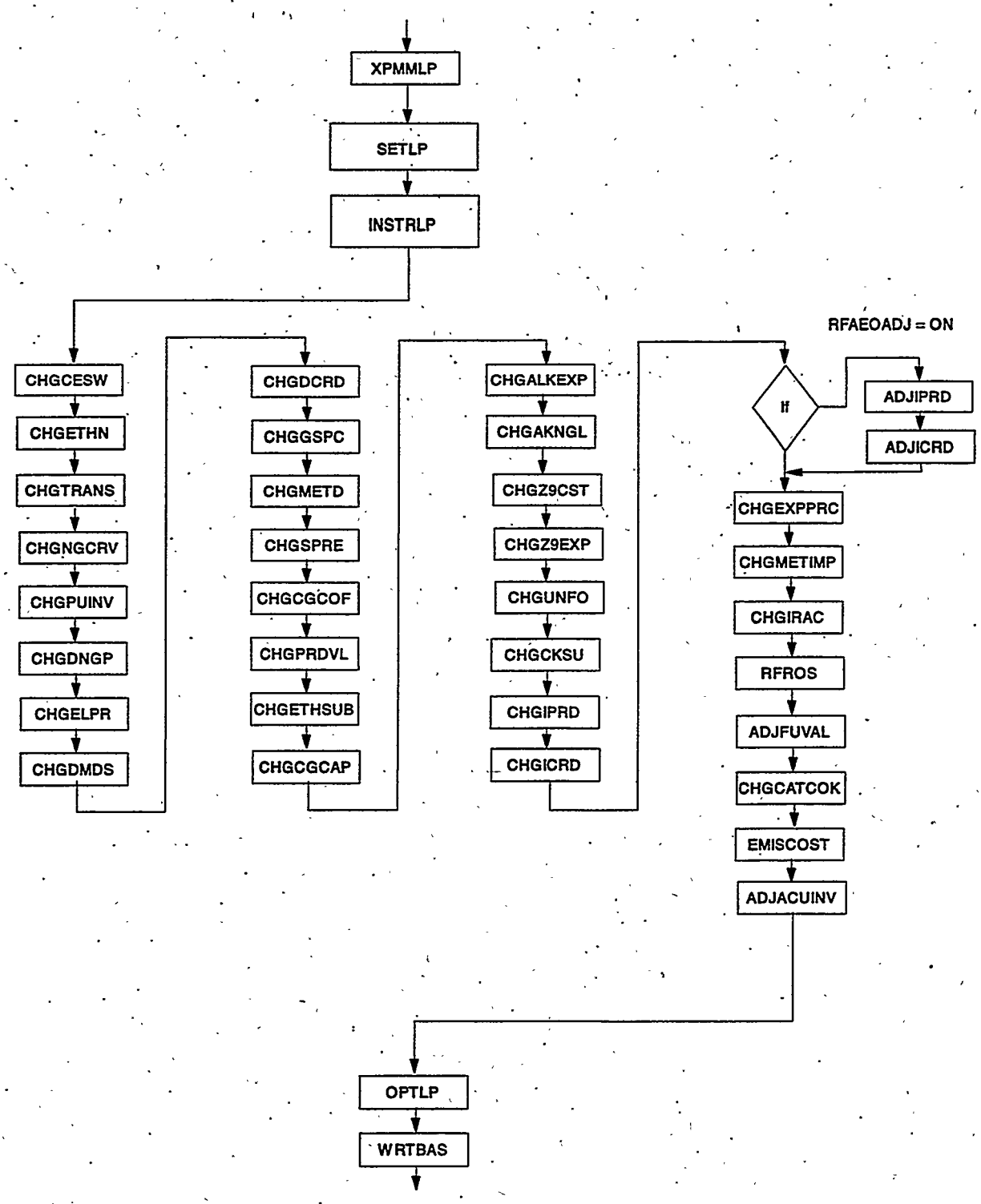


Figure 4.4 Capacity Expansion Subroutines



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: Opens PMM iteration report file and PMM solution print file and initializes certain variables.

Equations:

$PUCUM_{pr,pu,yr} = 0.0$
$PUINV_{pr,pu,yr} = 0.0$
$RFQDINPOT_{pr,yr} = 0.0$
$PRDDMD_{pr,yr,prd} = 0.0$
$CRDOTHOT_{pr,yr} = 0.0$
$CRDUNACC_{pr,yr} = 0.0$
$CRDSTWDR_{pr,yr} = 0.0$
$CRDPRDSUP_{pr,yr} = 0.0$
$PRDSTKWDR_{pr,yr} = 0.0$
$BLDIMP_{pr,yr} = 0.0$
$QEXCRDIN_{pr,yr,pu} = 0.0$
$PUBASE_{pr,yr,pu} = 0.0$
$PUBASEUT_{pr,yr,pu} = 0.0$
$CFRGQ_{yr} = 5.253$ Conversion factor Reformulated Gasoline, MMBtu/Bbl
$CFTGQ_{yr} = 5.253$ Conversion factor Traditional Gasoline, MMBtu/Bbl
$PETTR_{yr,6} = 11.50$ E85 price for history and STEO years
$PETTR_{yr,7} = 11.95$
$PETTR_{yr,8} = 11.96$
$PETTR_{yr,9} = 11.95$

$PMETR_{yr,6} = 9.23$ M85 price for history and STEO years
$PMETR_{yr,7} = 9.23$
$PMETR_{yr,8} = 9.23$
$PMETR_{yr,9} = 9.23$

where:

pr = 1,2,3: PAD District
pu = 1,2,...40: Processing unit identifier index
yr = 1,2,...31: 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 an input file.

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

Equations: None.

Input file: SPRFLRT PMM specific expectations input file.

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

Purpose: This subroutine defines the Optimization Modeling Library (OML) model space for PMM LP matrix. Loads the PMM LP matrix into memory and initializes OML model specific variables.

Equations: None.

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

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

Equations: None.

Data Passed: MODEL, model name, SIZE, model size

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

Purpose: Converts a model from and MPS format file to an OML model format and stores it in the model database using the OML function WFMSPIN.

Equations: None.

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

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

Equations: None.

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

Purpose: RFHIST1 reads in history data from an external file and updates PMM output data for history years 1990 to 1996 and STEO year 1997 and 1998.

Equations: 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 3
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 total transportation alcohol demand, and 15 percent of the total transportation alcohol demand 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 31

(DPRDPMM) Update domestic crude wellhead price and gas plant fuel consumption.

Purpose: Update domestic crude wellhead price and gas plant fuel consumption for the Oil and Gas Supply Model.

Equations: None.

(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:

$$PUINV_{pd,yr+1,pu} = PUEXP_{pd,yr+3,pu} / 2$$
$$PUINV_{pd,yr+2,pu} = PUEXP_{pd,yr+3,pu} / 4$$
$$PUINV_{pd,yr+3,pu} = PUEXP_{pd,yr+3,pu} / 4$$

where;

PUINV = processing unit investment bound, Mbbl/cd
$PUEXP_{pd,yr+3,pu}$ = processing unit expansion as determined in expansion year yr
pu = processing unit index, 1 through 60
pd = PAD District index 1 through 3
yr = NEMS index years 8,11,14,17,20,23,26,29

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. Capcity expansion for the crude unit has been limited to 1.4 MBCD for each PADD in the low macroeconomic and high world oil price cases and 1.1 MBCD for each PADD for all other cases.

Processing unit cumulative builds, PUBLD is:

$PUBLD_{pd,yr,pu} = 0$; when yr = 8
$PUBLD_{pd,yr,pu} = PUBLD_{pd,yr-1,pu} + PUINV_{pd,yr-1,pu}$

where yr > NEMS index year 8
pu = processing unit index, 1 through 60

pd = PAD District index 1 through 3
yr = NEMS index years 8,11,14,17,20,23,26,29

(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.

(CHGTRANS) Updates the transportation costsof crude and product.

Purpose: Update the crude and product transportation cost with the U.S.

Equations: Cost for moving crude and products from the supply region to the demand regions are updated to reflect changes in the world oil price, WOP. A factor called priced delta is calculated as the change between the current year WOP and the previous years WOP. The price delta is used to adjust the transporation cost for domestic crude and product shipments as the fractional change in price.

(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. This methodology effectively recenters the natural gas supply step function during each NEMS iteration.

(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.

Equations: None.

(CHGPUBLD) Updates the bounds on the processing unit investment columns.

Purpose: Sets the upper and lower bounds for the processing units investment colums to zero during initial model startup if the STEO benchmarking switch is off using the CBNDLP subroutine. During the first year the PMM model is run the CHGPUBLD subroutine insures that the model will not build any additional capacity. Capacity additions are handled by the capacity expansion portion of the PMM.

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 each PAD Districts. 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 refinery regions 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 refinery regions.

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 procssing unit.

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

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

where:
COEF = sales to grid coefficient
CNST = Percentage constant, 0.05092, 0.063237, 0.46287 for each refinery region I-III 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 for ethanol blended into motor gasoline. Only the ethanol portion of E85 receives the ethanol subsidy

Equations: The ethanol subsidy declines in real terms from $18.29/Bbl by the the macroeconomic GDP deflator.

(CHGCGCAP) Updates the refinery cogeneration capacities.

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

Equations: No planned editions for AEO97 due to unavailable cogeneration data.

(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 one dollars and thirty five cents. The volumes are set at fifty MBCD for each of the three points on the supply curve. These prices and volumes were set based 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.

(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. The ethanol supply curve volumes were adjusted to reflect nintey percent of current ethanol production on steps one and two and step three and four reflect eighty percent and one hundred sixty percent of current production.

(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:

$$ARB_{yr} = 0.90 * WOP_{yr}$$
$$NPP_{yr} = 1.14 * WOP_{yr}$$
$$HGM_{yr} = 1.02 * WOP_{yr}$$

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 31.

(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.

Equations: For all crudes in each PAD District adjustmensts the costs as follows: The imported crude prices were adjusted to be directly related to the world oil price plus or minus a constant to account for crude quality and plus or minus the price differential between the supply step points on the orginial supply curves. 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 to caliabrate the petrolleum product imports to values indicated in the Petroleum Supply Annual 1996. Adjustments are made to imports volumes and prices as follows:

Imported product	*Price Adjustment*	*Volume Adjustment*	*Region*
LPG	-1.00	5.0	1
TRG	0.00	15.0	1
RFG	0.00	40.0	1
JTA	-2.00	20.0	1
N2H	-2.50	0.0	1
DSL	-2.75	20.0	1
OTH	-3.00	65.0	1
LPG	2.00	0.0	2
TRG	3.00	0.0	2
RFG	2.00	0.0	2
JTA	3.00	0.0	2
N2H	3.00	0.0	2
N6I	15.00	0.0	2
N6B	15.00	0.0	2
MET	2.00	20.0	2
LPG	2.00	0.0	3
TRG	2.00	0.0	3
RFG	2.00	0.0	3
N6I	5.00	0.0	3
N6B	5.00	0.0	3
MTB	4.00	0.0	3

(CHGEXPPRC) Update exported petroleum product prices.

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

Equations: None.

(CHGMETIMP) 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 $0.50/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 1998 the ROS was off.

(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 19987 this value was 1.05.

Equations: None.

(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 set at the 70.8 percent current value from the PMM database. This value is calibrated to reflect catalytic coke use as reported by the Petroleum Supply Annual 1996.

(ADJACUINV) Updates the crude units investment costs

Purpose: This subroutine updates the distillation unit investment costs..

Equations: The investment coefficient is updated once at the beginning of the NEMS forecast and then remains constant throughout the NEMS forecast.

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 1997 to 2000 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.

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.

Purpose: The LP column bounds are updated with using the OML function WFCBND.

Equations: None.

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

(CNAMELP) Retrieves LP column name.

Purpose: Retrieves LP column name using the OML function WFCNAME.

Equations: None.

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

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

Purpose: Updates an LP matrix RHS using the OML function WFCRHS

Equations: None.

Data Passed: COLNAME, column name, RHSVAL, right hand value

(CVALLP) Updates coefficient value in the LP matrix.

Purpose: Updates coefficient value in the LP matrix using the OML function WFCVAL.

Equations: None.

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

(RVALLP) Retrieves coefficient value in the LP matrix.

Purpose: Retrieves coefficient value in the LP matrix using the OML function WFRVAL.

Equations: 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.

Equations: None.

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))	(not used)	Mbbl/cd,$87/bbl	QN,PN
D(cd)(prd) P (q(k))	(not used)	Mbbl/cd,$87/bbl	QP,PP
D(cd)(prd) S1		Mbbl/cd	PRDDMD(MNUMCR,MNUMYR,23)
D@METS1		Mbbl/cd	PRDDMDME(MNUMYR)
ZZAMHTOT		Mbbl/cd	Function of WOP
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(5)
P (pd) PFF		MFOED	PRPFF(5)
E (pd) (prcunit)INV		Mbbl/cd	PUINV(MNUMPR,60,MNUMYR+4), or Constants of 0, 1000
L (pd) (prcunit)BLD		Mbbl/cd	0.0 PUCUM (MNUMPR,60,MNUMYR+4), PUINV(MNUMPR,60,MNUMYR+4)
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

PMM LP Variable	LP Units	NEMS Variable
A@PRDEXP	Mbbl/cd	PRDEXPTOT(MNUMYR)
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(MNUMYR)
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

NAME	LP Units	NEMS Variable
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
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	

Code	Name	Values	No. in Set
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
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

NAME	UNITS	DEFINITION
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
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.

NAME	UNITS	DEFINITION
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
PALMG(MNUMCR,MNUMYR)	$87/bbl	Motor gasoline all combined
PDS(MNUMCR,MNUMYR)	$87/bbl	Distillate fuel oil
PDSL(MNUMCR,MNUMYR)	$87/bbl	Low sulfur diesel
PJF(MNUMCR,MNUMYR)	$87/bbl	Jet fuel
RFMETM85(MNUMYR)	MMbbl/cd	Methanol for M85
MGMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Transportation
DSMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	Distillate Fuel--Residential
DSMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Distillate Fuel--Transportation
JFMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Jet fuel transportation
RFMETI(MNUMYR)	MMbbl/cd	Imported methanol
RFMTBD(MNUMYR)	MMbbl/cd	Domestic MTBE
RFMTBI(MNUMYR)	MMbbl/cd	Imported MTBE
MUFTAX(15)	$87/MMBtu	Federal motorgasoline tax

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

NAME	UNITS	DEFINITION
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
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.

NAME	UNITS	DEFINITION
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
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

NAME	UNITS	DEFINITION
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	
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
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
PRL(MNUMCR,MNUMYR)	$87/bbl	Residual fuel oil low sulfur
PRLUT(MNUMCR,MNUMYR)	$87/bbl	Low sulfur utility resid.

NAME	UNITS	DEFINITION
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,6,4)	Mbbl/cd	Quantity of crude, refinery gate
QPRDRF(MNUMPR,MNUMYR,23)	Mbbl/cd	Refinery production volume by product
QPRDRFT(MNUMYR)	Mbbl/cd	Total refinery production volumes
QGPLTRF(MNUMPR,MNUMYR,16)	BCF	Refinery gas plant production volumes
QPRDEX(MNUMCR,23,MNUMYR)	Mbbl/cd	Refinery production export by product
QPRDEXD(MNUMPR,23,MNUMYR)	Mbbl/cd	Production distress export by product
QPRDIMD(MNUMCR,23,MNUMYR)	Mbbl/cd	Quantity of total distress product imports
RFCRDDCR(MNUMYR)	Mbbl/cd	Domestic crude production
RFCRDAKA(MNUMYR)	Mbbl/cd	Alaskan crude production
RFCRDL48(MNUMYR)	Mbbl/cd	Lower 48 crude production
RFCRDTOT(MNUMYR)	MMbbl/cd	Total crude production
RFNGFTOT(MNUMYR)	Mbbl/cd	Total natural gas production
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
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

NAME	UNITS	DEFINITION
	End use markups by sector	
MGMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Motor gasoline mark ups All Sectors
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
DSMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
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	
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
RHSTTX(MNUMCR)	$87/MMBtu	Same as RHMUTR above
RLSTTX(MNUMCR)	$87/MMBtu	Same as RLMUTR above
LGSTTX(MNUMCR)	$87/MMBtu	Same as LGMUTR above
MESTTX(MNUMCR)	$87/MMBtu	Same as MEMUTR above
ETSTTX(MNUMCR)	$87/MMBtu	Same as ETMUTR above
NLV(9)	Text	Census division character identifers
NLV2(9)	Text	Domestic crude supply regn identifers
QNT(9)	Text	Quantity character identifiers
PRD(23)	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(80)	Text	Mogas share character identifiers
BNDS(2)	Text	Bounds character identifiers
RFCESWTC	Text	Capacity expansion switch

NAME	UNITS	DEFINITION
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(60)	Text	Process unit character identifier
RFHIST	Text	History switch
RFOTHFU(20)	Text	Other fuel use character identifier
MGSPCS(80,MNUMYR)	Many	Motor gasoline specifications
MGSHR(MNUMYR,6,MNUMCR)	Percent	Motor gasoline market shares
PRDDMD(MNUMCR,MNUMYR,23)	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,60,MNUMYR+4)	Mbbl/cd	Process unit cumulative builds
PUINV(MNUMPR,60,MNUMYR+4)	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,60,MNUMYR)	Mbbl/cd	Processing units base capacity
PUBASEUT(MNUMPR,60,MNUMYR)	Pecent	Processing units base utilization
RFEMISST(MNUMPR,MNUMYR,12)	Many	Total refinery emissions
RFFMT(MNUMPR,MNUMYR,34)	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 Ditrict
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 cenus division
RFCGSELFCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Self by cenus division
RFCGFUELCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Fuel by cenus division
FLOWCRD(MNUMYR,14)	Mbbl/cd	Crude pipeline flow
CAPCRD(MNUMYR,14)	Percent	Crude pipeline utilization
FLOWPRD(MNUMYR,21)	Mbbl/cd	Product pipeline flow
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

NAME	UNITS	DEFINITION
FHLADD(MNUMPR)	Mbbl/cd	Additonal supply imports of HL crude
N6XQNT(9)	Fraction	Supply step adjustment for N6l/B
N6XPRC(9)	Fraction	Price step adjustment for N6l/B
IRACN	$87/bbl	Refiner acquisition cost min. tolerance
IRACX	$87/bbl	Refiner acquisition cost max. tolerance
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
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,MNUMYR,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(10)	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
CRDOTHTOT(MNUMPR,MNUMYR)	MMbbl/cd	Total other crude suplied
CRDUNACC(MNUNPR,MNUMYR)	MMbbl/cd	Unnaccouted crude
CRDSTWDR(MNUMPR,MNUMYR)	MMbbl/cd	Crude stock withdrawals
CRDPRDSUP(MNUMPR,MNUMYR)	MMbbl/cd	Crude product 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)	MMbbl/cd	Natural gas fuel use previous iteration
FCCACT(MNUMPR,MNUMYR,109)	Mbbl/cd	FCC unit activity variable by mode
FCCMOD(109)	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

NAME	UNITS	DEFINITION
IRACBND(2)	$87/bbl	IRAC bounds
CAPEXPFCT(5,60,MNUMYR)	Percent	Processing unit capacity expansions factor
RPTFY	Integer	Reproting first year
RPTLY	Integer	Reporting last year
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(MNUMCR)	$87/bbl	TRG benchmarking factor
RFBMRFG(MNUMCR)	$87/bbl	RFG benchmarking factor
RFBMTRH(MNUMCR)	$87/bbl	TRH benchmarking factor
RFBMRFH(MNUMCR)	$87/bbl	RFH benchmarking factor
RFBMJTA(MNUMCR)	$87/bbl	JTA benchmarking factor
RFBMN2H(MNUMCR)	$87/bbl	N2H benchmarking factor
RFBMN6I(MNUMCR)	$87/bbl	N6I benchmarking factor
RFBMN6B(MNUMCR)	$87/bbl	N6B benchmarking factor
RFBMOTH(MNUMCR)	$87/bbl	OTH benchmarking factor
RFBMPCF(MNUMCR)	$87/bbl	PCF benchmarking factor
RFBMAST(MNUMCR)	$87/bbl	AST benchmarking factor
RFBMDSL(MNUMCR)	$87/bbl	DSL benchmarking factor
RFBMN67(MNUMCR)	$87/bbl	N67 benchmarking factor
RFBMN68(MNUMCR)	$87/bbl	N68 benchmarking factor
RFBMCOK(MNUMCR)	$87/bbl	COK benchmarking factor
RFBME85(MNUMCR)	$87/bbl	E85 benchmarking factor
RFBMM85(MNUMCR)	$87/bbl	M85 benchmarking factor
RFBMKER(MNUMCR)	$87/bbl	KER benchmarking factor
QEXCRDIN(MNUMPR,MNUMYR)	Mbbl/cd	Exported crude excep alaskan
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

NAME	UNITS	DEFINITION
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
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,109)	$87/bbl	RFG specification row dual activity
PMM_OR_MRM	Text	5 region to 3 region PMM switch
WLLHDPR(MNUMOR,MNUMYR)	$1987/Bbl	Domestic crude well head price
RFAEOADJ	Text	Switch to turn on AEO adjustments
PMMSTEOBM	Text	Switch to turn on STEO benchmarking
PADD2CD_CT(2,100)	Integer	Padd To Cd Via Clean Tanker
CD2CD_CT(2,100)	Integer	Cd To Cd Via Clean Tanker
PADD2CD_DT(2,100)	Integer	Padd To Cd Via Dirty Tanker
CD2CD_DT(2,100)	Integer	Cd To Cd Via Dirty Tanker
PADD2CD_CB(2,100)	Integer	Padd To Cd Via Clean Barge
CD2CD_CB(2,100)	Integer	Cd To Cd Via Clean Barge
PADD2CD_DB(2,100)	Integer	Padd To Cd Via Dirty Barge
CD2CD_DB(2,100)	Integer	Cd To Cd Via Dirty Barge
PADD2CD_LT(2,100)	Integer	Padd To Cd Via Tanker (Lpg)
CD2CD_LT(2,100)	Integer	Cd To Cd Via Tanker (Lpg)
PADD2CD_ECB(2,100)	Integer	Padd To Cd Via Clean Barge (Eth)
CD2CD_ECB(2,100)	Integer	Cd To Cd Via Clean Barge (Eth)
PADD2CD_EDB(2,100)	Integer	Padd To Cd Via Dirty Barge (Eth)
CD2CD_EDB(2,100)	Integer	Cd To Cd Via Dirty Barge (Eth)
FLOWPD_CT(MNUMYR,100)	Mbblcd	Flow From Padd To Cd Via Clean Tanker
FLOWCD_CT(MNUMYR,100)	Mbblcd	Flow From Cd To Cd Via Clean Tanker
FLOWPD_DT(MNUMYR,100)	Mbblcd	Flow From Padd To Cd Via Dirty Tanker
FLOWCD_DT(MNUMYR,100)	Mbblcd	Flow From Cd To Cd Via Dirty Tanker
FLOWPD_CB(MNUMYR,100)	Mbblcd	Flow From Padd To Cd Via Clean Barge
FLOWCD_CB(MNUMYR,100)	Mbblcd	Flow From Cd To Cd Via Clean Barge
FLOWPD_DB(MNUMYR,100)	Mbblcd	Flow From Padd To Cd Via Dirty Barge
FLOWCD_DB(MNUMYR,100)	Mbblcd	Flow From Cd To Cd Via Dirty Barge
FLOWPD_LT(MNUMYR,100)	Mbblcd	Lpg Flow From Padd To Cd Via Tanker
FLOWCD_LT(MNUMYR,100)	Mbblcd	Lpg Flow From Cd To Cd Via Tanker
FLOWPD_ECB(MNUMYR,100)	Mbblcd	Eth Flow From Pd To Cd Via Clean Barge
FLOWPD_EDB(MNUMYR,100)	Mbblcd	Eth Flow From Pd To Cd Via Dirty Barge
FLOWCD_ECB(MNUMYR,100)	Mbblcd	Eth Flow From Cd To Cd Via Clean Barge
FLOWCD_EDB(MNUMYR,100)	Mbblcd	Eth Flow From Cd To Cd Via Dirty Barge

NAME	UNITS	DEFINITION
	Miscellaneous Variables	
RFGBCRFG(MNUMPR,13,MNUMYR)	Mbbl/cd	Gasoline blending composition (reform. & hioxygen)
RFGBCTRG(MNUMPR,13,MNUMYR)	Mbbl/cd	Gasoline blending composition (traditional & hioxygen)
RFMTBMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant MTBE production
RFETBMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant ETBE production
RFMETMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant methanol comsumption
RFETHMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant ethanol consumption
SBRFGRFH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of RBOB for RFH
SBRFGRFG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of RBOB for RFG
SBG08RFH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for RFH
SBG08RFG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for RFG
SBTRGTRH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of TBOB for TRH
SBG08TRH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for TRH
SBTRGTRG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of SSE for TRG
SBG08TRG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for TRG
SBG08TOT(MNUMCR,MNUMYR)	Mbbl/cd	Tot ethanol used for mogas blnd
PETHANOL(MNUMCR,MNUMYR)	87$/bbl	Marginal cost for ethanol
ETHE85CD(MNUMCR,MNUMYR)	Mbbl/cd	Tot ethanol used for E85 production
ETHTOTCD(MNUMCR,MNUMYR)	Mbbl/cd	Tot ethanol used
ROXYTOT(MNUMPR,MNUMYR)	MMbbl/cd	Total oxygenated volumes
PSRI(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream SRI
PFC8(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream FC8
PR10(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream R10
PALB(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream ALB
PKHL(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream KHL
P2HL(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream 2HL
PVAF(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream VAF
PTAE(MNUMPR, MNUMYR)	$87/bbl	Price of TAEE
PTHE(MNUMPR, MNUMYR)	$87/bbl	Price of THEE
PETB(MNUMPR, MNUMYR)	$87/bbl	Price of ETBE
PMTB25(MNUMPR, MNUMYR)	$87/bbl	Price of MTBE
PTHM(MNUMPR, MNUMYR)	$87/bbl	Price of THME
PTAM(MNUMPR, MNUMYR)	$87/bbl	Price of TAME
RETHRIMP(MNUMPR,MNUMYR)	Mbbl/cd	Imported ethers
HITSWTC	text	HiTech switch
PRCUNSWT(60)	none	Processing unit on/off switch for cap. expan.
RFOTHFU(20)	text	Refinery fuel use for OTH category (3-charID)
EXPRD(10)	text	list of product exports
EXPMIN(10,5)	Mbbl/cd	Minimum product export quantity
EXPMAX(10,5)	Mbbl/cd	Maximum product export quantity
NRMSWTC	text	NRM on/off switch
PRLEQ(MNUMCR,MNUMYR)	Cents/gal	Low sulfur resid (eq price)
PRHEQ(MNUMCR,MNUMYR)	Cents/gal	High sulfur resid (eq price)
PRLUTEQ(MNUMCR,MNUMYR)	Cents/gal	Low sulfur util. resid (eq price)
PRHUTEQ(MNUMCR,MNUMYR)	Cents/gal	High sulfur util. resid (eq price)
LLPRDEXP(10,5,MNUMYR)	Mbbl/cd	Lower bound on prod exports (for cap expan)
ULPRDEXP(10,5,MNUMYR)	Mbbl/cd	Upper bound on prod exports (for cap expan)
MGSBLND(5,5,11,5)		Gasoline blend specs for SSR, SST, RFH, TRH, SSE (PADD,TYP,BLND,YR)
ETHPRIC(2,MNUMYR)	$87/bbl	Cost coef for ETH, E85

NAME	UNITS	DEFINITION
MGSBCHAR(5,11)	text	Gasoline blend category for SSR, SST, RFH, TRH, SSE (TYP,BLND)
PRTYRS(5)	year	ID's 5 yrs to print data for MRM

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 and has 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.

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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).

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 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 of the importing PMM regions (E=PADD I, B=PADDs II,III,IV, and W=PADD V).

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	> 0.7	> 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 (section F.2).

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 Biofuels Supply Submodule of the PMM (Appendix I) 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 consumption is given in pounds per barrel (lb/bbl). Thus an activity in Mbbl/cd consumes 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. These changes are incorporated into the

data tables presented in this section. The tables have been grouped into nine categories: Matrix Control, Crude Oil Availability, Other Raw Materials Availability, Product Imports, Product Demands, Crude and Product Transportation, Refinery Capacities and Operations, Product Blending and Specifications, and Refining Technology. All data tables are located in a directory on the RS6000 named: /default/input.

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 PMM refining region (R) or Census division (D) where:

(R)*	Refining Region
E	PAD District I
B	PAD District II
B	PAD District III
B	PAD District IV
W	PAD District V

(D)	Census Division
1	New England
2	Mid Atlantic
3	East North Central
4	West North Central
5	South Atlantic
6	East South Central
7	West South Central
8	Mountain
9	Pacific, including California

*Note: For *AEO98*, the number of PMM refining regions were changed from 5 to 3, where PADDs I and V remained independent regions E and W, respectively, and PADDs II, III, and IV were aggregated into the single region B.

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 PMM REFINING REGIONS***
Column names	One column, PAD.
Row names	One character region codes, E, B, W.
Entries	numeric value for PADD, 1, 2, 5. (PADDs 2,3,4 represented by 2)

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 PMM refining region E, B, W.
Entries	numeric value for Census Division, 1-9.

TABLE RFNEXP	***LIST OF PMM 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 PMM refining region E, B, W.
Entries	numeric value for export regions, 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$***
Column names	One column, OVC.
Row names	One character PMM refining region code (E,B,W).
Entries	Conversion of variable operating costs to 1991$.

TABLE INVFACT	***INVESTMENT LOCATION AND ENVIRONMENTAL FACTORS***
Column names	LOC, ENV
Row names	One character PMM refining region code (E,B,W).
Entries	Column LOC contains the investment location factor multiplier. 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) (no longer used)

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	Three columns, one for each PMM refining region (E,B,W).
Row names	One row, VOL.
Entries	Volume estimate reference quantity supply in Bcf.

(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 UNFOIL	***UNFINISHED OIL IMPORT SHARES***
Column names	Three columns, E, B, and PD; represent three types of unfinished oil imports into the PMM refining regions.
Row names	Rows NPP, HGM, and ARB are unfinished oil streams imported to U.S.
Entries	Coefficients under refining regions represent volume fractions. Column PD values are imported costs in $/bbl.

(emish)

TABLE EMUNS	***EMISSIONS FROM PROCESS UNITS***
Column names	Five columns, representing type of emission - VOC, CO1, NOX, SOX, and CAR (Carbon).
Row names	Three character process unit codes.
Entries	Emissions in Mlb/Mbbl for VOC, NOX, SOX. Units of MM lbs/Mbbl for CO1, CAR.
TABLE EMFUM	***EMISSIONS FROM FUEL BURNING***
Column names	Five columns, representing type of emission - VOC, CO1, CO2, NOX, SOX, and CAR (Carbon).
Row names	three character 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)

TABLES (R)RCOL	***LIST OF VARIABLES TO BE EXCLUDED FOR PMM 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

(distress)

TABLE ZPX	***MAPPING OF DISTRESS IMP0RT COSTS***
Column names	One column, VALUE.
Row names	Three character product codes.
Entries	One character value to map costs ($/bbl): 0=$0; 1=0.1 * import price at import curve step 1; 2=$.99; 3=$.201.

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)

TABLES 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.)

(ermcrude)

TABLE CRUDEG	***CRUDE OIL QUALITIES AND COSTS FOR REGION G***
Column names	Three columns, CST, MIN, MAX.
Row names	Three character crude codes.
Entries	Objective function cost information; and minimum and maximum crude quantities available.

A.3.3 Other Raw Materials Availability

(ethanol)

TABLE SUPETH(D)	***ETHANOL SUPPLY BY CENSUS DIVISION (D)***
Column names	Eight columns, C1,R1,C2,R2,C3,R3,C4,R4
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.)
(Note: T:ETHTAX presented in section A.3.5)

(utility)

TABLES (R)UAP	***UTILITY PURCHASES - PMM REFINERY REGION (R)***
Column names	One column, CST.
Row names	Three character codes for purchased utilities.
Entries	Column CST contains the purchase price of the utility in dollars per unit.
TABLE UTITRS	***NATURAL GAS PURCHASES***
Column names	One column, COEF.
Row names	One row, NGFNGS.
Entries	Barrels of fuel oil equivalent (BFOE).
TABLE VALPNG	***INDUSTRUAL PRICE OF NATURAL GAS***
Column names	Single character ID for PMM refinery regions (E,B,W).
Row names	NEMS year code (1,2,3, etc.).
Entries	Price of Natural Gas by PMM refinery region.

TABLE VPELIN	***INDUSTRIAL ELECTRIC GENERATION PRICES***
Column names	Single character ID for PMM refinery regions (E,B,W).
Row names	NEMS year code (1,2,3, etc.).
Entries	Industrial electric utility prices (converted to $87/kwh using 3412 MMBtu/Gwh).

(ermother)

TABLE OTHERG	***OTHER RAW MATERIAL QUANTITIES AND COSTS FOR REGION G***
Column names	Three columns, CST, MIN, MAX.
Row names	Three character codes for intermediate streams (raw materials purchased).
Entries	Column CST contains the purchase price of the raw material; columns MIN and MAX contain minimum and maximum quantities of each material allowed to be purchased.

A.3.4 Product Imports

(prdimprt)

TABLES IPR(prd)(R) ***PRODUCT IMPORTS TO PMM REFINERY 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	R1 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.)
(Note: RFHA represents product RFH in T:RFHA)

TABLE PRODLIST	***LIST OF PRODUCT FOR DEMANDS***
Column names	One column DUMMY
Row names	Three characters for finished product codes.
Entries	None.

(Note: RFHA represents product RFH due to a table name conflict in data file **refproc**)

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

(Note: T:CKSMIX is presented in section A.3.8)

(prdexp)

TABLE (D)PRDEXP	***PRODUCT EXPORTS FROM CENSUS DIVISION (D)***
Column names	One column VOL for volume exported
Row names	Three character export finished product codes.
Entries	Export volume in Mbbl/cd

(Note: (D) represents CDs 2,3,7,8,9 only--product export regions)

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.

(ethanol)

TABLE ETHTAX	***ETHANOL TAX SUBSIDY***
Column names	Two columns, TAXETH, TAXE85.
Row names	NEMS year code (1,2,3,etc)
Entries	Tax subsidy.

(ermprod)

TABLE PRODUCTG	***PRODUCT DEMANDS AND REVENUES FOR REGION G***
Column names	Three columns, REV, MIN, MAX.
Row names	Three character product codes.
Entries	Objective function revenue information; and minimum and maximum product demands.

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 the following first two characters to represent the corresponding modes of transportation - 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) EXITING 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) EXITING 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 TPPR(R)	***PRODUCT SHIPPING COSTS (TANKER) EXITING REGION (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) EXITING REGION (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) EXITING REGION (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 EXITING REGION (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 EXITING 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 PLLB(R)	***LPG & PCF SHIPPING COSTS (PIPELINE) EXITING REGION (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 AND PRODUCTS) CAPACITY***
Column names	MAX for maximum capacity
Row names	TVC (crude) or TVP (product), each followed by transportation mode (one character) and CP
Entries	Capacity in thousands of dead weight tons (DWT)
TABLE PLCCAP	***PIPELINE (CRUDE, PRODUCTS, AND LPG) CAPACITY***
Column names	MAX for maximum capacity
Row names	TPC (crude), TPP (products), or TPL (LPG), each followed by source region code (one character), transportation mode (one character) and destination region code (one character)
Entries	Capacity in Mbbl/cd
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 PLNK(R)	***PRODUCT PIPELINE TRANSPORT***
Column names	Three character codes for finished products.
Row names	Transportation mode (one character) and destination region code (one character) for a total of two characters. Currently shipped from PADD 3 (G) and CD 6 to CD 5 and CD 6.
Entries	.Cost of product pipeline transport

A.3.7 Refinery Capacities and Operations

(refproc)

TABLES (R)CAP	*REFINING CAPACITIES - PMM REFINERY REGION (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.
TABLE MATBAL	*STREAMS REQUIRING MATERIAL BALANCE CONSTRAINTS*
Column names	One column, A.
Row names	Three character intermediate stream codes.
Entries	A flag (1=yes) indicating a need for material balance constraint on intermediate stream.
TABLES (uns)	*REFINERY PROCESS UNIT YIELDS AND OTHER OPERATIONS* (See Section A.3.9 for detailed information on specific processing units.)
Column names	Three character process operating mode.
Row names	Three character input/output stream codes; three character utility codes; three character policy codes; and CAP.
Entries	Consumption and yield fractions for streams, utilities (bbl output/bbl input); costs for OVC ($/bbl).

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.

(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)(r).
Entries	None.

(Note: the entries in tables LIM(uns)(r), 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, DDS, FUM, KRF, ETH, and ETM.)

TABLE LIM(uns)(R)	***POLICY LIMITS FOR EACH PMM REFINERY REGION (R)***
Column name	Three character policy limit code.
Row names	One row, DUM.
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.

(accunit)

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
DSL C(650-690)	LP/HC/LS	low pour pt, high centane index, low sulfur	6HL
DSL C(650-690)	LP/HC/HS	low pour pt, high centane index, high sulfur	6HH
DSL C(650-690)	LP/LC/LS	low pour pt, low centane index, low sulfur	6LL
DSL C(650-690)	LP/LC/HS	low pour pt, low centane index, high sulfur	6LH
DSL C(650-690)	HP/LC/HS	high pour pt, low centane index, high sulfur	7LH
DSL C(650-690)	HP/HC/LS	high pour pt, high centane index, low sulfur	7HL
DSL C(650-690)	HP/HC/HS	high pour pt, high centane index, high sulfur	7HH
LGO (690-800)	N,LS	naphthenic, low sulfur	LGL
LGO (690-800)	N,MS	naphthenic, medium sulfur	LGM

Name	Quality	Description	Stream Mnemonic code
LGO (690-800)	N,HS	naphthenic, high sulfur	LGH
LGO (690-800)	P,LS	paraffinic low sulfur	LGP
HGO FD(800-1050)	NAP,LS	naphthenic, low sulfur	HGL
HGO FD(800-1050)	NAP,MS	naphthenic, medium sulfur	HGM
HGO FD(800-1050)	PFN,LS	paraffinic low sulfur	HGP
VAC RES	V LO SUL (0.5)	very low sulfur	RSL
VAC RES	HI SUL (2.3)	high sulfur	RSH
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.

In the past, crude oil quality information resided in the **crdval.dat** data file used for PMM matrix generation. It has been transferred into two MSAccess database files residing on the EIA LAN at the following location:

\\FS-F1\L6007\PRJ\MSACCESS\CRD95GRP (MRM processing)
\\FS-F1\L6007\PRJ\MSACCESS\CRD95IND (ERM processing)

The database file contains quantity, API gravity, sulfur, grade, and source information on individual crude oil streams. Macro programs have been developed to process this data to generate the following set of tables now residing in the **accunit.dat** data file: ***Table ACUCUTS***, ***Table ACUPOL***, and ***Table ACUUTI***. Note that the ***Table ACUCUTS*** yields have been volume balanced to 0; i.e., total yields equal 1.0 exactly. Process losses are accounted for using ***Tables PFA*** and ***REL***.

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).

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 PMM refinery region code and @ for total U.S.
Entries	Million dollars of total capacity expansion investment.

(setrows)

TABLES (R)POL	*REFINERY POLICY CONSTRAINTS - PMM REFINERY REGION (R)*
Column name	TYPE.
Row names	The three character row names correspond to processing constraints (as 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[2] 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,

[2]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.

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.

(nrfplant)

TABLE INVMOH	***INVESTMENT PARAMETERS METHANOL PLANT***
Column names	INV, CAPREC, FXOC
Row names	Process unit MOH.
Entries	Column INV contains investment in $/bbl, CAPREC has the daily annualized investment cost, and FXOC has the fixed operating cost in $/bbl.

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	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
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	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	FAC, gas residue factor, CAP, gas plant capacity, LIM, limit on propane shift, PCU, percent utilization.
Entries	Gas plant feed and CAP in Bcf/day, FAC is volume fraction, LIM in Mbbl/cd, PCU is percent utilization.
TABLE MOHPLT	***METHANOL PLANT***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
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	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	One row, CAP.
Entries	Plant capacity in Mbbl/cd.
TABLE CC1CAP	***DRY GAS PRODUCTION (DGP) CAPACITY***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	NEMS year code (1,2,3,etc)
Entries	Dry gas production capacity in BCF/day.

TABLE (R)CAPMCH MERCHANT PLANT CAPACITIES - PMM REFINING REGION (R)

Column names	CAP, PUL, and BLD
Row names	Process unit codes - C4X, OLX, ETX, FUX, STX.
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 no capacity expansion allowed for that unit.

TABLES (uns)POL MERCHANT PLANT POLICY ROW CONSTRAINTS

Column names	OVC for variable operating cost and LOS for losses
Row names	Three character mode.
Entries	$/bbl for costs. Volume fractions (bbl Output/bbl Input) for LOS.

TABLES (uns)UTI MERCHANT PLANT UTILITY CONSUMPTION FOR PROCESSING

Column names	KWH and STM
Row names	Three character mode.
Entries	Electricity (kWh) and steam (lb/bbl).

TABLES (uns)CAP MERCHANT PLANT CAPACITY FACTOR

Column names	One column, CAP
Row names	Three character mode.
Entries	Capacity factor.

TABLES (uns)REP	***MERCHANT PLANT PROCESS YIELDS***
Column names	Three character process mode codes.
Row names	Three character intermediate stream codes.
Entries	Volume fractions (bbl output/bbl input).

TABLE TRANSFER	***MAPPING OF STREAM TRANSFERS BETWEEN PLANTS***
Column names	One column, DUMMY.
Row names	Two character plant code - GP, MP, or RF.
Entries	No entry.

TABLES (xx)TRANS	***STREAM TRANSFER COSTS ACROSS PLANTS***
Column names	Two character plant code - GP, MP, or RF.
Row names	Three character intermediate stream codes.
Entries	Cost of transfering stream across plants ($/bbl).

(xx = GP (gas plant), MP (merchant plant), RF (refinery).)

TABLE MCHINV	***INVESTMENT PARAMETERS FOR MERCHANT PLANT UNITS***
Column names	INV, FXOC, CAPREC.
Row names	Three character 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.

(cogener)

TABLE CGNCAP	***COGENERATION PLANT CAPACITIES***
Column names	CAP, PUL, and BLD
Row names	One character PMM refinery region ID (E,B,W).

Entries	Column CAP contains existing cogeneration capacities in KWh/day units. 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 no capacity expansion allowed.
TABLE CGNINV	***INVESTMENT PARAMETERS FOR COGENERATION UNITS***
Column names	Three columns: INV, FXOC, CAPREC
Row names	One character PMM refinery region ID (E,B,W).
Entries	Column INV contains investment in $/bbl, FXOC has the fixed operating cost in $/bbl, and CAPREC has the daily annualized investment cost.
TABLE CGNPOL	***COGENERATION POLICY ROW CONSTRAINTS***
Column names	OVC for variable operating cost.
Row names	One row, three character mode - CGN.
Entries	$/bbl for costs.
TABLE CGNUTI	***UTILITY CONSUMPTION FOR COGENERATION***
Column names	KWH and STM
Row names	One character PMM refinery region ID (E,B,W).
Entries	Electricity (kWh) and steam (lb/bbl).
TABLE CGNREP	***COGENERATION FUEL CONSUMPTION***
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	One character PMM refinery region ID (E,B,W).
Entries	Fraction sold in each PADD.
TABLE VPELAS	***ELECTRIC UTILITY PRICES***
Column names	One character PMM refinery region ID (E,B,W).
Row names	NEMS year code (1,2,3,etc).
Entries	Electric utility prices converted to $87/kwh using 3412 MMBtu/Gwh.

(stream)

TABLE TRS	***STREAM TO STREAM TRANSFERS***
Column names	Two columns, MIN and CST
Row names	Six character code, consisting of a three character intermediate stream code and another three character intermediate stream code; and OVCOBJ.
Entries	No entry; except CST column: -1 for OVCOBJ and -10 for BNZARO (premium placed on BNZ to ARO transfer).
TABLE XSALE	***STREAM TO PRODUCT TRANSFERS***
Column names	One column, DUMMY.
Row names	Six character code, consisting of a three character intermediate stream code and a three character product stream code.

A.3.8 Product Blending and Specifications

(gasoblnd)

TABLES Q(R)GSL	***REGIONAL GASOLINE SPECIFICATIONS--PMM REGION (R)***
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--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing five transition years for changes in specifications.
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; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year. 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--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing five transition years for changes in specifications.
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; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year. 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.

TABLES (R)RFH	***SUBSPEC RFG QUALITY SPECIFICATIONS--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing five transition years for changes in specifications.
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; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year.
TABLES (R)TRH	***SUBSPEC TRG QUALITY SPECIFICATIONS--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing five transition years for changes in specifications.
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; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year.
TABLES (R)SSE	***SUBSPEC TRG QUALITY SPECIFICATIONS--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing five transition years for changes in specifications.
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; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year. The quality coefficients of SSE reflect a 10% ethanol blend.
TABLE GCB	***GASOLINE QUALITIES (EX OCTANE)***
Column names	Quality codes
Row names	Intermediate product codes
Entries	Blending values

TABLE GCC	***GASOLINE COMPONENT USAGE CONTROL***
Column names	Finished product codes.
Row names	Intermediate stream codes
Entries	A non-blank entry indicates that the intermediate is allowed as a component to the finished blend.
TABLE GASGROUP	***GAS GROUP CLASSIFICATION***
Column names	One column, TEXT(1).
Row names	Three character stream code matching those in ***Table GCB***.
Entries	Three character gas group classification: G00-G12.
TABLE GSLUTI	***GASOLINE BLEND UTILITIES***
Column names	Utility, electricity, KWh.
Row names	Three character gasoline type or blend ID.
Entries	KWh per barrel of feed.
TABLE MCO	***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	Base research and motor octane blending numbers for each component at four levels of lead.

TABLES (xxx)BV	***GASOLINE COMPONENT BONUS BLENDING VALUES***
Column names	Nine columns, R00, R05, R15, R30, M00, M05, M15, M30, TEL 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	Bonus research and motor octane blending numbers for each component at four levels of lead. Non-zero entries are added to the base octanes from ***Table MCO*** and used in the relevant gasoline blend. 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.

(xxx = UNC and RFM (representing TRG and RFG, respectively).)

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)

TABLES Q(R)DFO	***REGIONAL DISTILLATE/FUEL OIL SPECIFICATIONS--PMM REFINERY REGION (R)***
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.
TABLE DCB	***DISTILLATE QUALITIES (EX OCTANE)***
Column names	Quality codes
Row names	Intermediate product codes
Entries	Blending values

TABLE DCC	***DISTILLATE COMPONENT USAGE CONTROL***
Column names	Finished product codes.
Row names	Intermediate stream codes
Entries	A non-blank entry indicates that the intermediate is allowed as a component to the finished blend.
TABLE DFOUTI	***DISTILLATE BLENDING UTILITIES***
Column names	One column, STM, steam.
Row names	Five distillate fuel oil products: JTA, N2H, DSL, N6I, N6B.
Entries	Steam use per barrel of feed.

(recipes)

TABLE RCP	***RECIPE BLEND CONTROL***
Column names	Three columns, A, CST, and STM, 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 RCPEIA	***RECIPE BLEND CONTROL***
Column names	Seven columns, A, CST, and five selected product streams (JTA, N2H, SLP, CKH, CKL).
Row names	Special products: salable sulfur, low and high sulfur coke.
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 (including unit conversions).

(splash)

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.

TABLES BLNSP(D) RECIPE BLENDING FOR KEROSENE AND RESIDUAL OIL TO UTILITIES--CENSUS DIVISION (D)

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.

TABLES BLOX(D)YXX RECIPE BLENDS FOR HIGH OXYGEN GASOLINES IN CENSUS DIVISION (D)

Column names	Six columns, E85, M85, TRH, RFH, RFG, and TRG.
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.

TABLE HOXETH	***ETHANOL RECIPES FOR SPLASH BLENDING***
Column names	Four columns, TRH, RFH, RFG, TRG.
Row names	Gasoline blend streams.
Entries	Consumption and yield fractions for ethanol blending streams.
TABLE XETH	***OXYGEN CONTENT OF ETHANOL***
Column names	One column, PO.
Row names	One row, XETH.
Entries	Percent oxygen for ethanol.
TABLE SCB	***OXYGEN CONTENT OF OXYGENATES***
Column names	One column, PO.
Row names	Three character oxygenate stream codes (ETB,MTB,TAE,TAM,THE,THM).
Entries	Percent oxygen for oxygenate streams.

(demand)

TABLE CKSMIX	***SALABLE COKE RECIPES***
Column names	Two columns, CKL and CKH for low sulfur and high sulfur coke, respectively.
Row names	Coke stream codes (CKL, CKH) and product coke (COK); OBJ is scaled for selling price for coke.
Entries	Price ratio for coke (to be multiplied by WOP). Conversion from tons to bbls, and 1.0 coefficient for material balance.

(fuelmix)

TABLE GROUP	*FUEL MIX COMPONENTS*
Column names	One column, DUMMY.
Row names	Six character code, consisting of a three character intermediate stream code and a three character fuel stream code.
Entries	No entry.

A.3.9 Refining Technology

The tables described in this section are essential to the representation of refining technology. All the tables are names (uns), representing the refining technology processing unit. The Column names represent modes of operation. The Row names represent refinery process input and output streams (intermediate streams), policy (OVC, LOS, etc.) cost information, and utiity (KWH,STM) consumption. The table entries volume fractions (bbl Output/bbl Input) for intermediate streams; costs ($/bbl) for policy information; and utility consumption rates (kWh/bbl and lb/bbl) for electricity and steam, respectively.

(refproc)

TABLE VCU 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 KRD 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 KRF 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 SDA 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 VBR 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 NDS 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 DDS 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 FDS 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, LGM, and LGH:	paraffinic, low, medium, and high sulfur light gas oils, 690 to 800 degrees Fahrenheit.
HGP, HGL, HGM, and HGH:	paraffinic, low, medium, and high sulfur heavy gas oils, 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 aromatics 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 isobutylene/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 REL 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 (R)POL***. 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 PFA 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 (R)POL***. 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)

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.

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 AEO98 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).

Table B1. PMM Linear Program Structure

PMM Linear Program Overview

	Crude Trans.	Purchases Crude Oil, Other Inputs	Crude Distillation	Other Process Unit Operations	Capacity Expansion	Stream Transfers	Blending	Product Sales	Product Trans.	Row Type	RHS
Objective	-ct	-c	-o	-o	-I			+p	-pt	NC	Max
Crude Oil Balance	+1 +1 -1	+1 +1 +1	-1 -1							GE	0
Intermediate Stream Balance			+y +y	-1 -1 +y +y		-1 +1 -1 +1	-1 -1			GE	0
Utilities		+1	-u	-u +1						GE	0
Policy Constraints				+z -z				+z -z		GE LE	0
Environmental Constraints			+q	+q						GE LE	B
Unit Capacities			+1	+1	-1					LE	K
Quality Specifications							+q +q -Q			GE LE	0
Product Sales							-1	-1	-1 + 1 +1 -1	GE	0
Pipeline/Marine Capacities	+1 +1								+1 + 1	LE	C
Bounds	Up/Lo/Fix	Up/Lo/Fix						Up/Lo/Fix			

Legend: c = crude cost; p = price; Q = product specifications; y = yield; z = policy ratio; C = pipeline/marine capacity; u = utility consumption; q = stream quality; E = environmental quality limit; K = unit capacity; I = investment cost; ct = crude transportation cost; o = operating cost; pt = product transportation cost

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
(a)	Alcohol
(b)	Domestic crude oil production region
(c)	Crude oil type
(d)	Marketing region (demand)
(e)	Emissions source
(h)	Product recipe
(i)	Intermediate stream
(l)	Utility type
(m)	Processing mode or shipping mode
(p)	Refined product
(pc)	Shipping class
(q)	Pricing level
(r)	Refinery region
(s)	Refinery stream
(u)	Processing unit type
(v)	Crude oil source (foreign(F), domestic(D), Alaska(A))
(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).
$E_{u,r}$	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).
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.

Column Notation	Description
N_rNGRFN_q	Volume at price discount (q) of natural gas in refinery region (r).
N_rNGRFP_q	Volume at price increment (q) of natural gas in refinery region (r).
$O_{c,v,b}$	Export volume of crude oil (c) with source code (v) produced in domestic region (b). At present, only Alaska exports are allowed.
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).
TAAMHXZ	Volume of AMH crude transported from Alaska to Valdez.
$TCBN_r$	Total tax levied on total carbon emissions resulting from refinery operations 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. (Not used in 3-region pmm.)

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 transfer mode (m).
$W_{a,r,d,m}$	Volume of alcohol (a) shipped from refinery region (r) to demand region (d) via transfer mode (m).
$W_{p,r,d,m}$	Volume of product (p) shipped from refinery region (r) to demand region (d) via transfer mode (m).
$W_{p,d,d',m}$	Volume of product (p) transhipped from demand region (d) to demand region (d') via transfer 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 transfer 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 transfer mode (m).
Zt	Total volume of crude oil processed over all refinery regions.
ZET_d	Total volume of ethanol supplied from demand region (d).
Z_rFLO_u	Sum of the base, build, and expanded capacity in processing unit (u) at refinery region (r).
ZOX_r	Total quantity of percent oxygen-barrels in reformulated gasoline produced in refinery 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.

PRAMHXZ is the cost of transferring Alaskan exports to Valdez.

PR_rNGRFN_q is the discount from target natural gas fuel price in refinery region (r).

PR_rNGRFP_q is the premium added to the target natural gas fuel price in refinery region (r).

$C_{u,r,m}$ 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:

$$\Sigma_d\Sigma_p D_{d,p}*PR_{d,p} + \Sigma_p\Sigma_h\Sigma_r H_{p,h,r}*PR_{p,h,r} + \Sigma_p\Sigma_h\Sigma_d H_{p,h,d}*PR_{p,h,d} + \Sigma_p\Sigma_d X_{p,d}*PR_{p,d}$$

$$+ \Sigma_d ZET_d * TE_d + ZZAMHTOT * PRAMH + \Sigma_q NZAMHP_q * PRAMHP_q$$

$$+ \Sigma_r \Sigma_q N_rNGRFN_q * PR_rNGRFN_q$$

minus the following cost terms:

$$\Sigma_a\Sigma_d\Sigma_q\, B_{a,d,q}{*}C_{a,d,q} + \Sigma_p\Sigma_r\, I_{p,r}{*}C_{p,r} + \Sigma_p\Sigma_d\, I_{p,d}{*}C_{p,d} + \Sigma_b\, P_b{*}C_b + \Sigma_c\Sigma_r\Sigma_q\, Pi_{c,r,q}{*}C_{c,r,q}$$

$$+ \Sigma_i\Sigma_r\, T_{i,r}{*}C_{i,r} + \Sigma_l\Sigma_r\, U_{l,r}{*}C_{l,r} + \Sigma_u\Sigma_r\Sigma_m\, R_{u,r,m}{*}C_{u,r,m} + \Sigma_u\Sigma_r\, E_{u,r}{*}C_{u,r} + \Sigma_u\Sigma_r\, L_{u,r}{*}C_{u,r} +$$

$$+ \Sigma_s\, \Sigma_i\, \Sigma_r\, \Sigma_l\, W_{s,d,r,m}{*}C_{s,d,r,m} + \Sigma_p\Sigma_r\Sigma_d\Sigma_m\, W_{p,r,d,m}{*}C_{p,r,d,m} + \Sigma_p\Sigma_d\Sigma_{d'}\Sigma_m\, W_{p,d,d',m}{*}C_{p,d,d',m}$$

$$+ \Sigma_c\Sigma_v\Sigma_b\Sigma_r\Sigma_m\, Y_{c,v,b,r,m}{*}C_{c,v,b,r,m} + \Sigma_c\Sigma_v\Sigma_r\Sigma_{r'}\Sigma_m\, Y_{c,v,r,r',m}{*}C_{c,v,r,r',m} + \Sigma_r\, TCBN_r$$

$$+ \Sigma_q\, NZAMHN_q * PRAMHN_q + TAAMHXZ * PRAMHXZ$$

$$+ \Sigma_r\Sigma_q\, N_rNGRFP_q * PR_rNGRFP_q$$

Note: (1) $\Sigma_u\Sigma_r\Sigma_m\, R_{u,r,m}{*}C_{u,r,m}$ term is represented in the matrix as T(r)OVCOBJ + T(r)GPLOVC + T(r)MCHOVC as represented by rows P9r)OVC, G(r)OVC, H(r)OVC, respectively.
(2) ZZZAMHTOT=TAAMHXZ as defined by row CZAMH.
(3) Row P(r)CBNTAX is used to set $TCBN_r$ regional totals for tax on carbon emissions.

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:

$$\Sigma_c\Sigma_r\Sigma_q \, Pi_{c,r,q} * C_{c,r,q} - WOP * Nwop * Zt \geq 0$$

where:

$Pi_{c,r,q}$ 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 foreign 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:

$$\Sigma_c\Sigma_r\Sigma_q \, Pi_{c,r,q} * C_{c,r,q} - WOP * Nwop * Zt \leq 0$$

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 confines 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 foreign crude oil processed by summing all crude oil volumes processed over all refinery regions:

$$\Sigma_c \Sigma_v \Sigma_r Ra_{c,F,r} - Zt = 0$$

where:

$Ra_{c,F,r}$ is the crude oil volume distilled in refinery region (r) from foreign source (F) of crude oil type (c).

I.e. the total U.S. refined foreign crude oil volume equals the sum of all foreign 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:

$$\Sigma_u E_{r,u} * A_{r,u} \leq Emax_r \quad \forall \ r$$

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 (refinery region E) 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. (Region B limit is $29,000 million, region W limit is 19,000 million.)

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:

$$\Sigma_r \Sigma_u E_{r,u} * A_{r,u} \leq Emax$$

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 ($\Sigma_i \Sigma_r A_{i,r} = 1.0$).

I.e., the volume distribution of each type of unfinished oil processed at each refinery region is constrained to the historical pattern.

Note: No unfinished oil processing in PADD 5 (refinery region W).

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:

$$\Sigma_q B_{a,d,q} + \Sigma_r \Sigma_m W_{a,r,d,m} + \Sigma_{d'} \Sigma_m W_{a,d',d,m} - \Sigma_p H_{p,a,d} * A_{p,a} - \Sigma_r \Sigma_m W_{a,d,r,m} - \Sigma_{d'} \Sigma_m W_{a,d,d',m} = 0 \qquad \forall \; a, d$$

where:

$a \in h$ so that a is a subset of all recipe blends (h) and in fact, a = ETH and MET.

$B_{a,d,q}$ 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.

$W_{a,d',d,m}$ is the volume of alcohol (a) received in demand region (d) from demand region (d') via shipping mode (m). This column exists only for ethanol.

$H_{p,a,d}$ is the volume of recipe product (p) manufactured by alcohol blend recipe (a) consumed in demand region (d).

$A_{p,a}$ is the volume fraction of recipe product (p) represented by alcohol (a), 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.

$W_{a,d,d',m}$ is the volume of alcohol (a) shipped from demand region (d) to demand region (d') via mode (m). This column is valid only for ethanol.

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.

Note: 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.

11. For those products which are not blended by recipe at the demand regions, for 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 (local and exports):

$$I_{p,d} + \Sigma_r \Sigma_m W_{p,r,d,m} + \Sigma_h H_{p,h,d} - \Sigma_{p'} \Sigma_h H_{p',h,d} * A_{p',h} - X_{p,d} - D_{p,d} = 0 \qquad \forall\ d, p$$

where:

$I_{p,d}$ is volume of product (p) imported into demand region (d).

$W_{p,r,d,m}$ is product (p) received in demand region (d) from refinery region (r) via transfer 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).

$H_{p',h,d}$ 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') represented by product (p), consumed by recipe (h), an input.

$D_{p,d}$ is a sales volume (local and export demand) of product (p) in demand region (d), this activity is fixed at the last NEMS iterative demand value; i.e., it does not influence the cost decision in the solution.

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.

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 recipe 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:

$$\Sigma_r \Sigma_m W_{p,r,d',m} + \Sigma_d \Sigma_m W_{p,d,d',m} - \Sigma_d \Sigma_m W_{p,d',d,m} = 0 \quad \forall \; d', p$$

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 (Alaska only) and shipments to domestic refineries:

$$P_b * A_{c,v,b} - \Sigma_r \Sigma_m Y_{c,v,b,r,m} - O_{c,v,b} - TAAMHXZ = 0 \quad \forall \; b, c, v$$

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.

$Y_{c,v,b,r,m}$ 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).

$O_{c,v,b}$ is the export volume of crude oil (c) with source code (v) produced in domestic region (b). At present, only Alaska crude exports are allowed (set to 0 in code).

TAAMHXZ is total volum of AMH crude transferred from Alaska to Valdez. Only used with Alaska production region (A) row constraint.
(Note: TAAMHXZ = ZZAMHTOT as defined by row constraint CZAMH.)

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...):

$$\Sigma_{p'}\Sigma_{r}\Sigma_{d}\Sigma_{m'} W_{p',r,d,m'} * A_{p'} - V_{pc} = 0 \quad \forall \text{ product class (pc)}$$

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').

$A_{p'}$ 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

(Note: Not used in latest 3-region version of PMM.):

$$\Sigma_{v}\Sigma_{c} Y_{c,v,G,C,m} - Vcts = 0$$

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:

$$\Sigma_c \Sigma_v \Sigma_m Y_{c,v,b,r,m} - Vcp_{b,r} = 0 \quad \forall \; b, r$$

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:

$$\Sigma_{p'} \Sigma_r \Sigma_d \Sigma_m W_{p',r,d,m} - Vpp_{r,d,m} = 0 \quad \forall \; r, d, m$$

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.

Note: Special cases exist for transfer from CD6 to CD5, from CD5 to CD2, from CD6 to CD6 (P/L sales), and from CD5 to CD5 (P/L sales).

20. For each refinery/demand region applicable combination, limit pipeline shipments of liquid petroleum gas and PCF volumes to available LPG pipeline capacity:

$$\Sigma_{p'}\Sigma_{t}\Sigma_{d}\Sigma_{m} W_{p',r,d,m} - Vtpl_{r,d,m} = 0 \quad \forall \; r, d, m$$

where:

$p' \in p$ — p' is the set of LPG and PCF 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 and PCF product (p') shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$Vtpl_{r,d,m}$ — is total volume of LPG and PCF 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.

Note: Special case exists for transfer from CD6 to CD5.

21. Refinery 'policy' table entries are adhered to:

$$\Sigma_{u}\Sigma_{m} R_{u,r,m} * A_{e,u,r,m} - A_{e,r} * Z_{t}FLO_{u} \;\; \leq,\geq,= 0 \quad \forall \; e, r$$

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 (≤,≥,=) 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:

$$Z_{t}FLO_{u} - K_{u,r} - A_{u,r}*(L_{u,r} + E_{u,r}) = 0 \quad \forall \; r, u$$

where:

$Z_{t}FLO_{u}$ — 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:

$$\Sigma_b \Sigma_m Y_{c,v,b,r,m} + \Sigma_{r'} \Sigma_m Y_{c,v,r',r,m} - \Sigma_{r'} \Sigma_m Y_{c,v,r,r',m} - Ra_{c,v,r} = 0 \quad \forall \ c, v, r$$

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). (Not applicable in 3-region model.)

$Y_{c,v,r,r',m}$ 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). (Not applicable in 3-region model.)

$Ra_{c,v,r}$ 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:

$$\Sigma_q Pi_{c,r,q} + \Sigma_{r'} \Sigma_m Y_{c,F,r',r,m} - \Sigma_{r'} \Sigma_m Y_{c,F,r,r',m} - Ra_{c,F,r} = 0 \quad \forall \ c, r$$

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). (Not applicable in 3-region model.)

$Y_{c,F,r,r',m}$ is volume of imported crude oil type (c) that is transhipped from refinery region (r) to refinery region (r') via mode (m). (Not applicable in 3-region model.)

$Ra_{c,F,r}$ 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:

$$Q_{p,r} + \Sigma_h H_{p,h,r} + \Sigma_q I_{p,r,q} + \Sigma_s Tx_{s,p,r} - \Sigma_u \Sigma_m R_{u,r,m} * A_{p,u,r,m}$$

$$- \Sigma_m \Sigma_d W_{p,r,d,m} = 0 \quad \forall \; p, r$$

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).

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r). (Applicable to product N6I and N6B only.)

$A_{p,u,r,m}$ is the volume fraction of manufacturing activity level in mode (m) operation in processing unit (u) which defines the volume of product (p) produced (or consumed if the sign is negative) per unit of manufacturing activity level in refinery region (r).

$W_{p,r,d,m}$ 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:

$$\Sigma_u \Sigma_m R_{u,r,m} * A_{i,u,r,m} + \Sigma_s (Tx_{s,i,r} - Tx_{i,s,r}) - \Sigma_p G_{i,p,r} - \Sigma_p \Sigma_h H_{p,h,r} * A_{i,h} = 0 \quad \forall \; i, r$$

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 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 product (p) for which intermediate stream (i) is 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:

$$\Sigma_i G_{i,p,r} * A_{y,i,p} - Q_{p,r} * A_{y,p,r} \quad \leq,\geq,= \quad 0 \quad \forall \quad y, p, r$$

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 spec blend 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. Balance blending rows with specific blended products:

$$\Sigma_i G_{i,p,r} - \Sigma_{p'} Q_{p',r} = 0 \quad \forall \quad p, r$$

where:

p is only TRG, RFG, N6I, N6B, DSL, N2H, and JTA.

$p' \in p$ for p=TRG, p'=TRG, TRH, SST, SSE;
for p=RFG, p'=RFG, RFH, SSR;
for remaining products (p), p'=p only (i.e., for JTA, p'=JTA only).

$G_{i,p,r}$ is the volume of intermediate stream (i) blended into spec-blended product (p) at refinery region (r).

$Q_{p',r}$ is the total volume of spec-blended product (p) manufactured at refinery region (r).

30. Sum oxygen percentage contribution by oxygenates blended to reformulated gasoline

$$\Sigma_{OX} G_{OX,RFG,r} * PO_{OX} + H_{ETH,RFG,r} * PO_{ETH} * F_{ETHRFG} + H_{ETH,RFH,r} * PO_{ETH} * F_{ETHRFH} - ZOX_r = 0$$

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.

31. Sum oxygen percentage contribution by renewable oxygenates blended to RFG.

$$\Sigma_{OE} G_{OE,RFG,r} * PO_{OE} + H_{ETH,RFG,r} * PO_{ETH} * F_{ETHRFG} + H_{ETH,RFH,r} * PO_{ETH} * F_{ETHRFH} - L * ZOX_r \geq 0$$

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).

32. Calculate refinery consumption of natural gas supply by summing volumes processed for each refinery region:

$$\Sigma_q N_r NGRFN_q + \Sigma_q N_r NGRFP_q - U_r NGF = 0$$

where:

$N_r NGRFN/P_q$ is the volume of natural gas consumed in refinery region (r) at supply price delta (q).

$U_r NGF$ is the total volume of natural gas consumed in refinery region r.

33. Place an upper bound on each natural gas supply step volume:

$$N_rNGRFN/P_q \leq NG_q\,max$$

where:

N_rNGRFN/P_q is the volume of natural gas allowed on step q in region (r) at cost a cost delta.

$NG_q\,max$ is the maximum volume of natural gas supply allowed, based on an input value. Note that step N1 has a minimum lower bound volume.

34. 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.

35. Place an upper bound on each Alaskan crude supply step volume:

$$NZAMHx_q \leq NZAMHx_q\,max$$

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.

36. 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 & D(d)(p)SX
$E_{u,r}$	E(r)(u)INV
$G_{i,p,r}$	B(r)(p)(i) & F(r)(p)(i)
$H_{p,h,r}$	X(r)(h)(p) & G(r)(i)(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
N_rNGRFN_q	N(r)NGRFN(q)
N_rNGRFP_q	N(r)NGRFP(q)
$NZAMHN_q$	NZAMHN(q)
$NZAMHP_q$	NZAMHP(q)
$O_{c,v,b}$	O@CRDEXP
P_b	P(b)DCRQ1
$Pi_{c,r,q}$	P(r)F(c)Q(q)

Column Notation	Matrix Name
$Q_{p,r}$	Q(r)(p)
$Ra_{c,v,r}$	R(r)ACU(v)(c)
$R_{u,r,m}$	R(r)(u)(m) & H(r)(u)(m)
Tu	T@UNFTOT
$T_{i,r}$	T(r)UNF(i)
TAAMHXZ	TAAMNXZ
$TCBN_r$	T(r)CBNTAX
$Tx_{s,p,r}$	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)
U_rNGF	U(r)NGF
Vcj	VTVC(m)CP
V_{pc}	VTVP(m)CP
Vcts	VTPCGAC (not used)
$Vcp_{b,r}$	VTPC(b)(m)(r)
$Vpp_{r,d,m}$	VTPP(r)(m)(d)
$Vtpl_{r,d,m}$	VTPL(r)(m)(d)
$W_{a,r,d,m}$	W(r)(a)(m)(d)
$W_{a,d,r,m}$	W(d)(a)(m)(r)
$W_{a,d,d',m}$	W(d)(a)(m)(d')
$W_{p,r,d,m}$	W(r)(p)(m)(d)
$W_{p,d,d',m}$	W(d)(p)(m)(d')
$X_{p,d}$	D(d)(p)Z9, D(d)(p)SX

Column Notation	Matrix Name
$Y_{c,v,b,r,m}$	Y(b)(v)(c)(m)(r)
$Y_{c,v,r,r',m}$	Y(r)(v)(c)(m)(r') (not used)
Zt	Z@TOTCRD
ZET_d	Z(d)ETHTAX
Z_tFLO_u	Z(r)FLO(u)
ZOX_r	Z(r)RFGOXY
ZZAMHTOT	ZZAMHTOT

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(r) INVST
7	A@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)(c), (CZAMH)
15	TVC(m)CP
16	TVP(m)CP
17 (not used in 3-reg model)	TPCGAC
18	TPC(b)(m)(r)
19	TPP(r)(m)(d)
20	TPL(r)(m)(d)
21	P(r)(e), Z(r)CAP(u), H(r)(e), G(r)(e)
22	C(r)(v)(c)
23	C(r)F(c)
24	M(r)(p)
25	U(r)(l)
26	L(r)(u)CAP, H(r)FUMCAP
27	B(r)(i), G(r)(i), H(r)(i)
28	Q(r)(p)(y)
29	S(r)(p)E
30	S(r)RFGOXY
31	Q(r)RFGREN
32	Z(r)NGFSUM
33*	N(r)NGRFN/P(q)
34	ZZAMHSUM
35*	NZAMHN/P(q)

* Bound on column variable.