EIA Model Documentation

PETROLEUM MARKET MODEL
OF THE
NATIONAL ENERGY MODELING SYSTEM

Part 1 – Report and Appendix A

February 5, 2001

Oil and Gas Division
Office of Integrated Analysis and Forecasting
Energy Information Administration

For Further Information...

The Petroleum Market Model (PMM) of the National Energy Modeling System is developed and maintained by the Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting. General questions about the use of the model can be addressed to James Kendell (202) 586-9646, Director of the Oil and Gas Division. Specific questions concerning the PMM may be addressed to:

> Bruce Bawks
> Mail Code: EI-83
> U.S. Department of Energy
> 1000 Independence Avenue, S.W.
> Washington, D.C. 20585
> (202) 586-6579
> bruce.bawks@eia.doe.gov

This report documents the archived version of the PMM that was used to produce the petroleum forecasts presented in the *Annual Energy Outlook 2001*, (DOE/EIA-0383(2001)). The purpose of this report is to provide a reference document for model analysts, users, and the public that defines the objectives of the model, describes its basic approach, and provides detail on the methodology employed. The model documentation is updated annually to reflect significant model methodology and software changes that take place as the model develops. The next version of the documentation is planned to be released in the first quarter of 2002.

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
Mbtu	Thousand British Thermal Units
MMbbl/cd	Million Barrels Per Calendar Day
MMbtu	Million British Thermal Units
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 2001* (AEO2001) 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 and ethanol productions. 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 District (PADD) level.

1.3 Model Archival Citation

The PMM is archived as part of the National Energy Modeling System for AEO2001. The model contact is:

> Bruce Bawks
> Mail Code: EI-83
> U.S. Department of Energy
> 1000 Independence Avenue, S.W.
> Washington, D.C. 20585
> (202) 586-6579

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, PMM Data and Outputs; Appendix B, Mathematical Description of 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, Ethanol Supply Model.

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

---

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

petroleum products; crude oil prices; refinery processing unit capacities; changes in certain petroleum product specifications; energy policies and regulations; and taxes, tariffs, and subsidies.

The PMM is comprised of three geographical regions, defined using the five Petroleum Administration for Defense Districts (PADD's). 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 PADD 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 conventional 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. 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

Demand Models

Petroleum Product Demands

Petroleum Product Prices

Crude and Product Supply Curves

International Energy Model

Petroleum Supply Data

Macro Model

Refinery Revenue

Petroleum Market Model

Domestic Crude, Gas and EOR Production

Oil & Gas Supply Model

Integrating Model Model

System Controlling Information

Natural Gas Transportation & Distribution Model

Natural Gas Price

Electricity Prices & Petroleum Product Demand

Electric Utility Market Model

Petroleum Product Prices

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 District (PADD) I; the second of PADD's II, III, and IV; and the third of PADD 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 has been used since 1997. Prior to that 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 represented petroleum refining and marketing in the Intermediate Future Forecasting System, used econometric equations to represent the relationship between refinery production costs (product costs) and product yields. The econometric equations were estimated from pseudo data derived from a refinery linear programming model. Pseudo data 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 pseudo data. An accounting/econometric framework was used to estimate sources of supply to meet demand. Product imports were 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 were not being reflected in the results since regional production levels were not represented.

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

- The OMM could not model changes in product specifications such as those included in the Clean Air Act Amendments (CAAA).

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

---

[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).

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

In addition, any changes to refinery operating scenarios within OMM (whether significant or minor) would involve a three-step process -- (1) modify the linear programming model to reflect the changes, (2) rerun the LP model to generate new pseudo data (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 PADD I; the second of PADD's II, III, and IV; and the third of PADD 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 and other environmental legislation.

The costs of producing new formulations of gasoline and diesel fuel that are required by State and Federal regulations 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, except that the sulfur content of all gasoline will

be phased-down to less than 10 percent of recent levels to reflect new regulations published by EPA in Feruary 2000.[2] Proposed fuel changes can be modeled by changing the specifications used by PMM.

Motor Gasoline Specifications

The PMM models the production and distribution of three different types of gasoline: conventional, oxygenated, and reformulated (Phase 2).   The following specifications are included in PMM to differentiate between conventional 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).

The sulfur specification for gasoline is reduced to reflect recent regulations requiring the average annual sulfur content of all gasoline used in the United States to be phased-down to 30 ppm between the years 2004 and 2007. PMM assumes that RFG has an average annual sulfur content of 135 ppm in 2000 and will meet the 30ppm requirement in 2004. The reduction in sulfur content between now and 2004 is assumed to reflect incentives for "early reduction." The regional assumptions for phasing-down the sulfur in conventional gasoline account for less stringent sulfur requirements for small refineries and refineries in the Rocky Mountain region. The 30 ppm annual average standard is not fully realized in conventional gasoline until 2008 due to allowances for small refineries.

Starting in 1998 the specifications for conventional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline." These specifications prevent the quality of conventional 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 conventional 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 United States since January 1995. Beginning in 1998, the EPA has certified 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 reflects "Phase 2" of the Complex

---

[2]U.S. Environmental Protection Agency, "Tier2" Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, February 2000, Washington, D.C.

Model requirements which began in 2000. 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.

The State of California currently uses its own set of performance based gasoline standards which instead of the Federal Complex Model standards. The PMM assumes that all West Coast refiners must meet the current California Air Resources Board "CARB2" requirements until 2002 when a new set of "CARB3" requirements will take their place. The CARB3 standards reflect the removal ot the oxygen requirement designed to complement the State's plans to ban the oxygenate, methyl tertiary butyl ether (MTBE) by the end of 2002. Because MTBE is currently the main source of oxygen for gasoline in the State, California has petitioned the EPA for a waiver to the Federal RFG oxygen requirement. As no waiver had been granted prior to AEO2001, PMM reflects no oxygen waiver in the three areas of California covered by the Federal reformulated gasoline program: Los Angeles, San Diego, and Sacramento. RFG in these areas is classified in the PMM as "RFG" while CARB gasoline without an oxygen requirement is classified as "RFH."

AEO2001 reflects legislation which bans or limits the use of MTBE in seven additional States: Arizona, Connecticut, Maine, Minnesota, Nebraska, New York, and South Dakota. Since the oxygen requirement on RFG is assumed to continue in these States, the MTBE ban is modeled as a requirement to produce ethanol blended RFG.

Arizona also has a reformulated gasoline program for the Phoenix area which is mandated by State law. Phoenix had previously been part of the Federal RFG program but opted out when State requirements were adopted. Phoenix is required to use CARB gasoline in the winter but may use either CARB or Federal RFG in the summer. Arizona is in a different model region than California and, for the sake of simplicity, is assumed to use RFG meeting Federal specifications.

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 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 conventional, 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 1999 level, with minor adjustments reflecting known changes in in oxygenated or reformulated gasoline programs. The Census Divisions 3 and 4

reformulated gasoline market shares were adjusted because St. Louis, Missouri, joined the Federal reformulated gasoline program in mid-1999.

In Census Division 9, 73 percent of gasoline is assumed to be reformulated. After 2002 when MTBE is banned in California, this set of reformulated gasoline is broken out into two groups: CARB gasoline that does not require oxygen and gasoline in the three areas of California covered by the Federal reformulated gasoline program (Los Angeles, San Diego, and Sacramento) which will continue to require 2.0 percent oxygen. The market shares assume that 46 percent of the gasoline in Census Division 9 will continue to meet the Federal 2.0 percent oxygen requirement, and 27 percent will meet CARB with no oxygen requirement.

Although the shares are assumed to remain constant after 2003, 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 CAAA90 diesel desulfurization regulations, low-sulfur diesel is differentiated from other distillates. Diesel fuel in Census Divisions 1 through 8 is assumed to meet Federal specifications including a maximum sulfur content of 500 parts per million (ppm) and a maximum aromatic content of 35 percent by volume.[3]   Diesel fuel in Census Division 9 is assumed to meet California Air Resources Board (CARB) standards which limit sulfur content to 500 ppm and aromatics to 10 percent by volume.[4]

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 1999* (online: http://www.eia.doe.gov/oil_gas/petroleum/data_ publications/fuel_oil_and_kerosene_sales/foks.html, September 2000). Since about 17 percent of current demand in the transportation sector is off highway, 85 percent of transportation demand for distillate fuel is assumed to be low sulfur. Consumption of low-sulfur distillate also occurs in the industrial sector where it is 50 percent of the market.

---

[3]Federal regulations require either a maximum 35 percent (volume) aromatics or a cetane index of 40.
[4]http://arbis.arb.ca.gov/diesel/diesregs/pdf

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[5] 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 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. An average local tax of 2 cents per gallon is also assumed to remain constant in real terms.[6]

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 crude oils for each category may differ because different crude streams make up the composites. For domestic crude oil, an estimate

---

[5]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).

[6]American Petroleum Institute, *How Much We Pay For Gasoline: 1997 Annual Review,* page 4 (Washington, DC, April 1998).

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 District (PADD) I, while the second, includes PADD's II, II, and IV, and the third includes PADD 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 crude unit (ACU) is limited to 1.0 million barrels per day in each refining region in a 3-year period.

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 in AEO2001 assume a 15-percent hurdle rate in the decision to invest and a 15-percent rate of return over a 15-year plant life.   These variables may be adjusted for sensitivity analysis, and the assumed hurdle rate and the rate of return may be different.

Capacity expansion is done in 3-year increments. For example, after the model has reached a solution for forecast year 2001, the PMM looks ahead and determines the optimal capacities given the demands and prices existing in the 2004 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 2002, 25 percent in 2003, and 25 percent in 2004. At the end of 2004, the cycle begins anew, looking ahead to 2007.

Strategic Petroleum Reserve Fill Rate

The PMM assumes no additions for the Strategic Petroleum Reserve during the forecast period. Any SPR draw is assumed to be in the form of a swap with a zero net annual change.

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.[7] 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. Since 1998 reformulated gasoline has been required to meet a performance based definition, "the Complex Model." The more stringent "Phase II" Complex Model performance measures have been in effect since January of 2000.

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.

"Tier2" Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements were finalized by EPA in February 2000. This regulation requires that the average annual sulfur content of all gasoline used in the United States be phased-down to 30 ppm between the years 2004 and 2007. The 30 ppm annual average standard is not fully realized in conventional gasoline until 2008 due to allowances for small refineries.

---

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

The Federal Highway Bill of 1998 extended the current tax credit for ethanol through 2007 but stipulated that the 54 cents per gallon credit be reduced to 53 cents in 2001, 52 cents in 2003, and 51 cents in 2005. The PMM reflects an assumption that the credit will be extended at the nominal level of 51 cents per gallon through 2020.

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.[8] 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　Pseudo data/Econometric Equation Approach

The OMM, as described above, used a pseudo data/econometric equation approach. The objective of this approach was 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 represented the output of the LP for given sets of inputs, and the econometric equations provide a means to quickly access the results.

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

---

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

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 pseudo data, 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 is used for analytical studies as well as mid-range forecasting, reestimation of the equations would have been required 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 pseudo data/econometric equation approach was not considered as a basis for PMM.

3.4.2   Linear Approximation Approach

Another type of pseudo data approach, called the linear approximation or lookup approach, was considered. Pseudo data 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 pseudo data, 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 pseudo data 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 pseudo data/econometric equation approach.[9]

3.4.3   Abbreviated Linear Programming Approach

Extreme point modeling is similar to the pseudo data 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.[10]

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.

---

[9]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).

[10]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 pseudo data 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 pseudo data 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,[11] 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 pseudo data 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.

---

[11]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's the first year and first iteration, historical values are read and the LP matrix is loaded into memory to await processing in the PMM base year.

- **(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.

---

[1]Mathematical Programming System format.

- **(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 ether 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 2000 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 2001, capacity expansion is done in 3-year increments. The PMM looks ahead and determines the optimal capacities given the estimated demands and prices expected in the 2004 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 2002, 25 percent in 2003 and 25 percent in 2004. At the end of 2004 the cycle begins anew.

Figure 4.1 PMM Flow Diagram
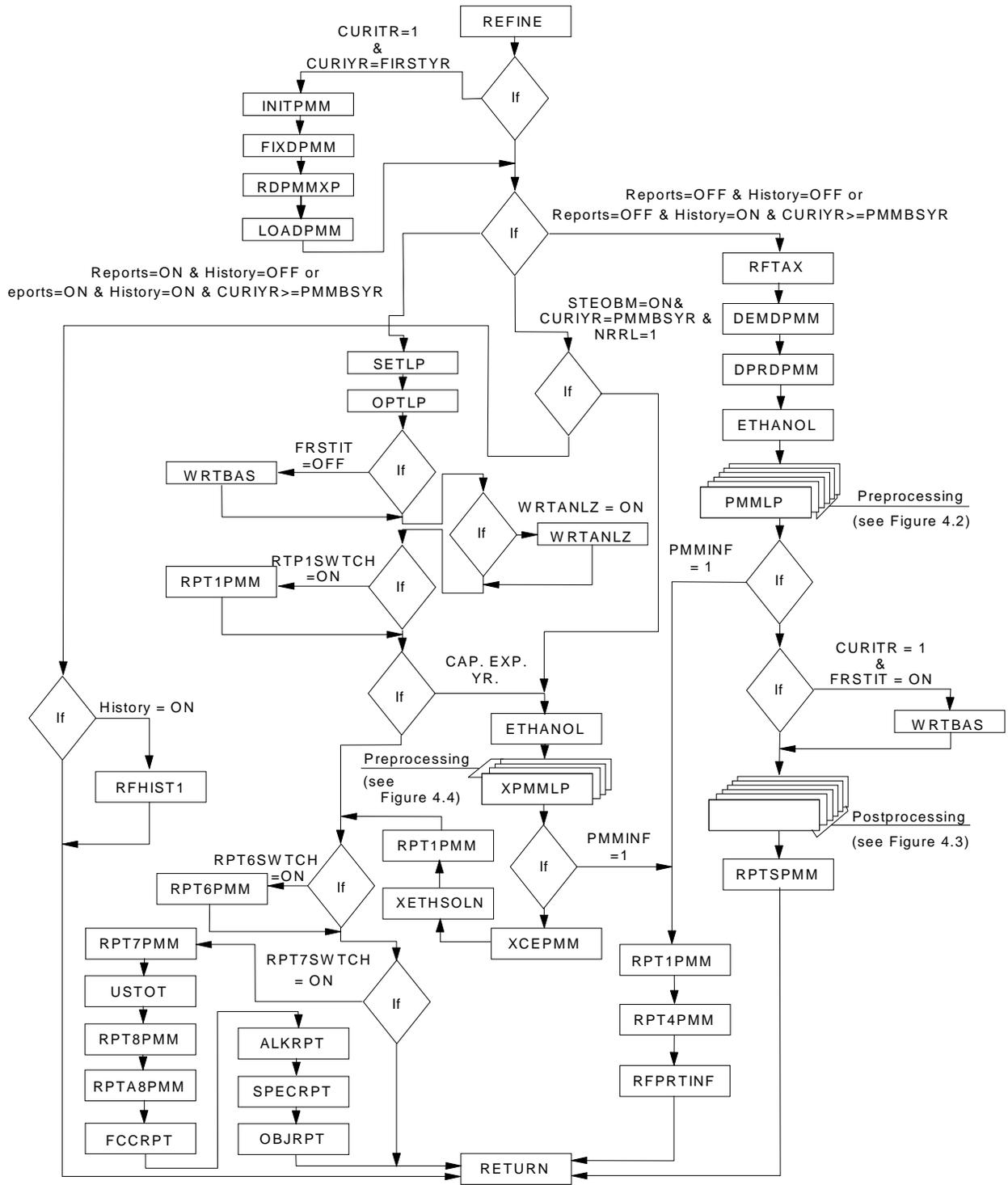
Figure 4.2 Matrix Preprocessing Subroutines
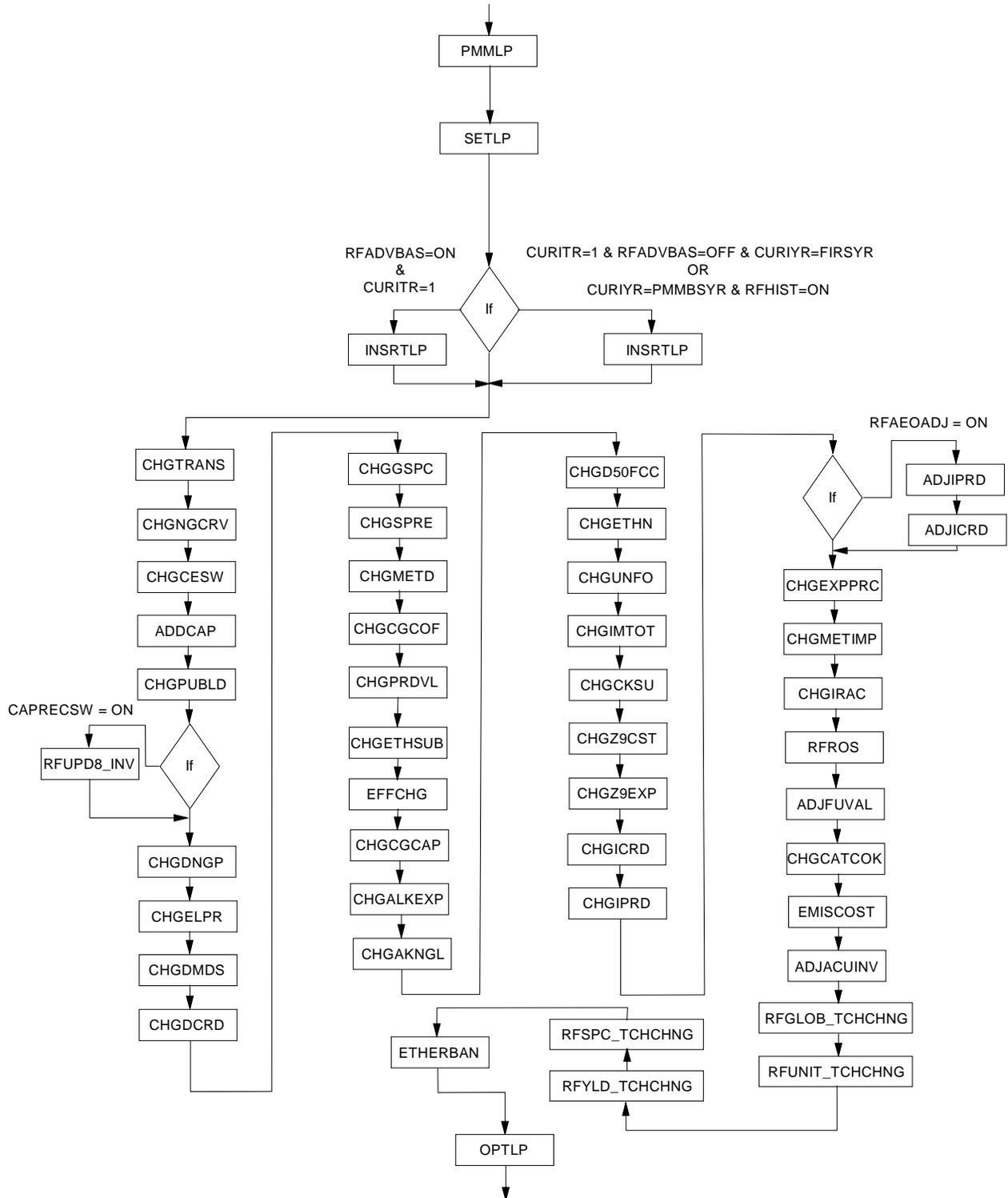
Figure 4.3 Matrix Postprocessing Subroutines

```
        ↓
   ┌─────────────┐
   │   E85TXC2   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   PMMOUT2   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   PRMUPMM   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   DSTCPMM   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   COGNPMM   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   ELPMMRD   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   SULFPMM   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   PMMRFFU   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   RFDMDFU   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   PMMOUTP   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   PMMOUT3   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   DCRDPRC   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   WCNVFCT   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │    DOMU     │
   └─────────────┘
        ↓
   ┌─────────────┐
   │  FCCMODOP   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   ALKMODE   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   GETPMMO   │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   RFCAPX    │
   └─────────────┘
        ↓
   ┌─────────────┐
   │   MGSPCDL   │
   └─────────────┘
        ↓
```

Figure 4.4 Capacity Expansion Subroutines

XPMMLP

SETLP

INSTRLP

CHGCESW → CHGTRANS → CHGNGCRV → CHGPUINV

CAPRECSW = ON

RFUPD8_INV → If → CHGDNGP → CHGELPR → CHGDMDS

CHGDCRD → CHGGSPC → CHGMETD → CHGSPRE → CHGCGCOF → CHGPRDVL → CHGETHSUB → EFFCHG → CHGETHN

CHGCGCAP → CHGALKEXP → CHGAKNGL → CHGZ9CST → CHGZ9EXP → CHGUNFO → CHGCKSU → CHGIPRD → CHGICRD

RFAEOADJ = ON

If → ADJIPRD → ADJICRD

CHGEXPPRC → CHGMETIMP → RFROS → CHGIRAC → CHGZ9EXP → ADJFUVAL → CHGCATCOK → EMISCOST → ADJACUINV → RFGLOB_TCHCHNG → RFUNIT_TCHCHNG

ETHERBAN → RFSPC_TCHCHNG
RFYLD_TCHCHNG

OPTLP

WRTBAS

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:
>
> $$QBMET_{ck,yr} = 0.0$$
> $$PUCUM_{pd,pu,yr} = 0.0$$
> $$PUINV_{pd,pu,yr} = 0.0$$
> $$RFQDINPOT_{pd,yr} = 0.0$$
> $$PRDDMD_{pd,yr,pr} = 0.0$$
> $$CRDOTHOT_{pd,yr} = 0.0$$
> $$CRDUNACC_{pd,yr} = 0.0$$
> $$CRDSTWDR_{pd,yr} = 0.0$$
> $$CRDPRDSUP_{pd,yr} = 0.0$$
> $$PRDSTKWDR_{pd,yr} = 0.0$$
> $$BLDIMP_{pd,yr} = 0.0$$
> $$QEXCRDIN_{pd,yr,pu} = 0.0$$
> $$PUBASE_{pd,yr,pu} = 0.0$$
> $$PUBASEUT_{pd,yr,pu} = 0.0$$

$CFRGQ_{yr} = 5.253$	Conversion factor Reformulated Gasoline, MMBtu/Bbl
$CFTGQ_{yr} = 5.253$	Conversion factor Conventional Gasoline, MMBtu/Bbl
$PETTR_{yr,6} = 11.53$	E85 price for history and STEO years, $/MMBtu
$PETTR_{yr,7} = 11.99$	

$PETTR_{yr,8} = 12.12$

$PETTR_{yr,9} = 10.58$

$PETTR_{yr,10} = 10.71$

$PETTR_{yr,11} = 12.56$

$PMETR_{yr,6} = 9.23$ M85 price for history and STEO years, $/MMBtu

$PMETR_{yr,7} = 8.33$

$PMETR_{yr,8} = 9.87$

$PMETR_{yr,9} = 6.63$

$PMETR_{yr,10} = 7.71$

$PMETR_{yr,11} = 9.99$

where:

pd = 1,2,3: refinery regions (PAD Districts 1, 2-3-4, 5)

cd = 1,2,...11: Census Division, CA, and totals

pu = 1,2,...72: Processing unit identifier index

yr = 1,2,...31: NEMS year index

pr = 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

              MU2PRDS   Sectoral end-use markups

              QDCRDCF   Fixed Data input file

              RFINVEST   Investment Data input file

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

Purpose: The RDPMMXP subroutine reads the SPRFLRT input file and updates PMM specific expectation 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 processing 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 the 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 1999.

Purpose: RFHIST1 reads in history data from an external file and updates PMM output data for history years 1990 to 1999 and STEO year 2000 and 2001.

Equations: None.

Input File: ELCGPUR PMM historical data input file

(PMM_NEXTDATA) Advances file pointer one record.

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

> Equations: None.

(RFTAX) Aggregates State and Federal petroleum product taxes.

> Purpose: RFTAX aggregates the State's 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. Disaggregates gasoline and distillate fuel into types. Calculates U.S. total petroleum product demand by sectors.

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

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

> The conversion from trillion Btu to MMbbl/d is captured in the following variables:

$$RFQ(PR)_{cd} = (Q(PR)AS_{cd,yr}/CF(PR)Q_{yr}) / 365$$

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

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

> where;

> PRDDMD = product demand by Census division (Mbbl/d)
> RFQ(PR) = product demand by Census division (MMbbl/d)
> Q(PR)AS = product demand in all sectors

Q(FPR)RF = product consumed for refinery fuel (applies only to products LG, RL, RH, DS, PC, SG, and OT)

CF(PR)Q = conversion factor (MMBtu/bbl)

(PR) = product types

(FPR) = refinery fuel products identifier

cd = Census divisions 1 through 9

pd = refinery regions 1,2,3 (PAD Districts 1, 2-3-4, 5)

yr = forecast year

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:

$$PRDDMD_{cd,yr,t+1} = ((QMGAS_{cd,yr}/CF(t)Q_{yr}) / 365 * 1000) * MGSHR_{yr,t,cd}$$

where;

PRDDMD = product demand by Census division

t = motor gasoline product designator index (1,2,3,4)

MGSHR = motor gasoline market shares

Refer to Appendix F (F.8) for more information on the derivation of the gasoline market shares, MGSHR.

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

$$PRDDMD_{cd,yr,13} = ((DSLSPLT*QDSTR(I,J)) + (DSLIND*QDSIN(I,J))) /CFDSQ/365*1000$$

where:

13 = product index for low sulfur diesel (DSL)

DSLSPLT = 0.85

DSLIND = 0.50

QDSTR = quantity of transportation distillate

QDSIN = quantity of industrial 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:

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

where;

11 = total U.S. demand index

pr = product index 1 through 20

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 and Natural Gas Transmission and Distribution Model.

Equations: None.

(ETHANOL) Calculates the ethanol supply step functions.

Purpose: Calculates the ethanol supply step functions for both corn and biomass based ethanol. Ethanol is used in the manufacture of gasoline, E85, and ETBE.

Equations: See Appendix I for a more detailed description of the biofuels supply submodule.

(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 and BAXPMM1 (for capacity expansion) 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 SCOLLP subroutine and calculates the processing unit build and investment bounds.

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

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

where:

PUINV = processing unit investment bound, Mbbl/cd
$BLD_{pd,pu,yr+3}$ = processing unit expansion as determined in expansion year yr
pu = processing unit index, 1 through 72
pd = refinery regions 1,2,3 (PAD Districts 1, 2-3-4, 5)
yr = NEMS index years 12,15,18,21,24,27,30

The decision to allow half of the expansion to come on line in the first year of each 3-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. Capacity expansion for the crude unit has been limited to 1.6 MBCD for each refining region in the low macroeconomic and high world oil price cases and 1.25 MBCD for each region for all other cases.

Processing unit cumulative builds, PUCUM is:

$PUCUM_{pd,pu,yr}$ = 0; when yr = 9
$PUCUM_{pd,pu,yr+2}$=$PUCUM_{pd,pu,yr+1}$ + $PUINV_{pd,pu,yr+1}$
$PUCUM_{pd,pu,yr+3}$=$PUCUM_{pd,pu,yr+2}$ + $PUINV_{pd,pu,yr+2}$
$PUCUM_{pd,pu,yr+4}$=$PUCUM_{pd,pu,yr+3}$ + $PUINV_{pd,pu,yr+3}$

pu = processing unit index, 1 through 72
pd = refinery regions 1,2,3 (PAD Districts 1, 2-3-4, 5)
yr = NEMS index years 12,15,18,21,24,27,30

(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

(XETHSOLN) Update Common Block Variables for ethanol production

    Purpose: Updates the PMM and NEMS system common block values of ethanol production volumes by NEMS by type of feedstock.   This is done at each iteration for every projection year.

    Equations: Column activity solution values of the PMM LP, representing total ethanol production are read and corresponding common block variables are updated.

(RPT4PMM) Write report 4, PMM iteration reports. (Exists, but no longer used in PMM.)

    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, OML formatted tables, supply curves and demands.

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

    Equations: None.

    Output File: IMPCURV OML data table output file

(RPTSPMM) Write additional reports, PMM forecast reports.

Purpose: This subroutine calls the report writer subroutines (including RPT7PMK, RPT7PMM, USTOT, RPT8PMM, RPTA8PMM, FCCRPT, ALKRPT, SPECRPT, OBJRPT) and overwrites to an external file (PMM analyst reports) each NEMS iteration and at the end of a NEMS run.

Equations: None.

Output File: PMMRPTS PMM reports output file

(RPT7PMM) Write report 7 (US end-use prices without Carbon tax), PMM forecast reports.

Purpose: RPT7PMM extracts solution values from the LP using the SCOLLP and SROWLP subroutines and overwrites 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

(RPT7PMK) Write report 7 (US end-use prices with Carbon tax), PMM forecast reports.

Purpose: RPT7PMK extracts solution values from the LP using the SCOLLP and SROWLP subroutines and overwrites 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 cracker's 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.

(CHGTRANS)   Updates the transportation costs of crude and product.

> Purpose: Update the crude and product transportation cost with the United States.

> 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 price 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 50 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 80 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 step 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 steps of the supply curve and the sum of activity levels on all steps of the supply curve from the previous NEMS iteration solution. If the upper bound on the first step of the supply curve, just described falls below the lower bound on the first step of the curve, then the upper bound is set at value 1 percent above

the lower bound on the first step 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: If the STEO benchmarking switch is off, this subroutine sets the upper and lower bounds for the processing units investment colums to zero during initial model startup. During the first year that 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.

(RFUPD8_INV) Update Investment Coefficients for Capacity Build and Investment Variables

> Purpose: This subroutine generates new capital recovery, fixed operating cost, and investment information (using subroutine RFINVST) and updates the capacity build and investment coefficients in the LP objective function row and other constraint rows (using subroutine CVALLP).

Equations: The subroutine RFINVST uses "Refinery Investment Recovery Thresholds" methodology defined in Appendix F (F.1) to generate the capital recovery, fixed operating cost, and total investment information. The first two components are then added and multiplied by an investment location factor and an environmental factor (and by -1). Next, in order to maintain an accounting of previous investment levels, this value is averaged using the function ADJBLD_COEF. The objective function row coefficients identified above are updated using these results. However, if the model is being set up for capacity expansion, then the original value, not the averaged value, is used to update the investment coefficient only. The original fixed cost and investment information are also used to update other row constraint coefficients that intersect the investment variable.

(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 District, translated into refinery regions (1=PADD I, 2=PADDs II,III,IV, 3=PADD V). 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 refining region (1=PADD I, 2=PADDs II,III,IV, 3=PADD V), 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 most products, the upper and lower bounds are equal. The bounds are set at the level of demand for each

product in each Census division. During the capacity expansion iteration the CHGDMDS updates bounds using the expected demands variables. CHGDMDS can also used to set bounds for product(s) subject to current laws and regulation, such as MTBE ban in California starting 2003.

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: 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: Sub-specification blends of reformulated and high-oxygenated-conventional gasoline are calculated for ethanol blends for these fuels using the percent ethanol blended.

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

Purpose: Sets the upper and lower bounds for SPR additions and non-Alaska crude oil exports. For both items, the upper and lower bounds are equal and are set using the CBNDLP subroutine. The bounds on SPR additions are set as exogenous inputs to the program, while non-Alaska crude oil exports are a function of total exports.

Equations: Total exports are calculated using a regression equation, with non-Alaska exports set at 40 percent of the total.

(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: $COEF_{pd,yr} = CNST_{pd} * PELAS_{cd,yr} * CFELBK$

   where:
   COEF = sales to grid coefficient
   CNST = Percent sales to grid for each refinery region *pd* based on historical data (see section F.15).
   PELAS = Prices of electricity to all sectors
   CFELBK = conversion factor, $3412 * 10^{-6}$ MMBTU/KWH
   pd = refinery regions 1,2,3 (PAD Districts 1, 2-3-4, 5)
   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 coefficients for the product demand columns in the objective row are updated as a function of corresponding end-use prices resulting from the previous NEMS iteration. For coke, the update is 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 (from corn or cellulose) blended into motor gasoline. Only the ethanol portion of E85 receives the ethanol subsidy

   Equations: The ethanol subsidy is set at $22.68 /Bbl in 1999 (nominal dollars), $22.26 /Bbl in 2000 and 2001 (nominal dollars), $21.84 /Bbl in 2002, 2003, and 2004 (nominal dollars), and $21.42 /Bbl after 2004 (nominal dollars). All these prices are converted to 1987 dollars (using the macroeconomic GDP deflator) before being put into the matrix; therefore, the model sees the ethanol subsidy declining in real terms over the entire forecast.

(EFFCHG) Updates the efficiencies for steam, electricity, and natural gas.

> Purpose: This subroutine updates the efficiency coefficients for steam, electricity, and natural gas in the NEMS hitech scenario only (using subroutine CVALLP).

> Equations: Sets percentage efficiency improvement based on estimated total carbon emissions.

(CHGCGCAP) Updates the refinery cogeneration capacities.

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

> Equations: No planned additions for *AEO2001* due to unavailable cogeneration data.

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

> Purpose: The LP Alaskan export crude supply curve is updated.

> Equations: The price steps on the supply curve are set as a function of world oil prices such that the price is 83.2 percent of the world oil price. Total Alaskan exports are set at 60 percent of total crude exports, with each step of the supply curve (6 steps total) representing 1/6 th of this volume. These prices and volumes were set based on analyst judgment.

(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 (winter) mode in the FCC.

> 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 throughput. 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 values determined by the Emission Policy Module.

(CHGETHN) Update ethanol supply curves in LP for both corn and cellulose sources.

> 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. See Appendix I for a more detailed description of the ethanol supply curves.

> Equations: None.

(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:

$$ARB_{yr} = 0.90 * WOP_{yr}$$
$$NPP_{yr} = 1.14 * WOP_{yr}$$
$$HGM_{yr} = 1.05 * WOP_{yr}$$

> 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

(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. Costs to export coke are set at 3.15 times the high sulfur coke costs. 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 times 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 10 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 refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) and five crude types to the PMM. These imported crude supply curves represent three price-quantity relationships for each imported crude in each refining region. 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 refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V), costs are adjusted as follows: the imported crude prices are 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 refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V). 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 makes adjustments to the international supply curve prices and/or volumes.

Equations: Adjusts the prices on the imported product supply curves to calibrate the petroleum product imports to values indicated in the *Petroleum Supply Annual 1999.* Adjustments are made to imports volumes and prices as follows. Note: volume adjustments for N6I and N6B occur only on the first step at a level one third that listed below.

Imported product	Price Adjustment	Volume Adjustment	Region
LPG	2.10	15.0	1
TRG	1.00	10.0	1
RFG	1.20	50.0	1
JTA	0.00	30.0	1
N2H	0.00	20.0	1
DSL	0.00	10.0	1
N6I	0.00	10.0	1
N6B	0.00	10.0	1
OTH	0.00	85.0	1
PCF	0.00	20.0	1
MET	0.00	0.0	1
MTB	0.00	0.0	1
LPG	3.00	0.0	2
TRG	3.50	0.0	2
RFG	3.00	0.0	2
JTA	-1.00	0.0	2
N2H	0.00	0.0	2
DSL	0.00	0.0	2
N6I	2.00	0.0	2
N6B	2.00	0.0	2
OTH	0.00	0.0	2
PCF	0.00	0.0	2
MET	0.00	0.0	2
MTB	0.00	0.0	2
LPG	2.10	0.0	3
TRG	0.00	0.0	3
RFG	0.00	0.0	3
JTA	0.00	0.0	3
N2H	0.00	0.0	3
DSL	0.00	0.0	3
N6I	0.00	10.0	3
N6B	1.00	0.0	3
OTH	1.00	15.0	3
PCF	0.00	10.0	3
MET	0.00	0.0	3
MTB	0.00	0.0	3

(CHGEXPPRC) Update exported petroleum product prices and demand limits.

Purpose: This subroutine updates the objective row and upper and lower bounds for each exported petroleum product (except coke).

Equations: Set prices for exported products (excluding coke) to 90 percent of the imported product prices defined on the first step of the import supply curve. Also, set the upper and lower bounds on exported products (excluding coke) as a function of regional product demand, as follows:

$$\text{LOWBND} = 0.65 * \text{EXPRDDMD}_{xpr,pd} * \text{DUMRAT} * \text{EXPMIN}_{xpr,pd} / 100.$$
$$\text{UPBND} \quad = 0.65 * \text{EXPRDDMD}_{xpr,pd} * \text{DUMRAT} * \text{EXPMAX}_{xpr,pd} / 100.$$

for PCF in CD = 9,	UPBND = UPBND * 6.5
for OTH in CD = 9,	UPBND = UPBND * 10.0
for years ≤ 1996,	DUMRAT = 1
for years > 1996,	DUMRAT = DUMTOT1 / DUMTOT2

Using regression analyses:
$$\text{DUMTOT1} = [\ 7.942 - (0.4073 * (\text{RFPQIPRDT}_{6,yr,2} / \text{RFQPRDT}_{11,yr}\ )\ )\ *\text{RFQPRDT}_{11,yr}\ *10^6$$
$$\text{DUMTOT2} = [\ 7.942 - (0.4073 * (\text{RFPQIPRDT}_{6,y-1r,2} / \text{RFQPRDT}_{11,yr-1}\ )\ )\ *\text{RFQPRDT}_{11,yr-1}\ *10^6$$

where,

UPBND = upper bound on export product demands
LOWBND = lower bound on export product demands
EXPRDDMD = product demand accumulated into PAD Districts (I - V)
EXPMIN = factor to establish minimum product export range
EXPMAX = factor to establish maximum product export range
DUMRAT = ratio of estimated exports for year yr and yr-1
DUMTOT1 = estimated exports in year yr
DUMTOT2 = estimated exports in year yr-1
RFPQIPRDT = total imports for each product
RFQPRDT = total supply for each product
yr = year index
xpr = exported product index
pd = PAD District containing Census Division export region (I=>2, II=>3, III=>7, IV=>8, V=>9)

(CHGMETIMP) Updates the methanol imports supply function.

> Purpose: This subroutine updates the 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 to $0.50/bbl off the world oil price. This tolerance level was chosen based on analyst judgement.

(RFROS) Updates the renewable oxygenates constraint.

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

> Equations: The motor gasoline minimum renewable oxygenates constraints are set at 0, 15, and 30 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 AEO2000 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 2000 this factor was 0.997.

> 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 90 percent of

the current value in the PMM database. This value is calibrated to reflect catalytic coke use as reported by the *Petroleum Supply Annual 1999.*

(ADJACUINV) Updates the crude units investment costs

Purpose: This subroutine updates the atmospheric 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.

(RFGLOB_TCHCHNG) Model technology changes as reflected by other variable cost (OVC) adjustment in all process units.

Purpose: This subroutine approximates technology changes in the refining industry by adjusting the OVC coefficient (by a user-specified amount) in the OVC constraint row for all process units (in the refinery, merchant, and gas plant).

Equations: If the global technology switch is on and the model year lies between the begining and end phase-in year, then the original OVC price coefficients for all processing units (except those also flagged for unit-specific technology improvement updates) included in the OVC constraint row are updated gradually during the phase-in years.

(RFUNIT_TCHCHNG) Model technology changes as reflected by other variable cost (OVC) adjustment only in specified process units.

Purpose: This subroutine approximates technology changes for specific processing units in the refining industry by adjusting the corresponding OVC coefficient in the OVC constraint row by a user-specified amount.

Equations: If the unit-specific technology switch is on and the model year lies between the begining and end phase-in year, then the original OVC price coefficients for the specified unit(s) included in the OVC constraint row are updated gradually during the phase-in years.

(RFYLD_TCHCHNG) Model technology changes as reflected by process stream adjustment in a process unit.

Purpose: This subroutine approximates technology changes in the refining industry by adjusting the the process stream yields coefficient (by a user-specified amount) of a user-defined process unit.

Equations: None.

(RFSPC_TCHCHNG) Model technology changes as reflected by process stream quality adjustment.

Purpose: This subroutine approximates technology changes in the refining industry by adjusting the process stream qualities (by a user-specified amount).

Equations: None.

(ETHERBAN) Updates motor gasoline blending constraints to eliminate ether blending in PADD 5 refiners.

Purpose: This subroutine updates PADD 5 gasoline blending constraints to eliminate ether blending into gasoline. This contraint takes effect in 2003 for California gasolines.

Equations: None.

4.3 Matrix Postprocessing Subroutines

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

(E85TXC2) Calculate ethanol consumption and E85 Tax Subsidy Adjustment.

Purpose: This subroutine retrieves the quantity and cost of ethanol from corn and cellulose using the SCOLLP subroutine; and calculates ethanol consumption and the E85 tax subsidy adjustment for carbon mitigation.

Equations: Daily ethanol consumption from cellulose is converted into MMgal/yr. The E85 tax subsidy adjustment $/bbl is calculated as the difference between the cost of ethanol from cellulose and the cost of ethanol from corn.

(PMMOUT2) 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. 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: Marginal prices for each gasoline are retrieved from the LP solution and refinery fixed costs are added to the marginal prices of each product:

$$P_{pr,cd,yr} = VALUE_{pr,cd} + RFPRDFX_{cd,yr,pr} * FXPCT$$
$$RFDL(pr)_{cd,yr} = VALUE_{pr,cd}$$

where:

RFDL(pr) = refinery marginal prices for each petroleum product pr (w/o markup)

P = refinery gate price of petroleum product pr [PMG(pr) and P(pr)] (w/ markup)

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. Fixed costs are allocated only at 80, 80, 90, and 100 percent during the years 2001 to 2004 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

yr = NEMS index years

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

$$P_{pr,cd,yr} = 42 * (INTCP + SLP * (WOP_{yr}/42) + (CNSNT * ((QRL_{cd,yr} + QRH_{cd,yr})/QPRD_{cd,yr})))$$

where:

P = refinery gate price of low and high sulfur residual fuel [PRLEQ, PRHEQ, PRLUTEQ, PRHUTEQ]

INTCP = -0.057507 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 (N6I, N6B, N67, N68)

cd = Census division

42 = gallons per barrel

yr = NEMS index years

Demands for all four types of gasoline are summed by Census division, and a national gasoline total is estmated by summing across Census Divisions:

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

$$MGDMDGT = \sum_{cd=1,9} MGDMDT_{cd}$$

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

National demand for each type of gasoline is estimated by:

$$MGDMD(t) = \sum_{cd=1,9} PRDDMD_{cd,yr,t}$$

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

A weighted average gasoline price (with and without markups) is calculated for each Census division based on prices of the various types of gasoline.

$$PALMG_{cd,yr} = \sum_{pr=2,3,4,5} ((PMG(pr)_{yr,cd} * PRDDMD_{pr,yr,cd})/MGDMDT_{pr})$$

$$RFDLMG_{cd,yr} = \sum_{pr=2,3,4,5} ((RFDL(pr)_{yr,cd} * PRDDMD_{pr,yr,cd})/MGDMDT_{pr})$$

where:
PALMG = weighted average gasoline price, with markups
RFDLMG = weighted average gasoline price, without markups
PMG(pr) = refinery gate price of motor gasoline product pr
PRDDMD = product demand (motor gasoline only) by Census Division
MGDMDT = total motor gasoline demand by Census Division
RFDL(pr) = refinery marginal prices for motor gasoline (pr) product only
pr = motor gasoline index 2,3,4,5
cd = Census division 1 through 9
yr = NEMS year index

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

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

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

where:

P = refinery gate price of petroleum product pr [PMG(pr) and P(pr)] (w/ markup)

RFDL(pr) = refinery marginal prices for each petroleum product pr (w/o markup)

PRDDMD = product demand by Census Division

MGDMDT = total motor gasoline demand by Census Division

pr = petroleum product index 1 through 20

cd = Census division 1 through 9

t = total (across CD) product demand index, 11, for product pr

A composite national average gasoline price is estimated by:

$$PALMG_{t,yr} = \sum_{prx=2,3,4,5} (PMG(pr)_{t,yr} * MGDMD(prx) / MGDMDGT)$$

$$RFDLMG_{t,yr} = \sum_{prx=2,3,4,5} ((RFDL(pr)_{t,yr} * MGDMD(prx) / MGDMDGT)$$

where:

PALMG = national weighted average gasoline price, with markups

RFDLMG = national weighted average gasoline price, without markups

PMG(pr) = refinery gate price of motor gasoline product pr

MGDMD(t) = national demand for each gasoline type (t)

MGDMDGT = total national motor gasoline demand

RFDL(pr) = refinery marginal prices for motor gasoline (pr) product only

pr = motor gasoline ID

prx = motor gasoline index, 2,3,4,5

yr = NEMS year index

t = total (across CD) product demand index, 11, for product pr

(DSTCPMM) Estimate atmospheric distillation capacity and refinery utilization.

Purpose: Extracts capacity expansion information from LP. Estimates annual distillation capacity, utilization, and annual and cumulative capacity expansion. Totals refinery region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) estimates to national estimates.

Equations: Refinery distillation capacity is defined as a percentage (ranging from 93 percent to 96 percent for *AEO2001*) of total capacity to account for over optimization 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. 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 refinery region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) data to the Census divisions.

(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 refinery regions (1=PADD I, 2=PADD's II,III,IV, 3=PADD V).

Equations: Retrieve fuel use values from the LP using the SCOLLP subroutine and converts units to MMBtu. Sums refinery region 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 refinery region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) level estimates for refinery consumption to Census division demands.

Equations: Calculates refinery fuel consumption in each Census division based on refinery region 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 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 refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) and 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 and exports, natural gas liquids, and motor gasoline.

Equations: The heat rate for imported petroleum product is calculated using the weighted average of each product's heat rate. This calculation is also performed for the exported petroleum product's heat rate and the natural gas liquids average heat rate. Each motor gasoline's heat rate is used to calculate 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 in the LP solution.

Equations: None.

(ALKMODE) Retrieves the utilizations for the alkylation units' modes of operation.

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

Equations: None.

(GETPMMO) Retrieve objective function values from the LP solution.

Purpose: This subroutine retrieves 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 Optimization Modeling Library (OML) specific LP 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

APPENDIX A PMM Data and Outputs

This appendix is divided in three parts; Section A.1 lists the variables and definitions used in the PMM, Section A.2 lists the data sources, and Section A.3 lists the data tables (and their structures) used by the MRM to create the initial PMM matrix that is loaded into 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 refining regions (beginning with *AEO98*, 1= PADD I, 2= PADDs II,III,IV, 3= PADD V).

A.1 PMM Variables and Definitions

This section presents the PMM variable names and definitions associated with the linear programming (LP) matrix, PMM outputs, PMM inputs, and internally used variables.

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
A (cd) TRGTRH	Mbbl/cd	SBTRGTRH
A (cd) G08TRH	Mbbl/cd	SBG08TRH, RFETHMGS
A (cd) G08TRG	Mbbl/cd	SBG08TRG, RFETHMGS
A (cd) G08RFH	Mbbl/cd	SBG08RFH, RFETHMGS
A (cd) G08RFG	Mbbl/cd	SBG08RFG, RFETHMGS
A (pd) (prd)	Mbbl/cd	RFDPRD(prd)
A (pd) SST	Mbbl/cd	RFDPRDTRG, QPRDRF
A (pd) SSR	Mbbl/cd	RFDPRDRFG, QPRDRF
A (pd) SSE	Mbbl/cd	RFDPRDTRG, QPRDRF
A (pd) STM	Mbbl/cd	STMDMD
A (pd) ETHRFN	Mbbl/cd	RFETHETB
A (pd) (gbc)RFG	Mbbl/cd	RFGBCRFG
A (pd) (gbc)TRG	Mbbl/cd	RFGBCTRG
A@CRDDCR	Mbbl/cd	RFCRDDCR
A@CRDEXP	Mbbl/cd	RFQEXCRD
A@CRDL48	Mbbl/cd	RFCRDL48
A@CRDAKA	Mbbl/cd	RFCRDAKA

NAME	LP Units	NEMS Variable
A@CRDTOT	Mbbl/cd	RFCRDTOT
A@CRDFCR	Mbbl/cd	RFQICRD
A@ETHPRD	Mbbl/cd	RFETHD
A@FUEL	Mbbl/cd	QCDUPD
A@GAIN	Mbbl/cd	RFQPRCG
A@INVST	MM$87/Yr	RFCAPEXP (or 0 or 50000)
A@MTBIMP	Mbbl/cd	RFMTBI
A@METIMP	Mbbl/cd	RFMETI, RFMETETH
A@METDEM	Mbbl/cd	RFMETCHM, RFMETETH
A@METM85	Mbbl/cd	RFMETM85, RFMETETH
A@NGFTOT	Mbbl/cd	RFNGFTOT
A@NGLPRD	Mbbl/cd	RFPQNGL
A@NGLRFN	Mbbl/cd	RFQNGLRF, NGLRF
A@NGSH2P	Mbbl/cd	OTHOXY
A@PRDEXP	Mbbl/cd	RFQEXPRDT
A@PRDIMP	Mbbl/cd	RFPQIPRDT (<9900)
A@PETCOK	Mbbl/cd	RFQPRCG
A@UNFIMP	Mbbl/cd	RFPQUFC
B (pd) ETB	$87/bbl	PETB
B (pd) TAE	$87/bbl	PTAE
B (pd) THE	$87/bbl	PTHE
B (pd) MTB	$87/bbl	PMTB2S
B (pd) THM	$87/bbl	PTHM
B (pd) TAM	$87/bbl	PTAM
B (pd) SRI	$87/bbl	PSRI
B (pd) FC8	$87/bbl	PFC8
B (pd) R10	$87/bbl	PR10
B (pd) ALB	$87/bbl	PALB
B (pd) KHL	$87/bbl	PKHL
B (pd) 2HL	$87/bbl	P2HL
B (pd) RSI	$87/bbl	PVAF
CAA (crd)	$87/bbl	RFCRDP, CRDTYPEP,WLLHDPR
C (pd) ALL	$87/bbl	PCRDRF
C (pd) AMH	$87/bbl	PCRDRF
C (pd) D (crdtype)	$87/bbl	PCRDRF,RFDCRDP,RDTYPEP,WLLHDPR
C (cd) ETHR (q(k))	Mbbl/cd,[$87/bbl]	WQETOH,SQETOH,CRNETHCD,[CRNCSTCD]
C (cd) ETCR (q(k))	Mbbl/cd,[$87/bbl]	WQETOH,SQETOH,CLLETHCD,CLLCAPCD,[CLLCSTCD]
C (pd) F (crdtype)	$87/bbl	PCRDRF
D (cd) ETH	$87/bbl	PETHANOL
D (cd)(prd) N (q(K))	Mbbl/cd,$87/bbl	QN,PN
D (cd)(prd) P (q(k))	Mbbl/cd,$87/bbl	QP,PP
D (cd)(prd) S1	Mbbl/cd	PRDDMD
D (cd) (prd) SX	Mbbl/cd	QPRDEX
D (cd) COKSX	$87/bbl, [Mbbl/cd]	RFWOP, PCOKH, [RFQEXPRDT]
D (cd) (prd) Z9	Mbbl/cd, [87$/bbl]	QPRDEXD, [RFWOP,WOPZ9EXP]
D (cd) COKZ9	$87/bbl	RFWOP, PCOKH, PRCPCNT
D (cd) (prd)	$87/bbl	RFDL (prd)
D@METS1	Mbbl/cd	PRDDMDME
E (pd) ACUINV	Mbbl/cd	RFDSTCAP, RFDSTUTL, RFDSCUM
E (pd) CGNINV	Mbbl/cd	EINVPD
E (pd) CGXINV	Mbbl/cd	EXINVPD
E (pd) (prcunit)INV	Mbbl/cd	PUBASEUT, PUINV, or Constants of 0, 1000

NAME	LP Units	NEMS Variable
E (pd) (emissn) (emisst)	MMton	RFEMISST
G (pd) CC3LPG	Mbbl/cd	QGPLTRF
G (pd) IC4LPG	Mbbl/cd	QGPLTRF
G (pd) NC4LPG	Mbbl/cd	QGPLTRF
G (pd) NATOTH	Mbbl/cd	QGPLTRF
G (pd) NATPCF	Mbbl/cd	QGPLTRF
G (pd) DGR	Bcf	QGPLTRF
G (pd) GPL01	Bcf	QGPLTRF
G (pd) IC4RFN	Mbbl/cd	QGPLTRF
G (pd) MOH01	Mbbl/cd	RFMETD, RFMETETH
G (pd) NC4RFN	Mbbl/cd	QGPLTRF
G (pd) NATRFN	Mbbl/cd	QGPLTRF
G (pd) PGSLPG	Mbbl/cd	QGPLTRF
G (pd) SC2CC1	Mbbl/cd	QGPLTRF
G (pd) SC3CC1	Mbbl/cd	QGPLTRF
H (pd) RFMPEH	Mbbl/cd	RFETHMCT
H (pd) RFMPMT	Mbbl/cd	RFMETMCT, RFMETETH
H (pd) ETXETB	Mbbl/cd	RFETBMCT
H (pd) ETXMTB	Mbbl/cd	RFMTBMCT
H (pd) GPMPI4	Mbbl/cd	QGPLTRF
H (pd) GPMPN4	Mbbl/cd	QGPLTRF
I (pd) (prd) Z9	$87/bbl	QPRDIMD
I (pd) (iprd) R (q(k))	Mbbl/cd,$87/bbl	PI(iprd), QI (iprd), QPRDIMP
I (pd) (iprd) R (q(k))	$87/bbl,Mbbl/cd	RFIPQ??, ITIM??SC, where ?? = LG GS RF LD DS RL RH JF OT PF
I (pd) MTBR (q(k))	Mbbl/cd	RETHRIMP
K (pd) (prcunit) CAP	Mbbl/cd	PUBASEUT
K (pd) ACUCAP	Mbbl/cd	DSTCAP, DSTUTL, RFBDSTCAP
K (pd) CGNCAP	MMlb/cd	RFCGCAPPD
K (pd) CGXCAP	MMlb/cd	RFCXCAPPD
L (pd) (prcunit)BLD	Mbbl/cd	PUBASEUT, PUCUM , PUINV, 0.0
L (pd) ACUBLD	Mbbl/cd	RFDSTCAP, RFDSTUTL,RFDSCUM
L (pd) CGNBLD	Mbbl/cd	LBLDPD
L (pd) CGXBLD	Mbbl/cd	LXBLDPD
M (pd) (prd)	$87/bbl	RFGT (prd)
N (pd) NGRFP (q(k))		NGRFUPIT
N (pd) NGRFN (q(k))		NGRFUPIT
N (pd) DGP	Bcf/day	PRNG_PADD, QNGPD
M (pd) (prd)	$87/bbl	RFGT (prd)
OBJ	$87./bbl	PMMOBJ
O@CRDSPR	Mbbl/cd	RFSPRFR
P (pd) COK	Mbbl/cd	QCDUPD, RFQPRCG, QCOKFU
PANGLQ1	BCF or Mbbl/cd	QGPLTBF
P (og) DCRQ1	Mbbl/cd	RFQTDCRD
P (pd)F(crdtype)Q(q(k))	Mbbl/cd,$87/bbl	RFIPQC (crdtype), QCRD, PCRD, FHLADD
P (pd) PFU	MFOED	PRPFU(5)
P (pd) PFF	MFOED	PRPFF(5)
Q (pd) RFG (spec)	$87/bbl	RFGSPCDL
Q (pd) TRG (spec)	$87/bbl	TRGSPCDL
Q(pd)(prd)(spec)(minmax)	Many	MGSPCS
R (pd) ALK (mode)	Mbbl/cd	ALKACT
R (pd) ACUF (crdtype)	Mbbl/cd	QCRDRF
R (pd) ACUD (crdtype)	Mbbl/cd	QCRDRF

NAME	LP Units	NEMS Variable
R (pd) ACUA (crdtype)	Mbbl/cd	QCRDRF
R (pd) CGNCGN	MM MWh/cd	RFCGGENPD
R (pd) CGXCGN	MM MWh/cd	RFCXGENPD
R (pd) ETHMTB	Mbbl/cd	RFMTBD
R (pd) ETHETB	M Bcf	RFETBD
R (pd) ETMTAE	M Bcf	RFTAED
R (pd) ETMTAM	M Bcf	RFTAMD
R (pd) ETMTHE	M Bcf	RFTHED
R (pd) ETMTHM	M Bcf	RFTHMD
R (pd) FUMN2H	Mbbl/cd	QDISFU
R (pd) FCC(mod)	Mbbl/cd	FCC (mod), FCCACT, FCCDUAL
R (pd) FUMN6I	Mbbl/cd	QRESFU
R (pd) FUMN6A	Mbbl/cd	QRESFU
R (pd) FUMN6B	Mbbl/cd	QRESFU
R (pd) FUMCC3	Mbbl/cd	QLPGFU
R (pd) FUMC2E	Mbbl/cd	QLPGFU
R (pd) FUMUC3	Mbbl/cd	QLPGFU
R (pd) FUMIC4	Mbbl/cd	QLPGFU
R (pd) FUMUC4	Mbbl/cd	QLPGFU
R (pd) FUMPGS	Mbbl/cd	QSTGFU
R (pd) FUMCC2	Mbbl/cd	QSTGFU
R (pd) FUMCC2	Mbbl/cd	QSTGFU
R (pd) FUMPGU	Mbbl/cd	QSTGFU
R (pd) FUMPGX	Mbbl/cd	QSTGFU
R (pd) FUMNGS	Mbbl/cd	QNTGFU
R (pd) FUMPGT	Mbbl/cd	QSTGFU
R (pd) FUM (rfothfu)	Mbbl/cd	QOTHFU
R (pd) FUM (pnfut)	Mbbl/cd	RFFMT
T (pd) UNFNPP	$87/bbl	RFWOP, NPPCOEF
T (pd) UNFHGM	$87/bbl	RFWOP, HGMCOEF
T (pd) UNFARB	$87/bbl	RFWOP, ARBCOEF
U (pd) KWH	$87/kWh	PELIN, RFELPURPD
U (pd) NGF	$87/MMcf	PGININ, OGWPRNG
VTPC (crd)	Mbbl/cd	FLOWCRD
VTPP (crd)	Mbbl/cd	FLOWPRD
VTPL (crd)	Mbbl/cd	FLOWLPG
W (pd) (prd) J (cd)	Mbbl/cd	FLOWPD_CT
W (pd) (prd) 4 (cd)	Mbbl/cd	FLOWPD_DT
W (pd) (prd) B (cd)	Mbbl/cd	FLOWPD_CB
W (pd) (prd) V (cd)	Mbbl/cd	FLOWPD_EBD
W (pd) (prd) O (cd)	Mbbl/cd	FLOWPD_LT
X (pd) CKLCOK	$87/bbl	RFWOP, PCOKL
X (pd) CKHCOK	$87/bbl	RFWOP, PCOLH
X (pd) SULSAL	$87/bbl	RFWOP, SULSAL
X (cd) ETHE85	Mbbl/cd	RFETHE85, ETHE85CD
X (cd) ETHRFG	Mbbl/cd	SBRFGRFG
X (cd) ETHRFH	Mbbl/cd	SBRFGRFH
X (cd) ETHTRG	Mbbl/cd	SBTRGTRG
ZZAMHTOT	Mbbl/cd	Function of WOP
Z (cd) ETHTAX	Mbbl/cd	ETHSUB, CORNETH, CORNSUB
Z (cd) ETCTAX	Mbbl/cd	ETHSUB, CELLETH, CELLSUB
Z@IRACX	$87/bbl	RFWOP
Z@IRACN	$87/bbl	RFWOP
Z@TOTCRD	$87/bbl	RFWOP, IRACN, IRACX

Code	Name	Values	No. in Set
(cd)	Census Divisions	1-9	9
(crdtype)	Crude Types	LL-HV	5
(emissn)	Emissions	VOC-CAR	6
(emisst)	Combustion/Noncombustion	C,N	
(gbc)	Gasoline Blend Component	00-12	13
(iprd)	Imported Products	LPG-DSL	12
(minmax)	Minimum or Maximum	N,X	
(og)	Oil and Gas Divisions	1-6,A	7
(pd)	Refinery Regions	E,B,W (*AEO2001*)	3-5
(pnfut)	Refinery Fuels	NGS-JNH	30
(prcunit)	Process Units	ACU-PFA	37
(prd)	Products	LPG-M85	20
(q(k))	Quantities	1-9	9
(rfothfu)	Refinery Fuel for Other	JIH-NPN	19
(spec)	Product Specificatons	RV-BZ	6

Code	Name	Values
DS	Imported product	Distillate
GS	Imported product	Conventional mogas
JF	Imported product	Jet Fuel
LD	Imported product	Low sulfur diesel
LG	Imported product	LPG
OT	Imported product	Other
PF	Imported product	Petrochemical Feeds
RF	Imported product	Reformulated mogas
RH	Imported product	High sulfur residual
RL	Imported product	Low sulfur residual

A.1.2 PMM Output Variables

REFINERY MODULE OUTPUT VARIABLES (pmmout)

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 (pmmrpt)

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

NAME	UNITS	DEFINITION
RFDPRDN6B(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; high sulfur oil
RFDPRDOTH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; other petroleum
RFDPRDPCF(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; petrochemical feeds
RFDPRDAST(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; asphalt & road oil
RFDPRDDSL(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; low sulfur diesel
RFDPRDSTG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; still gas
RFDPRDCOK(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; petroleum coke
RFDSCUM(MNUMPR,MNUMYR)	MMbbl/cd	Processin unit cumulative cap. expansion
RFBDSTCAP(MNUMPR,MNUMYR)	MMbbl/cd	Refinery base distillation capacity
RFETHD(MNUMYR)	MMbbl/cd	Domestic ethanol
RFMETD(MNUMYR)	MMbbl/cd	Domestic methanol
RFMETCHM(MNUMPR,MNUMYR)	MMbbl/cd	Chem. Demand for methanol
RFIPQRG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported reformulated mogas (P,Q)
RFIPQOT(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported other (P,Q)
RFIPQPF(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported petrochem feeds (P,Q)
RFIPQDL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported low sulfur distillate (P,Q)
RFCRDOTH(MNUMPR,MNUMYR	MMbbl/cd	Other crude imports by PAD District
BLDIMP(MNUMPR,MNUMYR)	MMbbl/cd	Blending component imports
RFMTBI(MNUMPR,MNUMYR)	MMbbl/cd	Imported MTBE
RFMTBD(MNUMPR,MNUMYR)	MMbbl/cd	Domestic MTBE production.
RFMETI(MNUMPR,MNUMYR)	MMbbl/cd	Imported methanol
RFETHE85(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for E85 production
RFMETM85(MNUMPR,MNUMYR)	MMbbl/cd	Methonal for M85 production
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
MUFTAX(MNUMYR,15)	$87/MMBtu	Federal motorgasoline tax
MGMUTR(MNUMCR,MNUMYR,2)	$87/bbl	Transportation Gasoline Markups
DSMURS(MNUMCR,MNUMYR,2)	$87/bbl	Residential Distillate Markups
DSMUTR(MNUMCR,MNUMYR,2)	$87/bbl	Transportation Distillate Markups
JFMUTR(MNUMCR,MNUMYR,2)	$87/bbl	Transportation Jet Fuel Markups
RFENVFX(MNUMCR,MNUMYR,20)	$87/bbl	Refinery Environmental Fixed Costs
DSSTTX(MNUMCR)	$87/bbl	Diesel State Tax
MGSTTX(MNUMCR)	$87/bbl	Gasoline State Tax
JFSTTX(MNUMCR)	$87/bbl	Jet Fuel State Tax
RFDPRDTRL(MNUMPR,MNUMYR)	Mbbl/cd	Domestic Production of Low Sulfur Gasoline
CRNETHCD(MNUMCR,MNUMYR)	Mbbl/cd	Ethanol produced from corn
CLLETHCD(MNUMCR,MNUMYR)	Mbbl/cd	Ethanol produced from cellulose

PRICE VARIABLES (mpblk)

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

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

NAME	UNITS	DEFINITION
CGREQ(MNUMCR,MNUMYR,5,2)	tBtu	Refinery Fuel Consumption
CGRECAP(MNUMCR,MNUMYR,5,2,2)	mW	Refinery Cogen Capacity
CGREGEN(MNUMCR,MNUMYR,5,2)	gWh	Refinery Cogen Generation

A.1.3 PMM Input Variables

QUANTITY VARIABLES (qblk)

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

NAME	UNITS	DEFINITION
QETTR(MNUMCR,MNUMYR)	MMBtu/Yr	Ethanol Transportation
QELRF(MNUMCR,MNUMYR)	MMBtu/Yr	Purchased Elec., Refinery
QELIN(MNUMCR,MNUMYR)	MMBtu/Yr	Purchased Elec., Industrial sector
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 (intout)

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)

NAME	UNITS	DEFINITION
ITIMRGSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Reformulated mogas
ITIMGSSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Tradition mogas
ITIMDSSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Distillate
ITIMLDSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low sulfur distillate
ITIMLRSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low sulfur. Resid.
ITIMHRSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	High sulfur Resid.
ITIMJFSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Jet fuel
ITIMLPSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	LPG
ITIMPFSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Petchemical Feedstocks
ITIMOTSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Other
ITIMMESC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Methanol
ITIMMTSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	MTBE
ITIMXGSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low S Gasoline
ITIMXDSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Ultra Low S Diesel

OIL AND GAS SUPPLY MODEL VARIABLES (ogsmout)

NAME	UNITS	DEFINITION
OGNGLAK(MNUMYR)	Mbbl/cd	NGL from Alaska

NATURAL GAS TRANSMISSION AND DISTRIBUTION SUPPLY MODEL VARIABLES (ngtdmout)

NAME	UNITS	DEFINITION
PRNG_PADD(MNUMPR,MNUMYR)	Bcf/Yr	Total dry gas production (W/L&P)

PRICE VARIABLES (mpblk, efpout)

NAME	UNITS	DEFINITION
PELIN(MNUMCR,MNUMYR)	$87/MMBTU	Purch. Elec. Industrial
PNGIN(MNUMCR,MNUMYR)	$87/MMBTU	Natural Gas. Industria
PGIIN(MNUMCR,MNUMYR)	$87/MMBtu	Noncore industrial sector prices
PELAS(MNUMCR,MNUMYR)	$87/MMBtu	Avg electricity prices for all sectors l
PELASMEN(MNUMNR,MNUMYR)	$87/kWh	Competitive energy comp. (All, by NERC)

RENEWABLE VARIABLES (wrenew)

NAME	UNITS	DEFINITION
WPETOH(MNCROP,MNUMCR,MNUMYR,MNETOH)	$87/bbl	Ethanol price/step

WQETOH(MNCROP,MNUMCR,MNUMYR,MNETOH)	Mbbl/cd	Ethanol quan/step
PBMET(MNUMCR,MNUMYR)	$87/MMBTU	Ethanol price
QBMET(MNUMCR,MNUMYR)	Mbbl/cd	Ethanol quantity

ECONOMIC VARIABLES (macout)

NAME	**UNITS**	**DEFINITION**
MC_PCWGDP(-2,MNUMYR)	Index	Implicit GDP price deflator, Ch-weighted

A.1.4 Other PMM Variables

VARIABLES USED INTERNALLY IN PMM (pmmcom1)

NAME	**UNITS**	**DEFINITION**
	Refinery products prices	
PMGTRG(MNUMCR,MNUMYR)	$87/bbl	Conventional 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.
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,18)	BCF	Refinery gas plant produnction 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

NAME	UNITS	DEFINITION
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)	Mbbl/cd	Distillate
QRESFU(MNUMPR,MNUMYR)	Mbbl/cd	Resid.
QCOLFU(MNUMPR,MNUMYR)	Mbbl/cd	Coal
QLPGFU(MNUMPR,MNUMYR)	Mbbl/cd	LPG
QSTGFU(MNUMPR,MNUMYR)	Mbbl/cd	Still gas
QNTGFU(MNUMPR,MNUMYR)	Mbbl/cd	Natural gas
QCOKFU(MNUMPR,MNUMYR)	Mbbl/cd	Petroleum coke
QOTHFU(MNUMPR,MNUMYR)	Mbbl/cd	Other
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
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	

NAME	UNITS	DEFINITION
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
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

NAME	UNITS	DEFINITION
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 census division
RFCGSELFCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Self by census 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
FHLADD(MNUMPR)	Mbbl/cd	Additonal supply imports of HL crude
N6XQNT(9)	Fraction	Supply step adjustment for N6I/B
N6XPRC(9)	Fraction	Price step adjustment for N6I/B
IRACN	$87/bbl	Refiner acquisition cost min. tolerance
IRACX	$87/bbl	Refiner acquisition cost max. tolerance
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 (trans)
DSLIND	Percent	Low sulfur diesel and distillate split (indus)
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	Unaccouted crude
CRDSTWDR(MNUMPR,MNUMYR)	MMbbl/cd	Crude stock withdrawals
CRDPRDSUP(MNUMPR,MNUMYR)	MMbbl/cd	Crude product withdrawals

NAME	UNITS	DEFINITION
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(MNUMCR,MNUMYR)	MMbbl/cd	Local expected electricity price
XRFNGP(MNUMCR,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
IRACBND(2)	$87/bbl	IRAC bounds
CAPEXPFCT(5,60,MNUMYR)	Percent	Processing unit capacity expansions factor
RPTFY	Integer	Reporting 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(MNUMCR)	$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 except Alaskan
Delivered petroleum product prices		
RFDLMG(MNUMCR,MNUMYR)	$87/bbl	Motor gasoline

NAME	UNITS	DEFINITION
RFDLLPG(MNUMCR,MNUMYR)	$87/bbl	LPG
RFDLTRG(MNUMCR,MNUMYR)	$87/bbl	TRG
RFDLRFG(MNUMCR,MNUMYR)	$87/bbl	RFG
RFDLTRH(MNUMCR,MNUMYR)	$87/bbl	TRH
RFDLRFH(MNUMCR,MNUMYR)	$87/bbl	RFH
RFDLJTA(MNUMCR,MNUMYR)	$87/bbl	JTA
RFDLN2H(MNUMCR,MNUMYR)	$87/bbl	N2H
RFDLDSL(MNUMCR,MNUMYR)	$87/bbl	DSL
RFDLPCF(MNUMCR,MNUMYR)	$87/bbl	PCF
RFDLKER(MNUMCR,MNUMYR)	$87/bbl	KER
RFDLOTH(MNUMCR,MNUMYR)	$87/bbl	OTH
RFDLN6I(MNUMCR,MNUMYR)	$87/bbl	N6I
RFDLN6B(MNUMCR,MNUMYR)	$87/bbl	N6B
RFDLN67(MNUMCR,MNUMYR)	$87/bbl	N67
RFDLN68(MNUMCR,MNUMYR)	$87/bbl	N68
RFDLAST(MNUMCR,MNUMYR)	$87/bbl	AST
RFDLCOK(MNUMCR,MNUMYR)	$87/bbl	COK
RFDLE85(MNUMCR,MNUMYR)	$87/bbl	E85
RFDLM85(MNUMCR,MNUMYR)	$87/bbl	M85
Refinery Gate product prices		
RFGTMG(MNUMPR+1,MNUMYR)	$87/bbl	Motor gasoline
RFGTLPG(MNUMPR+1,MNUMYR)	$87/bbl	LPG
RFGTTRG(MNUMPR+1,MNUMYR)	$87/bbl	TRG
RFGTRFG(MNUMPR+1,MNUMYR)	$87/bbl	RFG
RFGTTRH(MNUMPR+1,MNUMYR)	$87/bbl	TRH
RFGTRFH(MNUMPR+1,MNUMYR)	$87/bbl	RFH
RFGTJTA(MNUMPR+1,MNUMYR)	$87/bbl	JTA
RFGTN2H(MNUMPR+1,MNUMYR)	$87/bbl	N2H
RFGTDSL(MNUMPR+1,MNUMYR)	$87/bbl	DSL
RFGTPCF(MNUMPR+1,MNUMYR)	$87/bbl	PCF
RFGTKER(MNUMPR+1,MNUMYR)	$87/bbl	KER
RFGTOTH(MNUMPR+1,MNUMYR)	$87/bbl	OTH
RFGTN6I(MNUMPR+1,MNUMYR)	$87/bbl	N6I
RFGTN6B(MNUMPR+1,MNUMYR)	$87/bbl	N6B
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

NAME	UNITS	DEFINITION
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

Investment Variables

NAME	UNITS	DEFINITION
CAPRECSW	integer	Capital recovery switch for investment
INV	$87/bbl/cd	Proc unit investment
CAPREC	$87/bbl/cd	Capital recovery
FXOC	$87/bbl	Fixed operating costs
BM_ISBL	$M	B&M ISBL (convert fr 93$ to 87$ in code)
BM_LABOR	$/cd	B&M Labor (convert fr 93$ to 87$ in code)
PUCAP	Mbbl/cd	Proc unit capacity used for investment
INVENV	--	Environment invst cost factor
INVLOC	--	Location invst penalty factor
RQBLDRAT	fraction	Req. recovery rate for builds
RQOPRRAT	fraction	Req. recovery rate for operation
RQRECRAT	fraction	Req. recovery rate
INFLRAT	fraction	Inflation rate
FTAXRAT	fraction	FED income tax rate
STAXRAT	fraction	ST income tax rate
PCTENV	percentage	ENV: % of core P&E
PCTUTL	percentage	UTIL cost: % of core P&E
PCTLND	percentage	LAND cost: % of core P&E
PCTOFS	percentage	OFFSITES: % of core P&E
PCTLOC	percentage	Location factor
PCTCNTG	percentage	Contingency
PCTWC	percentage	Working capital
PCTSPECL	percentage	Special costs
INS_FAC	percentage	Yearly insurance, % of P&E
TAX_FAC	percentage	Local tax rate, % of P&E
MAINT_FAC	percentage	Yearly maintenance, % of P&E
SUP_FAC	percentage	Yearly supplies, % of P&E
OH_FAC	percentage	Yearly overhead, % of P&E

NAME	UNITS	DEFINITION
ENV_FAC	percentage	Yearly environ, % of P&E
BLDYRS	yrs	Construction period for proc units
PRJLIFE	yrs	Project life for proc units
Technology Improvement Variables		
TYR1	year	1st yr of tech change phase-in--GLOBAL
TYR2	year	Last yr of tech change phase-in--GLOBAL
UYR1(50)	year	1st yr of tech change phase-in--PROC UNIT
UYR2(50)	year	Last year of tech change phase-in-PROCUNIT
UTCHCNT	text	Num of proc units w/ tech chng defined
PCT_CHNG(MNUMYR)	fraction	% chng off base coef due to tech--GLOBAL
UPCT_CHNG(50,MNUMYR)	fraction	% chng off base coef due to tech--PROCUNIT
PUNIT	integer	# of proc units with tech imporvements
UNAMID(50)	text	Proc unit name
GLOBTECH	--	Flag to perform tech chng GLOBALLY
UNITTECH	--	Flag to perform tech chng for PROC UNIT
YLDUNIT(10)	text	Proc unit name for yield improvement
YLDYR(10)	integer	Start year for yield improvement
MNAMID(50)	text	Proc unit mode name
PMODE(10)	integer	# of proc unit modes for yield improvement
YLDMODE(10,10)	text	Proc unit mode ID for yield improvement
PSTRM(10,10)	integer	# of stream for yield improvement
YLDSTRM(10,10,11)	text	Stream ID for yield improvement
CHNGYLD(10,10,10)	real	new yield coeff for yield improvement
FLGGRX(50)	integer	Flag for gravity spec improvement
FLGSLX(50)	integer	Flag for sulfur spec improvement
SPCYR(50)	integer	Year for spec improvement
SSPEC(50)	integer	# of strm specs for spec improvement
SSPECID(50,10)	text	Stream spec ID for spec improvement
SSTRM	integer	# of strm for speck improvement
SSTRMID(50)	text	Stream ID for speck improvement
CHNGSPC(50,10)	real	new yield coeff for spec improvement
Miscellaneous Variables		
PICRD(MNUMYR,3,5,3)	87$/bbl	Price of imported crude
QICRD(MNUMYR,3,5,3)	Mbbl	Imported crude
QPRDIMP(MNUMYR,3,13,3)	Mbbl/d	Product imports
GPRDIMP(3,13)	fraction	Growth rate for product imports
RFCXCAPPD(MNUMPR,MNUMYR)	Mkw/day	Cogen capacity
RFCXGENPD(MNUMPR,MNUMYR)	Mkwh/day	Cogen generation
RFGBCRFG(MNUMPR,13,MNUMYR)	Mbbl/cd	Gasoline blending composition (reform. & hioxygen)
RFGBCTRG(MNUMPR,13,MNUMYR)	Mbbl/cd	Gasoline blending composition (conventional & 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

NAME	UNITS	DEFINITION
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
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
RFCAPREC(3,60,MNUMYR)	$/bbl	Refinery processing unit capital recovery factor
ALFA	fraction	weight for industrial electricity purchase
PCTCARB	fraction	Projected 2010 carbon emissions relative to 1990
STMDMD(MNUMPR,MNUMYR)	lb/bbl	Steam consumption at ref
XSTMDMD(MNUMPR,MNUMYR)	lb/bbl	Forecast steam consumption at ref (not used)
IETHHT	integer	Biomas switch for technology case
ARG(MNUMCR,MNUMYR)	real	Coeff in ethanol equation (tech dependent)
MARKET((MNUMCR,MNUMYR)	real	Factor in ethanol equation
CAPCSTCL(MNUMYR)	87$	Capital costs for Biomass conversion
OPCSTCL(MNUMYR)	87$	Operating costs for Biomass conversion
PWCRDCL(MNUMYR)	87$	costs for Biomass conversion

NAME	UNITS	DEFINITION
TRANSCL(MNUMYR)	87$	Transport costs for Biomass conversion
FSCSTCL(MNUMCR,MNUMYR)	87$	Costs
CONEFF(MNUMYR)	fraction	Biomass conversion efficiency
CLLCAPCD(MNUMCR,MNUMYR)	Mbbl/d	Biomass capacity--cellulose
CLLCSTCD(MNUMCR,MNUMYR)	$/bbl	Biomass cost--cellulose
CRNCSTCD(MNUMCR,MNUMYR)	$/bbl	Biomass cost--corn
ETHTOTPR(MNUMCR,MNUMYR)		Total ethanol production - corn + cellulose
SQETOH(2,MNUMCR,MNUMYR)		Ethanol soln from cap expansion
ETHSUB(MNUMYR)	$/bbl	Ethanol subsidy
E85TXPCT	fraction	E85 component of cellulose subsidy
ETHTECSW	integer	Hi tech switch for ethanol, cellulose
ETHSWTX	integer	Switch for ethanol subsidy for carbon tax case
WTRGSW	integer	Switch for alternate cal of west coast TRG
ATRHSW	integer	Switch for alternate cal of TRH price
MGOUTLR	integer	Switch for gasoline price outliner
PRDIMPSW	integer	Switch for product import calc
PRDIMPWR	integer	Switch for writing product import results
ONECESW	integer	Switch for 1 cap expansion iteration
EMISSCSSW	integer	Switch for emissions cost adjustment
IPMM	integer	Switch for International updates (not active)
PMMDBG	integer	PMM debug file unit ID

Legend for Codes

MNUMYR = NEMS year index, 1 through 31
MNUMCR = census region index, 1 through 11
MNUMPR = PAD District index, 1 through 6
MNUMOR = Oil and Gas Region Index, 1 through 13
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 May 2000 and is based on some ENSYS in-house data sources as well as review and commentary received from major oil companies. 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.

---

[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 are derived principally from EIA data and annual surveys published in the *Oil & Gas Journal*. 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. (Unit capacity is measured in calendar days.) Historical process unit utilization is derived from the EIA *Petroleum Supply Annual*.

It is also necessary to track 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%

Source: Derived from analysis of EIA-810, Monthly Refining Report.

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 within the PMM (Appendix I). Two sources of ethanol are modeled: ethanol from corn in Census Divisions 3, 4, 6, 8, and 9, and ethanol from cellulose in Census Divisions 2, 3, 4, 7, and 9. 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 was originally developed from the OSPR NACOD Model and updated for environmental costs reflecting the Oil Pollution Control Act. The current transportation costs were based on a 1993 study by National Petroleum Council and updated in 1999 based on Federal Energy Regulatory Commission (FERC) data for the oil pipelines.

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 mrm code (Appendix G) is still used to convert new data tables from OMNI to the current format. 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 EIA's network server named N:/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	(D)	Census Division
E	PAD District I	1	New England
B	PAD District II	2	Mid Atlantic
B	PAD District III	3	East North Central
B	PAD District IV	4	West North Central
W	PAD District V	5	South Atlantic
		6	East South Central
		7	West South Central
		8	Mountain
		9	Pacific, including California

[*]Note: Beginning with *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.

(refmain)

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 1993 DOLLARS***

Column names   One column, 1993.

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 1993$*

Column names   One column, OVC.

Row names   One character PMM refining region code (E,B,W).

Entries   Conversion of variable operating costs to 1993$.

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 (including Alaska)

Row names   Rows for selected years from Y90 to Y10.

Entries   Production volume in each OGSM region (Mbbl/d)

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 (including Alaska)

Row names   Five domestic aggregate crude groups plus 2 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 (crt) IN PMM REFINERY REGION (R)

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

Row names   NEMS year code (1,2,3,etc)

Entries   Columns Q(n) represent the availability in Mbbl/cd of each crude. Columns C(n) show the landed price in 87$/bbl at each refining region.

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

TABLE CRUDETYP TYPES OF FOREIGN CRUDE OIL

Column names   One column, DUMMY

Row names   3 character codes for foreign crude type

Entries   None.

(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 (1,2,3,etc)

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.

(Note: same table also appears in mchproc.dat)

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

TABLE PRODTYP   LIST OF PETROLEUM PRODUCT IMPORTS

Column names   One column, DUMMY

Row names   3 character product name

Entries   None.

A.3.5 Product Demands

<p align="center">(demand)</p>

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)

<p align="center">(prdexp)</p>

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) OR CENSUS DIVISION (D)***

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 EXITING REGION (R) OR CENSUS DIVISION (D)***

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 and used as initial investment parameters in the LP matrix. These values are updated in the refine.f code each year to reflect changes in investment costs (see Appendix F.1).

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., high 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
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 (1.0), min (-1.0), fixed (0.0), or free (99.0).

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, PFU, PFB 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 (KRF) capacities.

MSL, MSR, FCR, MSD, MSZ, 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

MXU, L00, L05, H00, H05, C05, control reformer operations (RFL, RFH):
- MXU: maximum use of R62 high octane catalyst on the RFL unit
- 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

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

---

[2]PFH, 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.

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, KWH electricity costs.

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.

(mchproc)

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, SMD, SOD.

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 (uns) 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 (uns) 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 (uns) CAPACITY FACTOR*

Column names   One column, CAP

Row names   Three character mode.

Entries	Capacity factor.

TABLES (uns)REP   ***MERCHANT PLANT (uns) 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   ***REFINERY 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 REFINERY 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   *REFINERY COGENERATION POLICY ROW CONSTRAINTS*
Column names   OVC for variable operating cost.

Row names   One row, three character mode - CGN.

Entries $/bbl variable operating costs.

TABLE CGNUTI   *UTILITY CONSUMPTION FOR REFINERY 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   *REFINERY COGENERATION FUEL CONSUMPTION*

Column names   One column, CGN

Row names   One row, FUL

Entries   Fuel consumption

TABLE SELCGN   *REFINERY 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 FOR REFINERY COGENERATION*

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.

TABLE CGXCAP   *MERCHANT 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 CGXINV *INVESTMENT PARAMETERS FOR MERCHANT 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 CGXPOL *MERCHANT COGENERATION POLICY ROW CONSTRAINTS*

Column names	OVC for variable operating cost.
Row names	One row, three character mode - CGN.
Entries	$/bbl variable operating costs.

TABLE CGXUTI *UTILITY CONSUMPTION FOR MERCHANT 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 CGXREP *MERCHANT COGENERATION FUEL CONSUMPTION*

Column names	One column, CGX
Row names	One row, FUL
Entries	Fuel consumption

TABLE SELCGX *MERCHANT 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 VPELWS **ELECTRIC UTILITY PRICES FOR MERCHANT COGENERATION**

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	Three columns, MIN, MAX, 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.

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.
Entries	-- blank --

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 5 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 percent 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 5 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 conventional gasoline that is to be blended with 7.8 percent 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 5 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 5 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 5 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 percent 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 required 15 percent in 1995 and 30 percent 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 stream 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 named (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 utility (KWH,STM) consumption. The table entries are 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. Most of the following tables described in this section are located in the file named (**refproc**). The cogeneration refinery processing unit data is located in the file named (**cogener**).

<div align="center">(refproc)</div>

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.

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,   paraffinic, low, medium, and high sulfur light gas oils,
LGM, and LGH: 690 to 800 degrees Fahrenheit.
HGP, HGL,   paraffinic, low, medium, and high sulfur heavy gas oils,
HGM, and HGH: 800 to 1050 degrees Fahrenheit.
LC6:   high aromatic content, high sulfur light cycle oil

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

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 SYD   DISTILLATE DEEP HYDROTREATER
(used to be identified as DHT prior to *AEO01*)

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 TRS** 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   (not used)

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   (not used)

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 TRS* 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 barrels of fuel oil equivalents (bblFOE) and the saturate co-product PGS (ethane) is used for refinery fuel gas and to meet any refinery sales requirements.

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

TABLE OLE C_2-C_5 DE-HYDROGENATION ("OLEX")

This process unit dehydrogenates saturated C2/C3/C4 and IC5 refinery streams to produce on the order of 1500 cf/bbl of hydrogen per bbl of feed and the corresponding olefin streams for alkylation and oxygenate plant feeds. The propylene may be used for alkylation (or ether DIPE) plant feed and petrochemical sales, the normal butylene for alkylation plant feed, the isobutylene for MTBE/ETBE oxygenate production and alkylation plant feed and the isoamylene for TAME/TAEE oxygenate production and alkylation plant feed. This process is suited for reformulated gasoline production and aids in RVP reduction through removing butane and isopentane from the gasoline pool.

Data sources include the following:

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

Buonomo, G. et al, *"The Fluidized Bed Technology for Paraffins Dehydrogenation: Snam Progetti-Yarsintez Process"*, presented to DEWITT 1990 Petrochemical Review, Houston, Texas, March 27-29, 1990.

TABLE C4I   BUTANE ISOMERIZATION

This unit isomerizes normal butane to produce isobutane. The isobutane may be used for alkylation plant feed and, potentially, for dehydrogenation to produce isobutylene for MTBE and ETBE production.

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

TABLE C4S   BUTENE TRANSFER PSEUDO-UNIT

This unit splits FCC and coker total butylenes into 70 percent normal butylene (C4E) and 30 percent isobutylene (I4E). No costs are attached to this unit because the total stream is normally fed to MTBE/ETBE plants without fractionation and only the isobutylene is consumed. The costs of processing the total butylene stream are included in the oxygenate plant costs.

The problem of reflecting the C4E/I4E split on alkylation plant costs is complex. The alkylate produced by normal butylene is approximately 4 RONC/MONC higher than that produced by isobutylene. Therefore, if the alkylation unit is preferentially consuming normal butylene from FCC/coker mixed butylenes, pre-fractionation costs should be attached to the alkylation plant for taking advantage of this option. However, if, as is often the case, oxygenate and alkylation units are both present in the LP solution (to produce reformulated gasoline), then the MTBE/ETBE unit is situated upstream of the alkylation unit so as to avoid the fractionation costs. The practice in this model is not to add additional alkylation plant feed pre-fractionation costs. This could cause over optimization (understate costs) for some cases.

Data sources are in-house ENSYS data.

TABLE ETH,ETM   OXYGENATE PRODUCTION

A process unit which consumes methanol or ethanol to produce a wide range of oxygenates. The olefin feeds and corresponding oxygenate products are:

Table A4. Oxygenate Products

Oxygenate Products				
Methanol Feed	Code	MTBE	TAME	THME
Isobutylene	I4E	X		
Reactive Amylenes	R5E		X	
Reactive Hexylenes	R6E			X
Ethanol Feed	Code	ETBE	TAEE	THEE
Isobutylene	I4E	X		
Reactive Amylenes	R5E		X	
Reactive Hexylenes	R6E			X

The *Tables (R)POL* constraint NME can be used to constrain or eliminate all modes other than iso-butylene/MTBE.

The data for THME and THEE were estimated by ENSYS, since there is little or no commercial experience to provide operating data. Other data sources include the following:

Bakas, S.T. et al, *"Production of Ethers from Field Butanes and Refinery Streams"*, presented at the AIChE Summer Meeting in San Diego, California, August 1990.

Prichard, *"Novel Catalyst Widens Octane Opportunities"*, NPRA Annual Meeting, San Antonio, Texas, March 29-31, 1987.

Miller, D. J., *"Ethyl Tertiary Butyl Ether (ETBE) Production"*, Paper 42B presented at the AIChE Summer Meeting, August 1989.

Des Courieres, J., *"The Gasoline Ethers: MTBE, ETBE, TAME & TAEE: Their Production"*, Paper 13A presented at the AIChE Summer Meeting, August 1990.

Chemical Engineering Progress, August 1991, p.16.

Unzelman, G. W., *"Future Role of Ethers in U. S. Gasoline"*, Paper AM-89-06 presented at the NPRA Annual Meeting, March 1989.

Refinery Handbook, Ethers, Hydrocarbon Processing, November 1990, p.126.

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

Prichard, G., *"Novel Catalyst Widens Octane Opportunities"*, Paper AM-87-48 presented at the NPRA Annual Meeting, March 1987.

TABLE DIP   PROPYLENE OXYGENATE PRODUCTION   (not used)
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 one 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.

TABLE ARD   ATMOSPHERIC RESIDUUM DESULFURIZATION

This is an atmospheric residuum desulfurizatin process which uses residuum as feed to produce high-value light products, such as transportation fuels, low sulfur fuel oil (0.1 percent - 0.5 percent sulfur), RFCC feed (3-6 MCR, 5-15 ppm vanadium & nickel), and coker feed. Chevron manufactures a hydrogen-efficient, fixed-bed atmospheric RDS hydroprocessing unit.
Source: • ORNL

TABLE CDT   CATALYTIC DESULFURIZATION

Catalytic distillation from CDTech. This process uses two stages of catalytic distillation to desulfurize FCC gasoline (as high as 95 percent reduction), while producing high yield and very little octane loss. The first stage (a CDHydro® dehexanizer, combining fractionation with hydrogenation) receives FCC gasoline (C5+) to produce a C5/C6 overhead stream and a C7+ bottoms stream. The bottoms stream is further processed in the second stage (using CDHDS^{SM} technology, a catalytic distillation process combining

hydrodesulfurization and distillation) to remove up to 95 percent of the sulfur. Octane number loss is limited to only 1.0 (R+M)/2. The output stream from the second stage is combined with the C5/C6 overhead stream from the first stage. Data sources are based on in-house Ensys data.

Source: • Rock, Kerry L., Richard Foley, and Hugh M. Putman, "Improvements in FCC Gasoline Desulfurization Via Catalytic Distillation," AM-98-37, presented at the 1998 NPRA Annual Meeting, March 15-17, 1998, San Francisco, California.

TABLE HCL   LOW CONVERSION HYDROCRACKER

Added for additional processing flexibility to allow for low conversion hydrocracking.

Source: • ORNL, July 2000.

TABLE SYG   CATALYTIC NAPHTHA HYDROTREATER   (not used)

Generic conventional cat naphtha desulfurization, producing 30-600 ppm sulfur cat naphtha product (depending on feed). A large drop in octane occurs. Data sources are based on in-house ENSYS data.

Source: • ENSYS, July 2000.

TABLE HD1   HYDRODESULFURIZER 1

A process to take the Criterion/Lummus SynSat process (SYD) product (low sulfur diesel) and desulfurizes to produce a feed for **HD2**. Requires a 20-30 ppm sulfur distillate product. Limited commercial applicatoins. Data sources are based on in-house ENSYS data.

Source: • ENSYS, July 2000.

TABLE HD2   HYDRODESULFURIZER 2

A process to take **HD1** product and saturate over 90 percent of the aromatics to make Swedish diesel type 5-7 ppm sulfur distillate product, high cetane. Limited commercial applications. Data sources are based on in-house ENSYS data.

Source: • ENSYS, July 2000.

TABLE MAK   HYDROCRACKER (PARTIAL)

This Mobil process uses a hydrocracker to convert a variety of refinery feedstocks into high-quality, lighter products. The feedstock can include AGO, VGO, FCC light cycle oil, DAO, and Coker gas oil. The processing goal can be to maximize 1) conversion to naphtha for gasoline production, 2) production of specification jet fuel, and 3) production of middle distillates. Also, it can be used in partial conversion operations to produce highly upgraded, low-sulfur heavy gas oils. Single stage, once-through partial conversion, and two-stage processing designs are available. The single-stage, single-train reactor is designed to process in excess of 30,000 bpsd fresh feed capacity. The MAK process utilizes a dual catalyst system to react feedstock and hydrogen to achieve desulfurization, denitrogenation, demodulation, and hydrocracking.

Optimal conditions are set depending on the processing goal. The product is gas oil with a 200-300 ppm sulfur content, with by-products produced at 50-100 ppm gasoline and 100-200 ppm sulfur distillate. Data sources are based on in-house ENSYS data.

Sources: • Internet web site on 11/4/99: http://www.mobil.com/industrial/rd/refin/indes.html
                 • ENSYS, July 2000.

TABLE MOD   CATALYTIC FLUIDIZED BED

A prospective commercial process by Mobil to convert olefins to gasoline and distillate with 20 ppm sulfur content. Mobil's Olefin to Gasoline (MOG) is a catalytic fluidized bed reactor process which utilizes a Mobil proprietary shape-selective zeolite catalyst (ZSM-5) to convert light olefins (in lower value refinery streams) into high octane gasoline (C5+ components), or distillate (MOD process). The feed to the MOG reactor can include reactive olefins (ethylene and propylene in FCC offgas), propylene in FCC C3 LPG cut, butenes in MTBE raffinate, and pentenes, hexenes, and heptenes in light FCC gasoline. The feed is converted into C5+ through oligomerization, carbon number redistribution, hydrogen transfer, aromatization, alkylation, and isomerization reactions. The quality of MOG gasoline produced depends on the processing severity and the feed olefins, with yields ranging from 60 - 75 percent of high octane gasoline blendstock. Typical qualities include: RONC (94 - 98), MONC (81 - 85), density (62 - 57 API), and RVP (7.2 psi/0.5 bar). The zeolite catalyst is considered to be environmentally safe, and can be reused in the FCC unit to increase octane quality.

Sources: • Internet web site on 11/4/99: http://www.mobil.com/industrial/rd/refin/indes.html
                 • ENSYS, July 2000.

TABLE MDH   MOBIL HYDROGENATION   (not used)

(renamed from MOH to MDH because PMM already had MOH defined for another unit)

An ancillary Mobil process to saturate **MOD** distillate olefins. Produces a 20 ppm surfur distillate. Data sources are based on in-house ENSYS data.

Source: • ENSYS, July 2000.

TABLE OCT   CATALYTIC FIXED-BED HYDROPROCESSOR

OCTGAIN is a commercially proven process from Mobil which uses a proprietary catalyst system to selectively remove sulfur and saturate olefins from FCC naphtha or full range gasoline while maintaining (or even increasing) octane levels. Benzene content and vapor pressure in the product are nearly unchanged. The low mercaptan level of the desulfurized gasoline allows it to be directly blended into the refinery gasoline pool. There is a trade-off between C5+ yield and product octane (similar to naphtha reforming); however, the product yield has been increased with recent advancements in catalysts (OCT-220). The unit is a fixed-bed, low-pressure process that operates at essentially gasoline hydrofinishing conditions. Data sources are based on in-house Ensys data.

Source: • Shih, S.S., P.J. Owens, S. Palit, and D.A. Tryjankowski, "Mobil's OCTGAIN[TM] Process: FCC Gasoline Desulfurization Reaches a New Performance Level," AM-99-30, presented at the 1999 NPRA Annual Meeting, 1999.

          • ENSYS, July 2000.

TABLE SOX   CAUSTIC SOX SCRUBBER

FCC regenerator gas caustic scrubber to meet current emission standards. Allows full benefit of FCC feed hydrodesulfurization. Many commercial applications. Data sources are based on in-house ENSYS data.

Source: • ENSYS, July 1999.

TABLE MTO   METHANOL TO OLEFINS FLUID BED   (not used)

A Mobil fluid bed process which converts methanol to olefins (MTO), and by-product gasoline with 5 ppm sulfur content (via subsequent oligomerization of the light olefin product). Provides olefins for Mobil's MOG/MOD process. The MTO process was demonstrated in a semi-works plant (100 barrels per day) in Germany in 1982-83, a prospective commercial process.

(cogener)

TABLE CGN   COGENERATION UNIT

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.

(mchproc)

The processing units identified here are located outside the refinery at merchant facilities. These facilities provide the refinery with additional processing streams which are merged into the refining process. The following processing units located at the merchant facilities correspond with the refinery processing units defined as follows:

Merchant Processing Unit ID	*Refinery Processing Unit ID*
C4X	C4I
OLX	OLE
ETX	ETH
FUX	FUL
STX	STG
CGX	CGN

For detailed descriptions of these merchant processing units, refer to the corresponding refinery processing units defined above.

TABLE SMD   SHELL MIDDLE DISTILLATE SYSTHESIS

A Shell GTL (gas to liquids) process for converting natural gas into ultra clean middle distillates, including diesel, kerosene, and naphtha. These GTLs can be used as a blending stock to improve the quality of other products. GTL products have no sulfur, aromatics, nitrogen compounds, or particulates.

Source: • ENSYS, July 2000

TABLE SOD   SASOL MIDDLE DISTILLATE UNIT

A Sasol Ltd. GTL (gas to liquids) process for converting natural gas into ultra clean middle distillates.

Source: • ENSYS, July 2000

EIA Model Documentation

PETROLEUM MARKET MODEL
OF THE
NATIONAL ENERGY MODELING SYSTEM

Part 2 – Appendices B thru I

February 5, 2001

Oil and Gas Division
Office of Integrated Analysis and Forecasting
Energy Information Administration

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX B

Mathematical Description of Model

APPENDIX B. Mathematical Description of Model

Each refiner is trying to minimize the cost of meeting demands. Therefore, the market moves toward lower-cost refiners who have access to crude oil and markets. A key premise is that the selection of crude oils, refinery process utilization, and logistics will adjust to minimize the overall cost of supplying the market with petroleum products.

In order to generate refined product prices, the PMM contains a static linear program model of the U.S. petroleum refining and marketing system that meets demand for refined products while minimizing costs. The PMM, like the other NEMS models, is written in FORTRAN. The 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 *AEO2001* 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.

---

[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).

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	N C	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	E
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
- ct – crude transportation cost
- i – investment 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
$N_r NGRFN_q$	Volume at price discount (q) of natural gas in refinery region (r).
$N_r NGRFP_q$	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.

Column Notation	Description
$Vcts$	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.)
$Vcp_{b,r}$	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 (from corn and cellulose) supplied from demand region (d).
$Z_{r}FLO_{u}$	Sum of the base, build, and expanded capacity in processing unit (u) at refinery region (r).

Column Notation	Description
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:

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

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

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

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

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

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

_____

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:

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

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 five 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:

$$\Sigma_p \Sigma_r \Sigma_q \, I_{p,r,q} \quad \leq \quad IPmax$$

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 United States, 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:

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

where:

$E_{r,u}$ is a capacity addition for this operating year for processing unit type (u) in refinery region (r).

$A_{r,u}$ is the capital investment required per unit of capacity for processing unit type (u) in refinery region (r), million dollars per Mbbl/d.

$Emax_r$ is the upper limit on capital expenditures in refinery region (r), an input. $MM

                    I.e., total capital expenditures are limited for each refinery region. This limit allows the user to place limits on expansion for a given scenario. The default values are large such that they are not constraining, except in PADD I (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:

$$\sum_r \sum_u E_{r,u} * A_{r,u} \quad \leq \quad Emax$$

where:

Emax   is the upper limit on capital investment over all refinery regions, an input. $MM

I.e., total capital expenditures are constrained to some maximum. This limit allows the user to place limits on expansion for all regions in the United States. The default value is $50 billion and is not constraining.

Note: This constraint has been used to determine maximum product import needs by setting Emax to zero. It has not been operative in any production runs thus far. However, like the previous row, it is a potential policy exploration handle. For instance, one could hypothesize that in a capital-short domestic environment, total industry investment is limited.

8. Limit the volume of unfinished oil processed in U.S. refineries:

$$\Sigma_c \Sigma_v \Sigma_r \, Ra_{c,v,r} \; - \; B1 * Tu \;\; \geq \;\; B0$$

where:

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

Tu is total processed unfinished oil over all refinery regions.

$B0, B1$ are regression equation coefficients (see Appendix A). $B0 = 11{,}674.3$, $B1 = 4.087$.

I.e., the maximum allowable unfinished oil processed is a linear function of total crude oil processed.

9. Limit the volume of each unfinished oil component processed in each refinery region:

$$A_{i,r} * Tu \; - \; T_{i,r} \;\; \geq \;\; 0 \quad \forall \; r, i$$

where:

$T_{i,r}$ is the volume of unfinished oil component (i) processed in refinery region (r).

$A_{i,r}$ is the fraction of component (i) of total unfinished oil that is processed in refinery region (r), an input ($\Sigma_i \Sigma_r \, A_{i,r} = 1.0$).

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:

$$\Sigma_h\ H_{p',h,d} + I_{p',d} - D_{p',d}\ =\ 0\ \ \ \ \forall\ \ p',d$$

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 $\leq$ 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:

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

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:

$$\Sigma_u \Sigma_m R_{u,r,m} * A_{e,u,r,m} - A_{e,r} * Z_r FLO_u \quad \leq, \geq, = 0 \quad \forall \quad e, r$$

where:

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{e,u,r,m}$ is the coefficient entered into the processing unit (u) table for refinery region (r) in the operating mode (m) column at policy row (e), an input.

$A_{e,r}$ is the fractional amount of total capacity value entered in the policy table in row (e) for refinery region (r), an input, i.e., constraints may be introduced by the analyst via the "policy" rows.

Note: The type of row ($\leq, \geq, =$) is determined by the entry in column heading TYPE of the policy table (r)POL where $A_{e,r}$, appears. It may also be a non-constraining row, in which case the row is free. The total processing unit throughput is the base for the policy limits in each refinery region:

$$Z_r FLO_u - K_{u,r} - A_{u,r} *(L_{u,r} + E_{u,r}) = 0 \quad \forall \quad r, u$$

where:

$Z_r FLO_u$ is the sum of the base, build, and expanded capacity in processing unit (u) at refinery region (r).

$K_{u,r}$ is the base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded rather than fixed. See note below.

$A_{u,r}$ is the stream factor for processing unit (u) at refinery region (r) defined as the ratio of calendar day capacity to stream day capacity.

$L_{u,r}$ is the cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is, of course, fixed.

$E_{u,r}$ is the stream day capacity added during this simulated period for processing unit (u) at refinery region (r). This column is generally upper bounded.

22. For each applicable combination of domestic crude oil and refinery region, balance shipments received directly from the producing region plus transhipments received from other refinery regions against crude oil consumed at the refinery and crude that is transhipped to other refinery regions:

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

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:

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

where:

$Pi_{c,r,q}$ is the quantity of imported crude oil acquired by refinery region (r) of crude type (c) at price level (q).

$Y_{c,F,r',r,m}$ is volume of imported crude oil type (c) that is received at refinery region (r) by transhipment from refinery region (r') via mode (m). (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:

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

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

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:

$$U_{l,r} + \Sigma_u \Sigma_m R_{u,r,m} * A_{l,u,r,m} - \Sigma_p Q_{p,r} * A_{l,p,r} - \Sigma_p \Sigma_h H_{p,h,r} * A_{l,h,r} = 0 \quad \forall \quad r, l$$

where:

$U_{l,r}$ is the quantity of utility (l) that is purchased in refinery region (r). Of course (l) = KWH, STM, and NGF (power, steam, and natural gas fuel) with units in thousands of kWh, lbs., and Mcf respectively.

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{l,u,r,m}$ is the quantity of utility (l) consumed (-) or manufactured (+) per unit of operation of processing unit (u) in mode (m) in refinery region (r). The (u) index includes the utility manufacturing units.

$Q_{p,r}$ is the volume of spec product (p) manufactured at refinery region (r). This column exists only when product (p) is a spec blend.

$A_{l,p,r}$ is the quantity of utility (l) consumed per unit of spec product (p) manufactured at refinery region (r).

$H_{p,h,r}$ is the volume of product (p) manufactured by recipe blend (h) at refinery region (r). This column exists only when product (p) is a spec blend.

$A_{l,h,r}$ is the quantity of utility (l) consumed per unit of recipe product (h) manufactured at refinery region (r).

I.e., for each utility at each refinery region, the quantity purchased plus the amount manufactured must equal the consumption.

26. Constrain each processing unit throughput to maximum capacity at each refinery region:

$$\Sigma_m \, R_{u,r,m} - K_{u,r} - A_{u,r}*(L_{u,r} + E_{u,r}) \;\; = \;\; 0 \quad \forall \;\; r, u$$

where:

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$K_{u,r}$ is the base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded rather than fixed. See note below.

$A_{u,r}$ is the stream factor for processing unit (u) at refinery region (r) defined as the ratio of calendar day capacity to stream day capacity.

$L_{u,r}$ is the cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is, of course, fixed.

$E_{u,r}$ is the stream day capacity added during this simulated period for processing unit (u) at refinery region (r). This column is generally upper bounded.

I.e., the activity of a particular processing unit must be limited to the maximum operating capacity.

Note: By making this row fixed with the base capacity upper bounded, the processing throughput is calculated as $K_{u,r} + A_{u,r}*(L_{u,r} + E_{u,r})$. Of course, in a model lacking capacity expansion capability, the capacity constraint row is commonly constructed as throughput and is equal to or less than a right-hand-side capacity value so that the throughput is merely the row activity.

27. Balance each intermediate refinery stream at each refinery region:

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

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:

$$\Sigma_i \ G_{i,p,r}*A_{y,i,p} - Q_{p,r}*A_{y,p,r} \quad \le, \ge, = \ \ 0 \qquad \forall \ \ y, p, r$$

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 percent min oxygen (= 5.8 percent).

$H_{ETH,RFH,r}$ is the volume of RFH splash blended with ethanol in region r.

F_{ETHRFH} is the fraction of ethanol in RFH for 2.7 percent min oxygen (= 7.8 percent).

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:

$$N_r NGRFN/P_q \leq NG_q \text{ max}$$

where:

$N_r NGRFN/P_q$ 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:

$$NZAMHx_q \leq NZAMHx_q \text{ max}$$

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
$N_r NGRFN_q$	N(r)NGRFN(q)
$N_r NGRFP_q$	N(r)NGRFP(q)
$NZAMHN_q$	NZAMHN(q)
$NZAMHP_q$	NZAMHP(q)
$O_{c,v,b}$	O@CRDEXP

Column Notation	Matrix Name
P_b	P(b)DCRQ1
$Pi_{c,r,q}$	P(r)F(c)Q(q)
$Q_{p,r}$	Q(r)(p)
$Ra_{c,v,r}$	R(r)ACU(v)(c)
$R_{u,r,m}$	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)
$U_r NGF$	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')

Column Notation	Matrix Name
$W_{p,r,d,m}$	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
$Y_{c,v,b,r,m}$	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(d)ETCTAX
Z_rFLO_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.

APPENDIX C

Bibliography

APPENDIX C Bibliography

1.   Abt Associates Inc. 1991. *A Methodology for Evaluating the Costs and Global Warming Implications of Ethanol*. Report prepared for Office of Policy Analysis, U.S. Environmental Protection Agency, April 2, 1991.

2.   F. Gerard Adams and James M. Griffin, "An Economic-Linear Programming Model of the U.S. Petroleum Refining Industry," *Journal of the American Statistical Association* (September 1972), 67:339, pp. 542-551.

3.   ASM Consulting Services, *Petroleum Market Module Review*, prepared for the Office of Statistical Standards, EIA/DOE, (July 1992).

4.   American Petroleum Institute, *How Much We Pay For Gasoline: 1996 Annual Review*, (Washington, DC, May 1997).

5.   ASM Consulting Services, *Petroleum Market Module Review*, prepared for the Office of Statistical Standards, EIA/DOE, (September 1992).

6.   C.E. Bodington, "A History of Mathematical Programming in the Petroleum Industry," *Interfaces* (July-August 1990), 20:4, pp. 117-127.

7.   Bureau of the Census, *1989 Annual Survey of Manufacturers, Statistics for Industry Groups and Industries* (M89AS1).

8.   Chowdhury, A., E.O. Heady, and S. Bhide. 1981. *Optimum Crop Production and Resource Use Under Alternative Energy Prices and Agricultural Exports: A Separable and Change-Constrained Programming Analysis*. Report 103. The Center for Agricultural and Rural Development, Ames, IA.

9.   Christensen, D.A., R.J. Schatzer, E.O. Heady, and B.C. English. 1981. *The Effects of Increased Energy Prices on U.S. Agriculture: An Econometric Approach*. Report 104. The Center for Agricultural and Rural Development, Ames, IA.

10.   Decision Analysis Corporation of Virginia, *The Oil Trade Model (OTM) Draft Documentation, User's Manual [and] Data Base*, (Vienna, VA, October 31, 1989).

11.   Decision Analysis Corporation of Virginia, *Transportation and Refining of International Petroleum (TRIP) Model Documentation, Volume I* (Vienna, VA, December 1988).

12.   Decision Analysis Corporation of Virginia, *Transportation and Refining of International Petroleum (TRIP) Model Documentation, Volume II* (Vienna, VA, December 1988).

13.   DiPardo, Joseph. April 2000. *Outlook for Biomass Ethanol Production and Demand*. Energy Information Administration, U.S. Department of Energy.

14.   Dvoskin, D., E.O. Heady, and B.C. English. 1978. *Energy Use in U.S. Agriculture: An Evaluation of National and Regional Impacts from Alternative Energy Policies*. The Center for Agricultural and Rural Development. Report 78. Ames, IA.

15.   Energy Information Administration, *Annual Energy Review*, DOE/EIA-0384(99)(Washington, DC, July 2000).

16.   Energy Information Administration, *Component Design Report: The Integrating Module*, (Washington, DC, May 1992).

17.   Energy Information Administration, *Component Design Report: The Macroeconomic Activity Module of the National Energy Modeling System*, (Washington, DC, March 1992).

18.   Energy Information Administration, *Fuel Oil and Kerosene Sales 1999*, DOE/EIA-0535(99)(Washington, DC, September 2000).

19.   Energy Information Administration, *International Energy Annual 1998*, DOE/EIA-0219(98)(Washington, DC, January 2000).

20.   Energy Information Administration, *Modeling Environmental Costs*, memorandum prepared by S.R. MacIntyre (Washington, DC, February 1993).

21.   Energy Information Administration, "Motor Fuels Tax Trands and Assumptions", *Issues in Midterm Forecasting 1998*, DOE/EIA-0607(98), (Washingtion DC, July 1998).

22.   Energy Information Administration, *Natural Gas Annual 1999*, DOE/EIA-0131(99), (Washington, DC, October 2000).

23.   Energy Information Administration, *NEMS Crude Oil Categories*, memorandum prepared by Xavier Szebrat (Washington, DC, July 1992).

24.   Energy Information Administration, *Outstanding Issues of Refinery Plant Expansion*, memorandum prepared by G.R. Harp (Washington, DC, May 1993).

25.   Energy Information Administration, *Petroleum Marketing Annual 1998*, DOE/EIA-0487(98) (Washington, DC, January 2000).

26.   Energy Information Administration, *Petroleum Supply Annual 1999*, DOE/EIA-0340(99/1)(Washington, DC, June 2000).

27.   Energy Information Administration, *PMM Procedure to Calculate Investment Recovery and Fixed Cost Charges on Existing U.S. Refinery Plant*, memorandum prepared by G.R. Harp (Washington, DC, August 1993).

28.   Energy Information Administration, *Preliminary Design for the PMM and Detailed Refinery Model*, memorandum prepared by S.R. MacIntyre (Washington, DC, February 1992).

29.   Energy Information Administration, *Proceedings of the National Energy Modeling System Conference*, (Washington, DC, May 1993).

30.   Energy Information Administration, *Requirements Analysis for a National Energy Modeling System* (Washington, DC, 18 May 1992).

31.   Energy Information Administration, *Test Plan for the Petroleum Market Module (PMM)*, memorandum prepared by G.R. Harp (Washington, DC, May 1993).

32.   Energy Information Administration, *The Treatment of Foresight and Expectation*, Decision Memorandum, Mary J. Hutzler and Mark E. Rodekohr, (Washington, DC, March 12, 1992).

33.   Energy Information Administration, *NEMS Component Design Report for Biofuels (Ethanol) Supply Submodule - Renewable Fuels Model - National Energy Modeling System*. Draft 3/12/93.

34.   English, Smith, Atwood, Johnson, and Oamek. 1989. *Resource Conservation Act Analysis; An Overview of the CARD Agricultural Resource Interregional Modeling System*. The Center for Agricultural and Rural Development, Iowa State University, Ames, IA, Technical Report 89-TR11.

35.   Ensys Energy & Systems, Inc., *WORLD Reference Manual*, prepared for the Department of Energy, Contract No. DE-AC01-87FE-61299, September 1992.

36. Farmer, Richard D., "Problems and Lessons in Estimating Supply Curves for Refined Petroleum Products," *The Journal of Energy and Development*, Autumn, 1986, Vol. XII, No. 1, pp. 27-42.

37. J.H. Gary and G.E. Handwerk, *Petroleum Refining: Technology and Economics* (New York: Marcel Dekker, 1975), Chapters 13 and 14.

38. Giovando, CarolAnn June 1998. "1998 Powerplant Awards Sweeny Cogeneration Facility", *Power.*

39. Haverly Systems, Inc., *OMNI Linear Programming System, User Reference Manual*, (Denville, NJ, January 1987).

40. ICF Resources, *North American Crude Oil Demand Model*, July 1992.

41. Kane, S.M., and J.M. Reilly. 1989. *Economics of Ethanol Production in the United States*. Agricultural Economic Report 607. USDA/ERS, Washington, DC.

42. Ketron Management Science, Inc., *MPS III Mathematical Programming System, User Manual*, (Arlington, VA, August 1988).

43. Ketron Management Science, Inc., *Optimization and Modeling Subroutine Library, User Manual*, Draft, (Arlington, VA, 1992).

44. LeBlanc, M. and J. Reilly. 1988. *Ethanol: Economic and Policy Tradeoffs*. Agricultural Economic Report No. 585. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

45. Lee, Hyunok. June 1993. "Ethanol's Evolving Role in the U.S. Automobile Fuel Market." *Industrial Uses of Agricultural Materials*, Situation and Outlook Report. United States Department of Agriculture, Washington, DC.

46. Lee, R., S.M. Cohn, and R.D. Perlack. 1991. *Prototype of an Integrated Model for Projecting Biofuels Consumption*. Draft report prepared for Energy Information Administration, U.S. Department of Energy. Oak Ridge National Laboratory, Oak Ridge, TN.

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

48. Macro International, Inc., *EIA-888 and EIA-878 Data Comparisons and Performance Measures*, Third Quarter 1997 (Washington, DC, December 15, 1997).

49. Marland, G. and A.F. Turhollow. 1991. "CO_2 Emissions From the Production and Combustion of Fuel Ethanol from Corn". *Energy*, 16(11/12):1307-1316.

50. National Petroleum Council, *Petroleum Storage and Transportation*, (Washington, DC, April 1989).

51. National Petroleum Council, *U.S. Petroleum Refining* (Washington, DC, June 2000).

52. National Renewable Energy Laboratory 1999. *Bioethanol Multi-Year Technical Plan*.

53. National Research Council, *The National Energy Modeling System* (Washington, DC, January 1992).

54. Oak Ridge National Laboratory, *Review of the Component Design Report for the Petroleum Market Module*, letter prepared by Jerry Hadder (Oak Ridge, TN, July 1992).

55. The Pace Consultants, Inc., *Pace Petrochemical Service: Annual Issue*, (Houston, TX, October 1990).

56. Solar Energy Research Institute. March 1990. *The Potential of Renewable Energy: An Interlaboratory White Paper,* SERI/TP-260-3674, Golden, CO, prepared for the Office of Policy, Planning, and Analysis, U.S. Department of Energy, in support of the National Energy Strategy.

57. Trumble, David A. 1994. *Estimation of Supply Curve for Ethanol with Corn as the Feedstock.* Draft report prepared for Energy Information Administration, U.S. Department of Energy. Oak Ridge National Laboratory, Oak Ridge, TN.

58. Turhollow, A.F. 1991. *Economic Consideration for the Production of Wood for Energy*. Presentation at Trees for Energy, First National Fuelwood Conference, November 11-13, 1991, Lincoln, NE.

59. Turhollow, A.F., D.A. Christensen, and E.O. Heady. 1984. *The Potential Impacts of Large-Scale Fuel Alcohol Production from Corn, Grain Sorghum, and Crop Residues Under Varying Technologies and Crop Expert Levels*. Report 126. The Center for Agricultural and Rural Development, Ames, IA.

60.   Turhollow, A.F., C. Short, and E.O. Heady. 1983. *Potential Impacts of Future Energy Price Increases on U.S. Agricultural Production*. Report 116. The Center for Agricultural and Rural Development, Ames, IA.

61.   Tyson, K.S. 1990. *Biomass Resource Potential of the United States*. Report prepared for Office of Transportation Technologies, U.S. Department of Energy, October 1990. Solar Energy Research Institute, Golden, CO.

62.   The University of Oklahoma, *Review of the Component Design Report for the Petroleum Market Module*, letter prepared by D.J. O'Neil (Norman, OK, July 1992).

63.   U.S. Department of Agriculture, *USDA Agricultural Baseline Projections to 2009*, Staff Report WAOB-00-1 (Washington, DC, February 2000).

64.   U.S. Department of Energy, *Integrated Analysis Supporting the National Energy Strategy: Methodology, Assumptions, and Results*, Technical Annex 2, First Addition, 1991/1992, DOE/S-0086P, p.148.

65.   U.S. Department of Energy, *National Energy Strategy* (Washington, DC, February 1991).

66.   U.S. Department of Energy, *Review of the Component Design Report for the Petroleum Market Module*, memorandum prepared by A.E. Haspel (Washington, DC, June 1992).

67.   U.S. Department of Energy, *Review of the Component Design Report for the Petroleum Market Module*, memorandum prepared by J.D. Pearson (Washington, DC, June 1992).

68.   U.S. Department of Energy, *Review of the Component Design Report for the Petroleum Market Module*, memorandum prepared by J.L. Petersen (Washington, DC, June 1992).

69.   U.S. Department of Energy, *Review of the Component Design Report for the Petroleum Market Module*, memorandum prepared by C.P. Shirkey (Washington, DC, June 1992).

70.   Urbanchuk, J.M. 1998. *Review of Alternative Ethanol Supply Curves Used in the Energy Information Administration's National Energy Modeling System.*

71.   Walsh, M. et al June 1997. *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price*. Oak Ridge National Laboratory.

72.   Wang, M. et al 1997. *Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Fuel Ethanol Produced from U.S. Midwest Corn.*

73.   Wharton Econometric Forecasting Associates, *WEFA Energy Analysis Quarterly*, Winter 1992.

74.   Also see citations in Appendix A.

APPENDIX D

Model Abstract

APPENDIX D Model Abstract

D.1 Model Name:

Petroleum Market Model

D.2 Model Acronym:

PMM

D.3 Description:

The Petroleum Market Model is a simulation of the U.S. petroleum industry. It includes 12 domestic crude oil production regions, 3 refining centers with full processing representations and capacity expansion capability and gas plant liquid production, and 9 marketing regions. The heart of the model is a linear program optimization which ensures a rational economic simulation of decisions of petroleum sourcing, resource allocations, and the calculation of marginal price basis for the products. Eighteen refined products are manufactured, imported, and marketed. Seven of these products are specification blended, while the remaining 11 are recipe blended. Capacitated transportation systems are included to represent existing intra-U.S. crude oil and product shipments (LPG, clean, dirty) via pipeline, marine tanker, barge, and truck/rail tankers. The export and import of crude oil and refined products is also simulated. All imports are purchased in accordance with import supply curves. Domestic manufacture of methanol is represented as though the processing plants were a part of the refinery complexes whereas ethanol sources are treated as merchant. Transportation is allowed for ethanol shipments to the demand region terminals for splash blending.

The program is written in FORTRAN which includes callable subroutines allowing full communication with the LP portion of the model which is in the form of an MPS resident file.

D.4 Purpose of the Model:

The PMM models domestic petroleum refining activities, the marketing of petroleum products to consumption regions, the production of natural gas liquids in gas processing plants, and domestic methanol production. The purpose of the PMM is to project petroleum product prices, refining activities, and movements of petroleum into the United States and among domestic regions. In addition, the model

contains adequate structure and is sufficiently flexible to examine the impact of a wide variety of petroleum-related issues and policy options, in order to foster understanding of the petroleum refining and marketing industry as well as determine the effects of certain policies and regulations.

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

D.5 Most Recent Model Update:

October 2000

D.6 Part of Another Model?

National Energy Modeling System (NEMS)

D.7 Model Interfaces:

Receives information from the International, Natural Gas Transmission and Distribution, Oil and Gas Supply, Renewable Fuels, Electricity Market, Residential, Commercial, Industrial, and Transportation Models. Delivers information to each of the models listed above plus the Macroeconomic Model.

D.8 Official Model Representative:

Bruce Bawks
Office of Integrated Analysis and Forecasting
Oil and Gas Division
(202) 586-6579

D.9 Documentation:

EIA Model Documentation: Petroleum Market Model of the National Energy Modeling System (NEMS), December 2000. (DOE/EIA-M059).

D.10 Archive Media and Installation Manual

Archived as part of the NEMS AEO2001 production runs.

D.11 Energy System Described:

Petroleum refining industry and refined products market.

D.12 Coverage:

Geographic: Twelve domestic crude oil production regions (East Coast, Gulf Coast, Mid-Continent, Permian Basin, Rocky Mountain, West Coast, Atlantic Offshore, Gulf Offshore, Pacific Offshore, Alaska South, Alaska North, Alaska Offshore); three refining regions (PAD District I, an aggregate of PAD Districts II-IV, and PAD District V); nine market regions, the Census divisions (New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific)

Time Unit/Frequency: Annual, 1990 through 2020

Products: LPG, conventional motor gasoline, conventional high oxygen motor gasoline, reformulated motor gasoline, reformulated high oxygen motor gasoline, M85, E85, jet fuel, distillate fuel oil, highway diesel, low-sulfur residual fuel oil, high-sulfur residual fuel oil, petrochemical feedstocks, asphalt/road oil, marketable coke, still gas, other.

Refinery Processes: crude distillation, vacuum distillation, delayed coker, fluid coker, visbreaker, fluid catalytic cracker, thermal cracker, hydrocracker-dist, hydrocracker-resid, solvent deasphalter, resid desulfurizer, FCC feed hydrofiner, distillate HDS, naphtha hydrotreater, catalytic reformer-450 psi, catalytic reformer-200 psi, alkylation plant, catalytic polymerization, pen/hex isomerization, butane isomerization, etherification, butanes splitter, dimersol, butylene isomerization, total recycle isomerization, naphtha splitter, C2-C5 dehydrogenator, cyclar unit, hydrogen plant, sulfur plant, aromatics recovery plant, lube + wax plants, FCC gasoline splitter, gas/H2 splitter, stream transfers, fuel system, steam production, power generation.

Crude Oil: Alaska low sulfur light, Alaska mid sulfur heavy, domestic low sulfur light, domestic mid sulfur heavy, domestic high sulfur light, domestic high sulfur heavy, domestic high sulfur very heavy,

imported low sulfur light, imported mid sulfur heavy, imported high sulfur light, imported high sulfur heavy, imported high sulfur very heavy.

Transportation Modes: Jones Act dirty marine tanker, Jones clean marine tanker, LPG marine tanker, import tankers, clean barge, dirty barge, LPG pipeline, clean pipelines, dirty pipelines, rail/truck tankers. These cover all significant U.S. links.

D.13 Modeling Features:

Model Structure: FORTRAN callable subroutines which update the linear programming matrix, re-optimize, extract and post-process the solution results, update system variables, and produce reports.

Model Technique: Optimization of linear programming representation of refinery processing and transportation which relates the various economic parameters and structural capabilities with resource constraints to produce the required product at minimum cost, thereby producing the marginal product prices in a manner that accounts for the major factors applicable in a market economy.

Special Features: Choice of imports or domestic production of products is modeled, capacity expansion is determined endogenously, product prices include fixed and environmental costs, oxygenated and reformulated gasolines and low-sulfur diesel fuel are explicitly modeled.

D.14 Non-DOE Input Sources:

Information Resources Inc. (IRI), WORLD model data, National Petroleum Council, ICF Resources, Oil and Gas Journal.

D.15 DOE Input Sources:

Forms:

EIA-14	Refiners' Monthly Cost Report
EIA-182	Domestic Crude Oil First Purchase
EIA-782A	Monthly Petroleum Product Sales
EIA-782B	Reseller/Retailer's Monthly Petroleum Product Sales
EIA-782C	Monthly Petroleum Products Sold into States for Consumption
EIA-759	Monthly Power Plant Report
EIA-810	Monthly Refinery Report
EIA-811	Monthly Bulk Terminal Report

EIA-812   Monthly Product Pipeline Report
EIA-813   Monthly Crude Oil Report
EIA-814   Monthly Imports
EIA-817   Monthly Tanker and Barge Movement
EIA-820   Annual Refinery Report
EIA-826   Monthly Electric Utility Sales
EIA-856   Monthly Foreign Crude Oil Acquisition
EIA-860B   Annual Nonutility Power Producer Report
FERC-423   Monthly Report of Cost and Quality of Fuels for Electric Plants

In addition to the above, information is obtained from several Energy Information Administration formal publications: *Petroleum Supply Annual*, *Petroleum Supply Monthly*, *Petroleum Marketing Annual*, *Petroleum Marketing Monthly*, *Fuel Oil and Kerosene Sales*, *Natural Gas Annual*, *Natural Gas Monthly*, *Annual Energy Review*, *Monthly Energy Review*, *State Energy Data Report*, *State Energy Price and Expenditure Report*.

D.16 Independent Expert Reviews Conducted:

Independent reviews of the Component Design Report of the PMM were conducted by:

A.S. Manne, ASM Consulting Services, July 1992

A.S. Manne, ASM Consulting Services, September 1992

N. Yamaguchi, Trans-Energy Research Associates, Inc., November 1997.

J. Urbanchuk, AUS Consultants, May 1998.

D.17 Status of Evaluation Efforts by Sponsor:

None.

APPENDIX E

Data Quality

APPENDIX E. Data Quality

E.1 Quality of Distribution Cost Data

Costs related to distributing petroleum products to end-users are incorporated by adding fixed transportation markups to the wholesale prices which include the variable and fixed refinery costs. Transportation markups for petroleum products are estimated as the average annual difference between retail and wholesale prices over the years 1990 through 1999[1]. The differences are based on **wholesale prices** in the producing Census division and **end-use prices** (which do not include taxes) in the consuming Census division. See Appendix F for a discussion of programs and input files used in estimating these markups.

Annual **wholesale prices** for all petroleum products are aggregated from state-level prices from the EIA-782A. The estimation and reliability of the EIA-782A data is discussed in the *Petroleum Marketing Annual 1999* (ftp://ftp.eia.doe.gov/pub/pdf/petroleum/048799.pdf , page 385, Explanatory Notes, December 8, 2000). See Explanatory Notes for inputs and sources.

With the exception of gasoline, non-utility distillate fuel, and jet fuel, **sectoral end-user prices** through 1997 are aggregated from prices from the State Energy Price and Expenditures Report 1997 (SEPER). The methodology behind these state-level sectoral prices are discussed in the *State Energy Price and Expenditures Report 1997 (*ftp://ftp.eia.doe.gov/pub/pdf/multi.fuel/037697.pdf, December 8, 2000*)* . One area of concern is the SEPER methodology for residual fuel transportation prices where the vessel bunkering prices are tied to State electric utility prices. This methodology is questionable because most utility residual fuel use is on the East Coast whereas vessel bunkering is concentrated on the Gulf and West Coasts.

Gasoline, jet fuel, and non-utility distillate prices are estimated as weighted averages using end-user prices from EIA-782A and sectoral consumption from the *State Energy Data Report* (DOE/EIA-0214(96)) (SEDS).

Due to a lag in the publication of the SEPER data, end-use price estimates for 1998 and 1999 are calculated using the same data series and methodology described in SEPER. The SEPER methodology uses prices from EIA-782A, FERC-423, EIA-759, and weights them with consumption volumes from SEDS. Refer to SEDS for a discussion of the reliability of consumption data (ftp://ftp.eia.doe.gov/pub/pdf/multi.fuel/021497.pdf, December 8, 2000). Due to electric restructuring

---

[1] Transportation markups for kerosene are based on the difference between end-user kerosene prices and wholesale distillate prices.

the number of electric utility survey respondents has been declining and the quality of the data is likely to be reduced. See the Electric Power Annual 1996 (ftp://ftp.eia.doe.gov/pub/pdf/electricity/0348982.pdf, December 8, 2000) for a discussion of the reliability of electric utilities data from FERC-423 and EIA-759. Table E1 shows the data series used in the estimation of end-use prices.

Table E1. Sources of Markup Inputs

Products	Sectors	Data Series Inputs
Distillate	CM, IN, RS	EIA-782A, SEDS
Jet Fuel	TR	EIA-782A, SEDS
Low Sulfur Diesel Fuel	TR	EIA-782A, SEDS
Motor Gasoline	CM, IN, TR	EIA-782A, SEDS
Asphalt and Road Oil	IN	SEPER, EIA-782A, SEDS
Kerosene	CM, IN, RS	SEPER, EIA-782A, SEDS
Liquified Petroleum Gases	CM, IN, RS, TR	SEPER, EIA-782A, SEDS
Low Sulfur Residual Fuel	CM, IN	SEPER, EIA-782A, SEDS
High Sulfur Residual Fuel	TR	SEPER, EIA-782A, SEDS
Distillate	EU	SEPER, EIA-759, FERC-423
Low Sulfur Residual Fuel	EU	SEPER, EIA-759, FERC-423
High Sulfur Residual Fuel	EU	SEPER, EIA-759, FERC-423

E.2 Quality of Tax Data

In the PMM, State and Federal taxes are added to the prices of gasoline, distillate fuel, liquefied petroleum gas (LPG), jet fuel, ethanol and methanol in the transportation sector. State taxes are assumed to keep pace with inflation (held constant in real terms) while Federal taxes are held at current nominal levels (deflated in each forecast year).[2] The Federal tax assumption supports the overall forecast assumption of current laws and legislation. The assumption that State taxes will increase at the rate of inflation supports an implied need for additional highway revenues as driving increases. An additional 2 cents per gallon is added to the State gasoline taxes to approximate local taxes. The average local tax estimate was taken from *How Much We Pay for Gasoline: 1996 Annual Review* published by the American Petroleum Institute in May 1997.

The State taxes are added as Census division weighted averages which are based on the most recently-available State taxes. State taxes for jet fuel are derived from unpublished data collected by the Petroleum Marketing Division of EIA, while state taxes for ethanol and methanol are taken from The Clean Fuels and Electric Vehicles Report, February 2000, published by Energy Futures Inc. State and Federal taxes for gasoline, transportation distillate, and LPGs are based on data from the Federal Highway Administration, but are modified to include other known changes to State taxes. The quality of the State level tax data is unknown but deemed reliable. The local tax estimate of 2 cents-per-gallon seems reasonable given that a comparison of two EIA data series, one including local taxes and one not, revealed a gasoline price difference of 1.6 cents-per-gallon.[3]   Federal taxes, which were increased by 4.3 per gallon in 1993, are widely published, and deemed highly reliable.

See Appendix F for a description of programs and input files used in the calculation of historical taxes and the estimation of taxes used in the price projections.

E.3 PMM Critical Variables

The PMM contains numerous variables and parameters. Some variables have greater impact on model results than others. The following is a list of variables that we believe has a high degree of influence on PMM results. It is provided to help users understand the critical factors affecting the PMM.

- World oil price
- Product demands

---

[2] Refer to Energy Information Administration, "Motor Fuels Tax Trends and Assumptions", *Issues in Midterm Analysis and Forecasting 1998*, DOE/EIA-0607(98), (Washington, D.C., July 1998).

[3] Macro International, Inc., *EIA-888 and EIA-878 Data Comparisons and Performance Measures*, Third Quarter 1997 (Washington, D.C., December 15, 1997).

- Imported crude supply curves
- Imported product supply curves
- Domestic crude production
- Prices and available supplies of methanol, ethanol, MTBE, and other ethers
- Investment cost for capacity expansion
- Market shares for gasoline and distillate types
- NGL supply volumes

Most of these variables are provided by other models in the NEMS system. Ethanol supply and prices are provided by the Ethanol Supply Model, a submodule of the PMM, documented in Appendix I. The investment cost and market share data are developed offline and read in to the PMM.

Tests on some of these variables are discussed in a separate appendix to this documentation, titled *Documentation of the Petroleum Market Model, Appendix: Model Developer's Report*. In an earlier effort, a detailed calibration was made, using the same refinery model technology database as in PMM, compared against the EIA Petroleum Supply Annual (PSA) for 1989.[4] This comparison indicated that the validation was quite good with total crude volumes from the model only 0.48 percent above actual PSA values and total production just 0.28 percent higher. A more complete comparison, including assumptions, can be found in the cited reference.

---

[4]"U.S. Detailed Refinery Model," Letter of October 20, 1993, from Martin Tallett of ENSYS to G. H. Harp of EIA.

APPENDIX F

Estimation Methodologies

APPENDIX F. Estimation Methodologies

F.1 Refinery Investment Recovery Thresholds

The threshold for expansion investment decisions is composed of the refinery capital recovery threshold ($CRT_{i,j}$) and the fixed costs (FC_i) associated with a processing unit. The negative of the sum of these two components is entered into the objective function row corresponding to the unit expansion vectors [E(r)(un)INV and B(r)(un)BLD] of the PMM LP to provide an investment decision criteria; i.e., the investment will occur to the extent that it is economic. The methodologies used to calculate the capital recovery threshold and the fixed costs are presented below.

Refinery Capital Investment Recovery Threshold

The calculation methodology for the capital investment recovery threshold values have been taken from a standard refinery industry reference.[1] The inside battery limits (ISBL) investment cost and labor costs for most of the processing unit types were obtained from a study by Bonner and Moore Associates.[2] The data for typical unit sizes and stream factors as well as supplementary investment and labor was obtained from the World Oil Refining, Logistics, and Distribution (WORLD) model.[3] A basic premise used in the PMM application is that the investment recovery value at the end of project life (PL) will equal site decommissioning cost, an expectation that seems to be widely shared in the petroleum industry.

The inside battery limits cost per barrel investment cost at the Gulf Coast (P) for each refinery process modeled was obtained from the cited data sources. The total investment cost (INV) was then calculated using the referenced methodology. Finally, the capital recovery threshold for each process was calculated.

Given that a Gulf Coast plant and equipment battery limits cost for an expansion of processing plant type I is P_i dollars per barrel per day of stream day capacity (assumed to include required storage facilities but not necessarily all mandated environmental systems), then the nominal total plant and equipment cost at some arbitrary location would be

---

[1]J.H. Gary and G.E. Handwerk, *Petroleum Refining: Technology and Economics* (New York: Marcel Dekker, 1975), Chapters 13 and 14; and (New York: Marcel Dekker Inc., 1994), Chapters 17 and 18.

[2]Bonner & Moore Associates, Inc., *A Capital Expansion Methodology Review of the Department of Energy's Petroleum Market Model*, prepared for the United States Department of Energy, Contract No. EI-94-25066 (Houston, TX, July 1994).

[3]Ensys Energy & Systems, Inc., *WORLD Reference Manual*, a reference for use by the analyst and management prepared for the United States Department of Energy, Contract No. DE-AC-01-87FE-61299 (Washington, D.C., September 1992).

$$NTPE_i = P_i * (1 + U) * (1 + O)\qquad(1)$$

where   U = Utilities cost multiplier
        O = Offsites multiplier

With construction occurring over a 3-year period at a constant rate, the present value of the nominal total plant and equipment is

$$PVNTPE_i = (NTPE_i/3) * \sum_{j=1}^{3} * (1+DEFi)^j\qquad(2)$$

where DEF = inflation rate during construction

The final land, plant, and equipment cost is

$$FLPE_i = PVNTPE_i * (1 + S + C)\qquad(3)$$

where   S = Special costs multiplier (includes land)
        C = Contingency cost multiplier

The total investment is

$$INV_i - (1 + W) * FLPE_i\qquad(4)$$

where   W = Working capital multiplier

A multiplier called the plant depreciation factor or PDF, is used in the investment recovery calculations. It is merely the ratio of depreciable investment to total investment. More specifically, the numerator of the PDF is total investment less land, working capital, and supplies.

The capital recovery threshold is calculated from:

$$CRT_{i,j} = CAPREC_{i,j} * L_j * E_j\qquad(5)$$

where,

$$CAPREC_{i,j} = (INV_i * (U_{R,PL} - PDF_i * (TR_j /(PL*365)))) / (1 - TR_j) \quad \textbf{(6)}$$

$CRT_{i,j} =$ The daily investment recovery required for processing unit type I at location j, $/bbl

$CAPREC_{i,j} =$ Base level daily investment recovery required for processing unit type I at location j, $/bbl

$INV_i =$ The investment required for processing unit type I on the Gulf Coast, $/bbl

$L_j =$ Location factor for PAD District j

$E_j =$ Investment factor for environmental capital expenditure for PAD District j (= 1)

$PDF_i =$ Plant depreciation factor (fraction of investment that may be depreciated) for processing unit type I

$TR_j =$ Effective combined income tax rate in PAD District j

$R =$ Investment return rate, fraction

$PL =$ Plant life, years

when R > 0, then

$$U_{R,PL} = (R / (365 * (1 - (1+R/365)^{-PL*365}))) \quad \textbf{(7)}$$

otherwise,

$$U_{R,PL} = (1 /(PL *365) \quad \textbf{(8)}$$

Also,

$$TR_j = TRF + TRS_j - TRFxTRS_j$$

where

$TRF =$ Federal income tax rate

$TRS_j =$ Average state income tax rate for PAD District j, weighted by crude oil charge

Note that an investment tax credit can be added to this investment model by decreasing the INV by the applicable fraction. Also, the investment return rate (R) is an input variable which may be different for build coefficient calculations ($RQBLDRAT_t$) versus investment coefficient calculations ($RQOPRRAT_t$); however, currently both are set equal to 15 percent.

The location factors (Lj) were taken from working papers developed for the 1993 NPC refinery study, and are presented in Table F2. In order to do this, several premises have been set in accordance with Table F1. The multipliers in Table F1 were obtained from the Gary and Handwerk reference. The variability of these factors is unknown. Examples of total Gulf Coast investment cost and depreciable investment fraction (PDF) as well as the fixed costs are presented in Table F4.

Table F1. Investment Multiplier Values

Multiplier	Value
U	0.075
O	0.15
DEF	0.03
C	0.15
S	0.04
W	0.10

Table F2. Location Index (J) and Location Factors

PAD District	Location Factor
I	1.2
II - IV	1.07
V	1.4

The reader may verify his understanding of the investment equations from a simple example. Calculating the capital recovery required to expand the crude oil distillation tower capacity in PAD District III by one barrel per day for a 15 percent return over a 15-year plant life with a combined income tax rate of 44.2 percent with no allowance for collateral environmental cost,

$$CRT_{ACU,I} = \$0.40/day.$$

Refinery Unit Fixed Cost Factor

The fixed cost, in conjunction with the capital recovery threshold, forms the threshold for expansion investment decisions for processing unit type I. Fixed cost is calculated from:

$$FXOC_i = (1/365) * (B_i + PVNTPE_i \sum_{j=1}^{6} F_j) \qquad \text{(1)}$$

$$FC_i = FXOC_i * L_j * E_j \qquad \text{(2)}$$

where

      B = Operations labor, $/year/BBL/day

      the 6 "F" multipliers are shown in Table F3.

Table F3. Fixed Cost Multiplier Values

Multiplier	Value
1, Insurance	0.005
2, Local tax rate	0.01
3, Maintenance	0.04
4, Supplies	0.002
5, Overhead	0.015
6, Environment	0.02

The labor charge, B, and the overhead multiplier is taken from the WORLD model. The first 4 multipliers was obtained from the Gary and Handwerk reference. The environment base multiplier results from analyst judgment. The 1993 NPC study estimates the new environmental refinery operation and maintenance cost as about one third of base operations and maintenance over the 1991-1995 time period. Gary and Handwerk estimate the maintenance factor to vary between 3 percent and 8 percent, 4 percent was used because the trend is for refineries to increase operating efficiency over time. Variability of the other factors is unknown.

Table F4. Refinery Investment Recovery Estimates
($1993)

Processing Unit	Unit Index	INV (Dollars per bbl/d)	PDF	Fixed Cost ($/bbl)
Crude oil tower	ACU	$565	0.775	$0.12
Vacuum unit	VCU	$895	0.775	$0.18
Solvent deasphalting	SDA	$1,909	0.775	$0.40
Delayed coker	KRD	$4,308	0.775	$0.85
Fluid/flexicoker	KRF	$5,502	0.775	$1.10
Visbreaker/TCC	VBR	$1,390	0.775	$0.29
Naphtha hydrotreater	NDS	$1,101	0.775	$0.24
Distillate desulfurizer	DDS	$1,622	0.775	$0.35
FCC feed hydrofiner	FDS	$1,971	0.775	$0.41
Residuum desulfurizer	RDS	$4,525	0.775	$0.95
Gas oil hydrocracker	HCR	$5,463	0.775	$1.14
Residuum hydrocracker	HCV	$7,300	0.775	$1.49
Naphtha hydrotreater	HCN	$3,347	0.775	$0.69
Lube and wax units	LUB	$13,514	0.775	$2.75
Gas oil dewaxer	DEW	$1,353	0.775	$0.30
Prefrac hi density ATF	JFP	$2,168	0.775	$0.76
Hi density ATF HD unit	HDN	$14,949	0.775	$3.11
HP Semi regen REFORMER	RFH	$1,810	0.775	$0.42
LP Cyclic reformer	RFL	$2,232	0.775	$0.50
LP Continuous reformer	RFC	$2,655	0.775	$0.59
Naphtha splitter	SPL	$724	0.775	$0.15
C3/C4 dehydrogenation	OLE	$11,101	0.775	$2.34
Fluid cat cracker	FCC	$3,656	0.775	$0.75
FCC fractionation	FGS	$579	0.775	$0.11
Alkylation unit	ALK	$5,999	0.775	$1.32
Polymerization unit	CPL	$1,882	0.775	$0.42
Dimersol unit	DIM	$2,606	0.775	$0.56
Aromatics recovery	ARP	$3,041	0.775	$0.67
Pen/Hex Isomerization	PHI	$3,620	0.775	$0.98
Butane isomerization	C4I	$5,213	0.775	$1.46

Processing Unit	Unit Index	INV (Dollars per bbl/d)	PDF	Fixed Cost ($/bbl)
Total recycle isom	TRI	$5,642	0.775	$1.17
Cyclar unit	CYC	$10,736	0.775	$2.13
H2 Steam ref bfoe/d	H2P	$27,499	0.775	$5.62
H2 Partial Ox bfoe/d	H2X	$27,378	0.775	$5.40
Sulfur, S tons/day	SUL	$168	0.775	$0.04
Steam gener, lbs/hr	STG	$60	0.775	$0.01
Power generation, MKW	KWG	$7	0.775	$0.00
M Dist Furfural trting	FEX	$1,722	0.775	$0.35
Synsat Distillate Hydrotreating	SYD	$2,392	0.775	$0.48
Methanol unit	MOH	$25,681	0.775	$3.41
Merchant MTBE	MBM	$37,332	0.775	$7.39
C4E based oxy unit	ETH	$5,744	0.775	$1.20
C5E+ based oxy unit	ETM	$10,241	0.775	$2.08
Cryogenic C2 fractionator	ETS	$1,485	0.775	$0.33
C2E - C4E Dimerization	C24	$10,682	0.775	$2.51
Hydrogenate NC5E/NC6E	C56	$2,020	0.775	$1.30
Atmospheric Residuum Desulfurization	ARD	$29,016	0.775	$5.68
CD Tech FCC naphtha desulfurization	CDT	$860	0.775	$0.17
Low Conversion Hydrocracking	HCL	$5,026	0.775	$1.03
Hydrodesulfurizer 1	HD1	$4,811	0.775	$0.96
Hydrodesulfurizer 2	HD2	$2,448	0.775	$0.52
Mobil MAK hydrocracker for FCC feed	MAK	$5,026	0.775	$1.03
Catalytic Fluidized Bed	MOD	$2,596	0.775	$0.50
Olefin Saturation Process	MDH	$1,477	0.775	$0.29
Octgain naphtha desulfurization	OCT	$1,604	0.775	$0.32
Caustic Sox Scrubber	SOX	$2.954	0.775	$0.57
SASOL Middle Distillate Unit	SOD	$42,205	0.775	$8.27

F.2 Gas Plant Models

The gas plant models for each PADD is maintained on the spreadsheet 'NGL.WK1' maintained within EIA by the Oil and Gas Division. These models require gas plant wet gas volumes as input. In order to accommodate the information available, dry gas production volume, and permit gas plant activity to be driven by dry natural gas demand, factors are applied to the dry gas demand volumes to calculate imputed volumes of processed wet gas. In PADD V, the PMM models only the California gas plants. Although Alaska produces and processes a considerable volume of natural gas, it is nearly all used for reinjection with some NGL dumped into the crude pipeline with the exception of modest volumes of southern Alaska production. The southern Alaska production does have a local NGL market with much of the dry gas shipped out as LNG. In any case, the PADD V refinery industry is virtually unaffected by Alaska NGL production. Thus, the PMM aggregate gas plant includes California only. Gas residue volumes are not available to the PMM but total dry gas volumes by PADD are. This information is in the NEMS common block region. Specifically, the total dry gas volumes are available in:

Common block:	NGTDMOUT
Variable matrix:	PRNG_PADD(PADD,YEAR), BCF
Description:	Total dry gas produced including plant fuel and lease fuel (P&L) for PADD 'PADD' in year 'YEAR' excluding Alaska.

Each of the five values must be multiplied by a factor to obtain an estimate of the corresponding wet gas that is processed by the gas plants; i.e. the total dry gas volumes are multiplied by the ratio of processed wet gas to total dry gas production. These ratios are derived from 1993 data[4] so that data variability is unknown. The five multipliers are shown in Table F5.

Table F5. Total Dry Gas Multiplier

PADD	Multiplier
I	0.4536
II	0.7659
III	0.7572
IV	1.0136
CA	0.7745

---

[4]Energy Information Administration, *Natural Gas Annual 1993*, DOE/EIA-0131(93), (Washington, DC, October 1994).

The multiplier for PADD I is low because relatively little of the modest PADD I gas production is processed beyond field decontamination. The multiplier is high for PADD IV because a great deal of Utah gas production is reinjected for field pressure maintenance. This reinjected gas is not counted in total dry gas production. The three region PMM uses the quantity weighted average multipliers of PADDs II, III, and IV for refining region two.

The NGL extraction is allowed to occur at a minimum, maximum, or average level. Complete ethane rejection is allowed with a processing credit for each barrel rejected. Propane rejection occurs in U.S. gas plants but to an unknown extent. The model allows propane rejection up to one fourth of the propane volume. The basic model structure is devised from the Pace Consultants annual petrochemical report[5]. The liquids extraction data have been calculated by averaging actual liquid extraction volumes from the 4-year period 1990 - 1993[6] as well as obtaining minimum and maximum values. The coefficients were then normalized. The minimum and maximum values seem to suggest the variability of the data but the reader is cautioned that statistically based models, as opposed to engineering models, may understate processing flexibility. Furthermore, the gas business is not statistical. It is driven by technology and economics, i.e. history is suspect as a basis for such values. The model for PADD III is shown in the following table. Models for the other PADDs are similar except the extraction coefficients differ.

---

[5]Pace Petrochemical Service, *Annual Issue*, (Houston, TX, September 1989).

[6]Energy Information Administration, *Natural Gas Annual 1991*, DOE/EIA-0131(91), (Washington, DC, October 1992) and similarly, the Natural Gas Annuals for 1986-1990.

Table F6. Gas Plant Model for PADD III

	MIN	MAX	AVG	ETH	PRO	Row Type	RHS
Wet Nat. Gas (MMcf)	-1.000	-1.000	-1.000			=	0
Dry Gas (MMcf)	0.945	0.938	0.941	0.002	0.002	=	+
Ethane (bbl)	14.070	14.332	14.562	-1.000			
Propane (bbl)	11.165	11.628	11.782		-1.000		
I-Butane (bbl)	4.375	4.776	4.693				
N-Butane (bbl)	2.506	4.409	3.349				
Nat. Gasoline (bbl)	7.025	7.310	7.286				
Volume Loss (MMcf)	-39.058	-42.394	-41.613	0.998	0.998		
Fuel (MMcfl)	-0.037	-0.040	-0.040				
Oper. Cost ($)	-115.07	-124.82	-122.51				
Oper. Cost ($/bbl)				5.88	2.94		
Capacity limit (bbl/d)					1.000	≤	+

Table F6 differs from the implemented model in three respects. Propane rejection is controlled via column limit in the LP rather than as a row limit and the operating costs are merely entered into the objective function row rather than occupying two rows as the above depiction suggests. Of course these things are shown in the above form for the sake of clarity. The major difference is that the wet gas balance row is an equal zero row in the LP representation. There is a column representing pseudo purchases of wet gas with a plus one in the wet gas balance row and minus the forecasted gas price in the objective function row. Of course, this column is fixed at the determined level of processed wet gas.

F.3 Chemical Industry Demand for Methanol

Since the PMM includes methanol plant models in each PADD representing all U.S. methanol capacity, U.S. chemical industry demand (demand other than for MTBE/TAME feedstock and neat fuel) is a required input. The Pace Consultants make long range forecasts of the chemical industry demand[7]. Their forecast is:

---

[7]Pace Petrochemical Service, *Annual Issue*, (Houston, TX, October 1992).

Table F7. Chemical Industry Demand for Methanol

Year	Demand (Mbbl/d)	Year	Demand (Mbbl/d)
1990	66.7	2006	102.1
1991	73.7	2007	106.6
1992	72.0	2008	111.4
1993	73.4	2009	116.4
1994	74.8	2010	121.6
1995	76.6	2011	127.1
1996	78.0	2012	132.8
1997	79.5	2013	138.8
1998	81.0	2014	145.0
1999	82.6	2015	151.6
2000	84.2	2016	151.6
2001	85.8	2017	151.6
2002	87.6	2018	151.6
2003	89.4	2019	151.6
2004	93.4	2020	151.6
2005	97.6		

The methanol plant model in each PADD is represented by a single column activity that consumes natural gas and produces methanol. Two additional transportation activities allow the methanol produced to be transported to the refining region for production of MTBE/TAME and/or splash blending in gasoline or sent to meet the national demand for methanol by chemical plants. The model also allows capacity expansion of the methanol plant.

F.4 Estimation of Refinery Fixed Costs

The marginal prices computed in the PMM by the use of the Simplex algorithm cannot be used directly to determine the wholesale (refinery gate) price because they do not include the refinery source environmental costs. These are expenditures incurred to satisfy regulations related to air and water pollutants, solid waste management, and health and safety controls at refineries. Related costs are based on estimates of capital investment, one-time, and operation and maintenance expenses provided in the 1993 National Petroleum Council Study.[8]

The NPC Study provides PADD level estimates of capital, one-time, and operating and maintenance expenses over three time periods: 1991-1995, 1996-2000, and 2000-2010. Operation and maintenance expenses existing prior to 1996 are not used as they are already reflected in the fixed operating cost estimates. The NPC estimates were converted to an annual average cost per barrel of distillation capacity for inclusion as a fixed cost (Table F8) The same fixed costs are assumed for forecast years 2011 through 2020.

The underlying NPC analysis reflects the actions described below:

Air related costs include attainment of ambient air quality standards (Title I of the Clean Air Act Amendments), hazardous air pollutants (Title III, MACT standards), and permits (Title V)[9].

Water related costs include technology required to satisfy toxicity requirements of the National Pollution Discharge Elimination System (NPDES) authorized by the Clean Water Act. Costs for additional measures to protect groundwater are also assumed[10].

Solid waste related costs include remediation of contaminated soil at refineries sites, recovery and monitoring wells, the listing of additional refinery wastes as hazardous, the closing of unlined impoundments, and an assumed phased replacement of half the tanks over 40 years of age[11].

Safety and health related costs includes an assumed phase-out of hydrofluoric alkylation (hf) plants due to the classification of hf as a highly hazardous material. Small costs associated with implementing process hazards analysis are also contained in the NPC estimates[12].

---

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

[9]Ibid, Section V-9-12.

[10]Ibid, Section V-13.

[11]Ibid, Section V-16.

[12]Ibid, Section V-19.

For comparative purposes NPC's estimated capital and OTE costs aggregated over 1991-2010 results in total environmental investments of $43.5 billion. The NPC sum can be compared to estimated investments published by the API,[13] by adding the API estimates for individual legislation that are consistent with NPC. The NPC total falls in the middle of the range of API investments of $19.4 to $60.0 billion.

Table F8. Refinery Source Environmental Costs, by PADD

(1987 $/bbl)

	PADD I	PADD II	PADD III	PADD IV	PADD V
Annual Environmental Cost	0.48	0.47	0.38	0.70	0.48

A methodology was developed to allocate refinery source environmental costs to the marginal prices of light products (LPG, gasoline, kerosine, jet fuel, No. 2 heating oil, and low sulfur highway diesel) thus including fixed costs in the prices reported at the refinery gate. The heavy products (residual oil, petrochemical feedstocks, asphalt, and other) are priced at their marginal cost due to competition from other fuels. Fixed refinery costs in each PADD are estimated as the sum of fixed operating costs, return on assets, and environmental costs associated with controlling pollution at refineries (Table F8). The PADD costs were allocated to their prospective PMM regions.

The average annual cost is applied to all years and is recovered in the prices of light products only. A variable cost methodology was investigated but was deemed to be an unnecessary complication. The costs for each 5-year time period were estimated to vary by less than 1-cent per gallon but would require significant changes to the model.

The methodology for allocating costs among light products is based on the concept of marginal cost and was developed from a similar approach used by the Gas Research Institute (GRI).[14] The steps used are as follows:

> (1) Determine the environmental investment and operating costs.
> (2) Determine the marginal revenue from the LP solution that will recover the marginal cost (the product of the marginal price of each product times the production volume).
> (3) Calculate ratios that will apportion the environmental costs to the light products marginal prices.

---

[13]The sum of the initial cost estimates in *Costs to the Petroleum Industry of Major New and Future Federal Government Environmental Requirements*, American Petroleum Institute, Discussion Paper #070, (Washington, D.C., October 1991), Tables ES-1 and ES-2. Aggregate estimates exclude product specification and off-site costs, and utilized minimum RCRA reauthorization.

[14]Gas Research Institute, "U.S. Refining Model Methodology", (May 1991).

(4)   Use the ratios from (3) to scale the marginal prices to refinery gate wholesale prices.

Equations: First, marginal revenue is determined for each refining region R:

$REVLP(LP)_R$ $= VALUE(LP)_R * VOLUME(LP)_R$
$REVHP(HP)_R$ $= VALUE(HP)_R * VOLUME(HP)_R$

where:

$VALUE(LP)$ is the marginal price for each light product (LP) that <u>will</u> bear the fixed cost
$VALUE(HP)$ is the marginal price for each heavy product (HP) that <u>will not</u> bear the fixed cost
$VOLUME(LP)$ is the production volume for each light product
$VOLUME(HP)$ is the production volume for each heavy product
$TOTREV_R$ $= REVLP(LP)_R + REVHP(HP)_R$

Second, the total revenue required, including the fixed costs, FIXCOST is determined:

$NTOTREV_R$ $= REVLP(LP)_R + REVHP(HP)_R +(FIXCOST_R*VOLUME)$
$NLTREV_R$ $= NTOTREV_R - REVHP(HP)_R$

The last step is to calculate the refinery gate price for each light product

$GATEPR(LP)_R$ $= (NLTREV_R/REVLP(LP)_R) * VALUE(LP)_R$

F.5 Estimation of Distribution Costs

Costs related to distributing petroleum products to end-users are incorporated by adding fixed transportation markups to the wholesale prices which include the variable and fixed refinery costs. Transportation markups for petroleum products except gasoline are estimated as the average annual difference between retail and wholesale prices. Due to an observable market shift before and after 1990, the transportation markups for all products except gasoline are estimated based on data between 1990 and 1999. Due to the requirement for oxygenated gasoline beginning in October of 1992, gasoline markups are estimated with data beginning in 1993. The differences are based on wholesale prices in the producing Census division and end-use prices (which do not include taxes) in the consuming Census division. Wholesale prices are aggregated from State-level prices from the EIA-782A. Sectoral end-user prices are aggregated from State-level prices from the State Energy Price and Expenditures Report (SEPER) 1997. End-use prices after 1997 are estimated according to the SEPER's methodology. Computer programs and data files used to estimate transportation markups are discussed below.

Data-Reading Programs

The following programs access EIA survey data and should be updated each year. Member names of SAS data sets are given in parenthesis.

Program: **PRJ6007.NEMS.MARKUP.WHOLSALE**

Files Read: PRJ6007.A.SASDB.STATE.AB
                                   (IMPSTATA)
                         PRJ6007.A.SASDB.STATE.AB9495
                                   (IMP94A)
                                   (IMP95A)
                         PRJ6007.A.SASDB.STATE.AB9697
                                   (IMP96A)
                                   (IMP97A)
                         PRJ6007.A.SASDB.STATE.AB9899
                                   (IMP98A)
                                   (IMP99A)
                           PRJ6007.NEMS.MARKUP.SASDB
                                   (REGIONS)
                                   (WHOLSALE)

This program reads databases containing State-level refiner wholesale prices from the EIA-782A. The program &PRJ6007.A.IMPYY.ADF must be run prior to this step to update the database (see Appendix H-3). A separate file is read for data prior to 1994 because the 782 data was kept in a different data system. Due to the number of data, prices for each year are kept in a separate file. Wholesale prices for asphalt and road oil, diesel (low sulfur), distillate fuel, gasoline, jet fuel, kerosene, liquefied petroleum gases, and residual fuel oil are aggregated into Census division prices (cents/gallon) and output to the NEMS database for other markup programs to access.   Program last run May 8, 2000.

Program: **PRJ6007.NEMS.MARKUP.EIA782.READ**

Files Read: PRJ6007.A.SASDB.STATE.AB9495
                                   (IMP94B)
                                   (IMP95B)
                         PRJ6007.A.SASDB.STATE.AB9697
                                   (IMP96B)
                                   (IMP97B)
                         PRJ6007.A.SASDB.STATE.AB9899
                                   (IMP98A)

(IMP99A)

PRJ6007.NEMS.MARKUP.SASDB

(REGIONS)

(PRODE)

This program updates retail prices on the NEMS database using the most recent data from the EIA-782A contained in IMP94B, IMP95B, IMP96, IMP97, IMP98, IMP99. The State-level prices for gasoline, diesel (low sulfur), distillate, kerosene, jet fuel, high and low sulfur residual fuel, and liquefied petroleum gases for the most recent 4 years, 1996, 1997, 1998, and 1999, are aggregated into regional prices and added to data for previous years (using PRODE). The program is updated by revising files and incrementing YEAR in line 82. Contact Tammy Heppner (586-4748) of the Petroleum Marketing Division of the Office of Oil and Gas concerning the EIA-782 data which is available in March. Program last run on May 12, 2000.

Program: **PRJ6007.NEMS.MARKUP.GDP87**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

(GDP87CH)

This program updates the chain weighted GDP deflators (1987 base) in the NEMS database. Program should be rerun after adding most recent year's deflator.

Program: **PRJ6007.NEMS.MARKUP.CREATE.CONFAC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

(CONVER84 through CONVER97)

This program provides annual conversion factors for each product. Factors for the most recent year of the SED's should be added to the data. These conversion factors are accessed by the SEPER.READ programs. The lpg factor is updated based on the upcoming SEDS (information available in April).

Program: **PRJ6007.NEMS.MARKUP.SEPER89.READ(no need to run anymore)**

Files Read: SSE6356.SEPER89.PRN

PRJ6007.NEMS.MARKUP.SASDB

(CONVER84 through CONVER97)

(SEPER89) contains data from 1984-1989

Program: **PRJ6007.NEMS.MARKUP.SEPER.READ**

Files Read: SSE6356.SEPER90S.PRN

                                PRJ6007.NEMS.MARKUP.SASDB

                                        (CONVER84 through CONVER97)

                                        (SEPER97) contains data from 1990-1997

This program reads State-level prices by sector from SEPER-1997 data query provided by Roy Stanley(586-5839) of Energy Markets and End-Use. The data is provided in an Excell file, after the top line is removed and the colums are formated with 3.0 with right alignment, they are saved as prn files and ported to the mainframe via ftp. On the mainframe these files must be resaved as card. The SEPER.READ programs puts the data into the NEMS database. Prices are accessed for the following products:

        gasoline (mg)
        distillate (df)
        kerosene (ks)
        residual fuel (rf)
        liquefied petroleum gases (lg)
        jet fuel (jf)
        asphalt and road oil (ar)
        petrochemical feedstocks (fs)
        naphtha feedstocks (fn)
        other feedstocks (fo)

Program last run June 12, 2000 but is usually run in late April.

Program: **PRJ6007.NEMS.MARKUP.READ.F759**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

                                      (REGIONS)

                                      (E759Y85 through E759Y97)

                                PRJ6944.F759.MAST1999, file has four digit year

This program reads monthly volumes of distillate, low and high sulfur residual fuel consumed by electric utilities from EIA-759. The volumes are by State and are in gallons. The program annualizes the volumes and assigns them to Census divisions. Contact Melvin Johnson (202)287-1754. Program last run May 19, 2000.

Program: **PRJ6007.NEMS.MARKUP.READ.F423**

Files Read: PRJ6501.F423.EX1984.DATA
                           PRJ6501.F423.EX1985.DATA
                           PRJ6501.F423.EX1986.DATA
                           PRJ6501.F423.EX1987.DATA
                           PRJ6501.F423.EX1988.DATA
                           PRJ6501.F423.EX1989.DATA
                           PRJ6501.F423.EX1990.DATA
                           PRJ6501.F423.EX1991.DATA
                           PRJ6501.F423.EX1992.DATA
                           PRJ6501.F423.EX1993.DATA
                           PRJ6501.F423.EX1994.DATA
                           PRJ6501.F423.EX1995.DATA
                           PRJ6501.F423.EX1996.DATA
                           PRJ6501.F423.EX1997.DATA
                           PRJ6501.F423.EX1998.DATA
                           PRJ6501.F423.EX1999.DATA
                           PRJ6007.NEMS.MARKUP.SASDB
                                    (EUSTATE)
                                    (UTDIV)

This program reads State-level quantities and costs of distillate, and high and low sulfur residual fuel consumed by electric utilities from FERC Form 423. The quantities and costs are converted to a trillion Btu basis and assigned to Census divisions. Contact Ken McClevey (202)287-1732. Program last run in May 19, 2000. Note: the survey has fewer and fewer respondents due to deregulation.

Program: **PRJ6007.NEMS.MARKUP.SEDSVOL.READ**

Files Read: PRJ6356.SEDS97A.DATA
                           PRJ6356.SEDS97B.DATA
                           PRJ6007.NEMS.MARKUP.SASDB
                                    (ARVOL)
                                    (GASVOL)
                                    (DSVOL)
                                    (KERVOL)
                                    (LPGVOL)
                                    (RSVOL)

This program reads the files that are a subset of the most recent SEDS file, provided by EMEU staff. The program updates members of the SAS database with the most recent volumes of the individual products by sector, and state.

Markup Estimating Programs

All "CALC" programs calculate markups as the difference between a products retail and wholesale price in each Census division and sector. The estimated markups are output to PRJ6007.NEMS.MARKUP. SASDB in 1987 dollars per trillion Btu. The output file from each program contains the variables PRODPMM, SECTOR, CENDIV, MEAN, AND STDERR.

Census Division "99" represents national data and Sector "ZZ" represents all sectors. The following table describes the source programs for petroleum product markups:

Table F9. Markups Output

Products	Sectors	Markup Program	File Name on MARKUP.SASDB
DS	CM, IN, RS, TR, ZZ	PMM.CALC	MARKPMM
JF	TR, ZZ	PMM.CALC	MARKPMM
MG	CM, IN, TR, ZZ	PMM.CALC	MARKPMM
AR	IN, ZZ	ASRO.CALC	MARKAR
KS	CM, IN, RS, ZZ	KERO.CALC	MARKOTH1
LG	CM, IN, RS, TR, ZZ	LPG.CALC	MARKLPG
RL	CM, IN	RESID.CALC	MARKRL
RH	TR	RHTR.CALC	MARKRH
DS	EU	ELECUTIL.CALC	MARKELEC
RL	EU	ELECUTIL.CALC	MARKELEC
RH	EU	ELECUTIL.CALC	MARKELEC

note: DS TR is 85 percent low sulfur diesel, DS IN is assumed 50 percent low sulfur.

Program: **PRJ6007.NEMS.MARKUP.PMM.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

                (PRODE)

                (WHOLSALE)

                (GDP87CH)

                (GASVOL)

                (CONVER84 through CONVER97)

                (RGAL87)

                (MGBTU)

                (MARKPMM)

This program uses retail gasoline, diesel (low sulfur), distillate, and jet fuel prices and volumes originating from the EIA-782A. Commercial and industrial gasoline prices are estimated by weighting the EIA-782 end-user (transportation) prices with SEDS volumes for these two sectors. Commercial and industrial gasoline volumes for 1997 are used to represent 1998 and 1999, since SEDS stops with 1997 data. Distillate and jet fuel markups are estimated as the average annual difference between end-use and wholesale prices for the years 1990 forward. Jet Fuel data from 1990 , Census divisions 3, 5, and 6 are dropped because the Gulf War resulted in a price spike . Due to a break in the data trend resulting in Clean Air Act requirements, gasoline markups are estimated based on data from 1992 forward. Program last run May 11, 2000.

To update: After updating "data" programs, revise this program to utilize more recent SEDS volumes by adding another data set that reads GASVOL98. Use CONVER98 and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.ASRO.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

                (PRODE)

                (WHOLSALE)

                (SEPER89)

                (SEPER97)

                (PRODE)

                (GDP87CH)

                (CONVER84 through CONVER97)

                (RGAL82)

                (ARBTU)

                (ARGAL)

                (MARKAR)

This program uses State-level asphalt and road oil prices to the industrial sector from SEPER's through 1997. End-use prices for 1998 and 1999 are estimated using annual changes in the EIA-782 high sulfur residual fuel prices. Prices for each Census division are calculated using 1997 volumes from the SEDS. Estimates for 1998 and 1999 are weighted using 1997 volumes. Markups are estimated as the average annual difference between end-use and wholesale prices for the years 1990 forward. Census division 8 data for 1990 is dropped as an outlier. Program last run June 12, 2000 but is usually run in late April.

To update: After updating "data" programs, revise this program to utilize more recent data. Use updated conversion factors, and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.KERO.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
                                    (PRODE)
                                    (WHOLSALE)
                                    (SEPER89)
                                    (STATE97)
                                    (PRODE)
                                    (KEROVOL)
                                    (GDP87CH)
                                    (CONVER97)
                                    (KEROGAL)
                                    (KEROBTU)
                                    (MARKOTH1)

This program uses State-level kerosene prices to the residential, commercial, and industrial sectors from SEPER's through 1997. End-use prices for 1998 and 1999 are estimated using the 1997, 1998, and 1999 changes in the EIA-782 distillate prices. Markups are estimated as the average annual difference between kerosene end-use and distillate wholesale prices for the years 1990 forward. Program last run June 19, 2000. The kerosene historical price data series was reestimated in 2000.

To update: After updating "data" programs, revise this program to utilize more recent data. Use updated conversion factors, and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.RESID.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
                                    (PRODE)
                                    (WHOLSALE)
                                    (SEPER89)

(SEPER97)

(GDP87CH)

(CONVER84 through CONVER97)

(RSGAL)

(RSBTU)

(MARKRL)

This program uses State-level residual fuel prices to the commercial, and industrial sectors from SEPERS through 1997. End-use prices for 1998 and 1999 are estimated using the 1997, 1998, and 1999 changes in the EIA-782 low sulfur residual fuel prices. Price estimates for 1998 and 1999 are weighted using 1997 volumes. Markups are estimated as the average annual difference between low sulfur end-use prices and aggregate residual fuel wholesale prices for the years 1990 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Use
                  updated conversion factors, and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.RHTR.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

                          (PRODE)

                          (WHOLSALE)

                          (SEPER89)

                          (STATE97)

                          (PRODE)

                          (REGIONS)

                          (EUSTATE)

                          (RSVOL)

                          (GDP87CH)

                          (CONVER96)

                          (RSTRGAL)

                          (RSTRBTU)

                          (MARKRHTR)

This program uses State-level residual fuel prices to the transportation sector from SEPERS through 1997. End-use prices for 1996, 1997, and 1998 are estimated using average residual fuel prices to electric utilities according to SEPER's methodology. The average Census division prices to utilities are multiplied by the ratio of national high sulfur price from the EIA-782 to the national residual fuel price to utilities from F-423. Prices for each Census division are calculated using 1996 volumes from SEDS. End-use price estimates for 1998 and 1999 are weighted using 1997 SEDS resid transportation volumes . Markups are estimated as the average annual difference between high sulfur end-use prices and aggregate residual fuel wholesale prices for the years 1990 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Use updated volumes and conversion factors, and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.LPG.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
                                        (PRODE)
                                        (WHOLSALE)
                                        (SEPER89 through SEPER97)
                                        (PRODE)
                                        (REGIONS)
                                        (LPGVOL)
                                        (GDP87CH)
                                        (CONVER96)
                                        (LPGGAL)
                                        (LPGBTU)
                                        (MARKLG)

This program uses State-level SEPER's prices for liquefied petroleum gases to the commercial, industrial, transportation, and residential sectors for 1989 through 1993.   Post-1993 prices for all sector's are the 782 sectoral prices, because the 782 began carrying sectoral data in 1994. Markups are estimated as the average annual difference between end-user lpg prices and wholesale prices for the years 1985 forward. The average residential markups exclude 1989 data because of the price spike related to a heating oil crisis that winter.   Program last run June 20, 2000 but is usually run in late April.

To update: After updating "data" programs, revise this program to utilize more recent data and updated conversion factors.

Program: **PRJ6007.NEMS.MARKUP.ELECUTIL.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
                                        (PRODE)
                                        (WHOLSALE)
                                        (SEPER89)
                                        (STATE97)
                                        (PRODE)
                                        (REGIONS)
                                        (UTDIV)
                                        (E759Y84 through E759Y99)
                                        (GDP87CH)

(CONVER84 through CONVER97)
(EURFRGAL)
(EURFBTU)
(MARKELEC)

This program uses State-level SEPER's prices for distillate, high sulfur, and low sulfur residual fuel to electric utilities through 1997. End-use prices for 1998 and 1999 are estimated using SEPER's methodology. The program breaks residual fuel consumption from the EIA-759 into high and low sulfur using a high/low sulfur breakout estimated from the FERC Form 423. The estimated high and low sulfur residual fuel volumes are used to estimate weighted average prices to the utility sector.

Markups are estimated as the average annual difference between prices to utilities and wholesale prices for the years 1990 forward. The average markup for commercial high sulfur residual fuel in Census division 8 excludes 1997 as an outlier. Note: the number of EI-759 respondents has declined significantly as non-utility generators have increased. It is uncertain how this affects prices.

To update: After updating "data" programs, revise this program to utilize more recent data. Add datasets CONVER98, and E759Y00.

Program: **PRJ6007.NEMS.MARKUP.CREATE.HISTORY**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
                          (MGBTU)
                          (DSBTU)
                          (LPGBTU)
                          (RSBTU)
                          (RSTRBTU)
                          (KEROBTU)
                          (ARBTU)
                          (EURFBTU)
                          (HISTMARK)
                          (HSTDOL99)
                     PRJ6007.NEMS.MARKUP.MU1PRDS.HIST.D062300A
                     PRJ6007.NEMS.MARKUP.DOL99.HIST.D062300A

This program pulls together historical markups from 1990 forward, transposes them and outputs them to a file in 1987 dollars and another file in 1999 dollars. M85 uses the gasoline markup in cents per gallon, converted to btu's. E85 uses a markup estimated from recent retail data from Oxyfuel News. The E85 markups are estimated in **AEO01E85.xls**.

Program: **PRJ6007.NEMS.MARKUP.CREATE.FLATFILE**

Files Read: PRJ6007.NEMS.MARKUP.SASDB

                (MARKPMM)
                (MARKLPG)
                (MARKRL)
                (MARKRHTR)
                (MARKOTH1)
                (MARKAR)
                (MARKELEC)
                (HISTMARK)
                (HSTDOL99)
        PRJ6007.MARKUP.NEMS.MU1PRDS.D062300A
        PRJ6007.NEMS.MARKUP.DOL98.D062300A

This program pulls together the markups for each product, transposes the data and outputs it to a file used by NEMS. Converts the markups into 1999 dollars and outputs to a file. Save as lrecl=120.

To update: Update the GDPCH87 deflator, GDPDEF99 and year dependent statements.

F.6 Estimation of Taxes

In the PMM, taxes are added to the prices of gasoline, transportation distillate fuel (diesel), transportation liquefied petroleum gases (LPG), and jet fuel. Taxes are also estimated for M85 (transportation methanol) and E85 (transportation ethanol). Weighted averages of the most recently-available State and Federal taxes are developed for each Census division. The State taxes are fixed in real terms; the Federal taxes decline at the rate of inflation (i.e., Federal taxes are fixed in nominal terms). An additional 2 cents per gallon is added to the State gasoline taxes to approximate local taxes. Historical values are also calculated for gasoline, transportation distillate, jet fuel and LPG, which are then added to historical end-use prices excluding taxes in order to develop a series with taxes included. The State taxes, including both historical and projected series by sector, product, and year, are contained in following file which resides in the default input directory:

    MU2PRDS

The Federal taxes are read into the PMM from file

    QDCRDCF

and are updated each forecast year by deflating the current value by the rate of inflation for that forecast year.

The following section traces the development of the taxes and lists the files used to produce both historical and forecast values. The historical data are developed on a monthly basis by State, then aggregated to volume-weighted annual averages by Census division. The outputs specified are members of the following SAS database unless otherwise stated:

PRJ6007.NEMS.TAX.SASDB

Program: PRJ6007.NEMS.TAX.Dyymm

Inputs: semi-annual tax information from the Federal Highway Administration and other sources

Outputs: STyymmS
STyymmM
where yymm refers to years 84 through 99, and months 01 and 07 (except for 1990 when the months are 01 and 08)

Sources: gasoline   Federal Highway Administration, Table MF-121T
diesel   Federal Highway Administration, Table MF-121T

State-level taxes are obtained from the Federal Highway Administration on a semi-annual basis (see www.fhwa.dot.gov/ohim/novmmfr.pdf), usually reflecting taxes as of January 1 and July 1, supplemented by information from EIA's *Petroleum Marketing Monthly* and the *Clean Fuels Report*.

We assume that taxes remain at the same level for the 6 months following each semi-annual report, unless information on effective dates of tax changes is provided. Thus, the tax level reported for say, 9207, is kept at the same amount for 9208-9212. The file STyymmS contains data for 1 month, while the file STyymmM reproduces the results for the subsequent 6 months, taking into account tax changes to the extent that they are known.

Program: PRJ6007.NEMS.TAX.DLPJTyy

Inputs: State-level LPG and jet fuel taxes collected once each year

Outputs: STLPJTyy

Sources: Jet fuel   Petroleum Marketing Division, Maureen Klein 301-495-8440

                     LPG   Federal Highway Administration, Table MF-121T

The annual tax data for jet fuel and LPG begin in 1995. A snapshot of annual taxes is reproduced for each month to create files with the same data for each month.

Program: PRJ6007.NEMS.TAX.M85E85

Inputs: State-level M85 and E85 taxes collected once each year

Outputs: STM8E8yy

Sources: M85   Clean Fuels Report, Table 9

                     E85   Clean Fuels Report, Table 9

The annual tax data for M85 and E85 begin in 1997.

Program: PRJ6007.NEMS.TAX.CALC95B

(Old Version):   PRJ6007.NEMS.TAX.CALC94

Inputs: PRJ6007.NEMS.TAX.SASDB

                    PRJ6007.NEMS.MARKUP.SASDB

                    PRJ6007.A.SASDB.STATE.AB

                    PRJ6007.A.SASDB.STATE.AB9495

                    PRJ6007.A.SASDB.STATE.AB9697

                    PRJ6007.A.SASDB.STATE.AB9899

                    StyymmM for years 1984 to current

                    IMPSTATB, a file containing State-level refiner and marketer prices for petroleum products

                    IMPSTATA, a file containing State-level sales of petroleum products, which are used as weights in calculating weighted averages

                    IMPyyB, a file containing State-level refiner and marketer prices for petroleum products for years 1994 and later

                    IMPyyA, a file containing State-level sales of petroleum products, which are used as weights in calculating weighted averages, for years 1994 and later

REGIONS, maps States to Census divisions

GDP87, GDP deflators for conversion to constant dollars

Outputs: STGAS_MO

STDES_MO

STLPG_MO

STJET_MO

The CALC program pulls together the monthly tax information and calculates Federal, State, and total taxes by month and State in cents per gallon and dollars per million Btu for both nominal and constant 1987 dollars. The program was revised in 1997 to incorporate state taxes for LPG and jet fuel back to 1995. Sales volumes and regional designations are added to facilitate volume weighting across time and regions as required. Refiner and marketer volumes are used to weight LPG taxes as Census division 1 and 2 data were missing in the A (refiner only) data. Product files are calculated and output separately. The programs were adjusted to incorporate changes in the EIA-782 database starting with the 1994 data.

Program: **PRJ6007.NEMS.TAX.YRREG**

(Old version):   **PRJ6007.NEMS.TAX.YRREG93**

Inputs: STGAS_MO

STDES_MO

STLPG_MO

STJET_MO

Outputs: STGAS_YR

STDES_YR

CDGAS_YR

CDDES_YR

STLPG_YR

STJET_YR

CDLPG_YR

CDJET_YR

The YRREG program takes the State monthly tax files created in the CALC program and develops weighted average annual taxes by State, then averages across Census divisions and outputs annual average taxes by Census division. The Census division annual averages are used to develop historical end-use prices including taxes by adding the calculated taxes to ex-tax prices from the *Petroleum*

Marketing Monthly. The program was adjusted to incorporate changes in the EIA-782 database starting with the 1994 data.

Program: **PRJ6007.NEMS.TAX.FORECAST**

Inputs: STGAS_MO
                      STDES_MO
                      STGAS_YR
                      STDES_YR

Outputs: GASCAST
                      DIESCAST

The FORECAST program uses the latest tax information, combined with the most recent year of sales data, and develops Census division weighted-average taxes which are used for the forecast. The latest tax information is in the file:

                    PRJ6007.NEMS.TAX.DCURR

The outputs include both nominal, constant 1987, and constant dollar denominations for the current AEO year in both cents per gallon and dollars per million Btu.

Program: PRJ6007.NEMS.TAX.FORECAST.E85
                      PRJ6007.NEMS.TAX.FORECAST.JET
                      PRJ6007.NEMS.TAX.FORECAST.LPG
                      PRJ6007.NEMS.TAX.FORECAST.M85

These programs perform the same function as the FORECAST program above, but for the transportation fuels indicated. The comparable data files are the following:

Inputs: PRJ6007.NEMS.TAX.SASDB:STGAS_YR
                      PRJ6007.NEMS.TAX.SASDB:STLPGJT00
                      PRJ6007.NEMS.TAX.SASDB:STM8E800,STM8E800
                      PRJ6007.NEMS.MARKUP.SASDB:REGIONS
                      PRJ6007.NEMS.A.SASDB.STATE.AB9899:IMP99A
                      PRJ6007.NEMS.A.SASDB.STATE.AB9899:IMP99B (use for LPG
                      because CD's 1 AND 2 EI-782A data are missing)
(Old versions):   PRJ6007.NEMS.TAX.DLPGJET.Y94

PRJ6007.NEMS.TAX.DM85E85.Y94

Outputs: PRJ6007.NEMS.TAX.SASDB:LPGCAST
        PRJ6007.NEMS.TAX.SASDB:JETCAST
        PRJ6007.NEMS.TAX.SASDB:E85CAST
        PRJ6007.NEMS.TAX.SASDB:M85CAST

Program: PRJ6007.NEMS.TAX.CREATE.HISTORY
        (contains State tax data only)

Inputs: CDGAS_YR
        CDDES_YR
        CDLPG_YR
        CDJET_YR

Outputs: PRJ6007.NEMS.TAX.HISTFILE

This program takes historical Census division taxes and creates a file that has the same format as the input tax file of the PMM (MU2PRDS), but only for the historical years.

Program: PRJ6007.NEMS.TAX.CREATE.FLATFILE
        (contains State tax data only)

Inputs: GASCAST
        DIESCAST
        LPGCAST
        JETCAST
        E85CAST
        M85CAST

Outputs: PRJ6007.NEMS.TAX.TAXFILE

This program takes the Census division taxes to be used in the forecast plus the historical taxes from HISTFILE and creates a file (MU2PRDS) that is used as input to the PMM. An additional 2 cents per gallon local tax estimate (in constant 1999 dollars) is added to the State gasoline tax estimates in this program. Save file as lrecl=120.

F.7 Gasoline Specifications

The PMM models the production and distribution of three different types of gasoline: conventional, oxygenated, and reformulated. The following specifications are included in PMM to differentiate between conventional 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).

The sulfur specification for gasoline is reduced to reflect recent regulations requiring the average annual sulfur content of all gasoline used in the United States to be phased-down to 30 ppm between the years 2004 and 2007. PMM assumes that RFG has an average annual sulfur content of 135 ppm in 2000 and will meet the 30 ppm requirement in 2004. The reduction in sulfur content between now and 2004 is assumed to reflect incentives for "early reduction". The regional assumptions for phasing-down the sulfur in conventional gasoline account for less stringent sulfur requirements for small refineries and refineries in the Rocky Mountain region. The 30 ppm annual average standard is not fully realized in conventional gasoline until 2008 due to allowances for small refineries.

Starting in 1998 the specifications for conventional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline." These specifications prevent the quality of conventional 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 conventional 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 United States since January 1995. Beginning in 1998, the EPA has certified 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. In 2000 the Complex Model was tightened to require further emissions reductions. The PMM uses a set of specifications that meet these "Phase II" Complex Model requirements, but it does not attempt to determine the optimal specifications that meet the Complex Model.

The State of California currently uses its own set of performance based gasoline standards which instead of the Federal Complex Model standards. The PMM assumes that all West Coast refiners must meet the current California Air Resources Board "CARBII" requirements until 2002 when a new set of "CARBIII" requirements will take their place. The CARBIII standards reflect the removal of the oxygen

requirement designed to compliment the State's plans to ban the oxygenate, methyl tertiary butyl ether (MTBE) by the end of 2002. Because MTBE is currently the main source of oxygen for gasoline in the State, California has petitioned the EPA for a waiver to the Federal RFG oxygen requirement. As no waiver had been granted prior to AEO2001, PMM reflects no oxygen waiver in the three areas of California covered by the Federal reformulated gasoline program: Los Angeles, San Diego, and Sacramento. In effect, these areas must use ethanol to meet the oxygen requirement. Other areas of California, do not have an oxygen requirement but use oxygenates because of their octane boosting, and volume extending properties. RFG in the areas with the Federal oxygen requirement is classified in the PMM as "RFG", while CARB gasoline in other areas is classified as "RFH."

AEO2001 reflects legislation which bans or limits the use of MTBE in seven additional States: Arizona, Connecticut, Maine, Minnesota, Nebraska, New York, and South Dakota. Since the oxygen requirement on RFG is assumed to continue in these States, the MTBE ban is modeled as a requirement to produce ethanol blended gasoline in the CHGDMDS subroutine.

Arizona also has a reformulated gasoline program for the Phoenix area which is mandated by state law. Phoenix had previously been part of the Federal RFG program but opted out when State requirements were adopted. Phoenix is required to use CARB in the winter but may use either CARB or Federal RFG in the summer. Arizona is in a different model region than California and, for the sake of simplicity, is assumed to use RFG meeting Federal specifications.

Annual Average Rvp Methodology

The annual average Rvp limits are derived based on existing summertime requirements and estimated wintertime levels. The assumed summer and winter Rvp specifications had been annualized by simple averaging using summer and winter weights provided by the EPA.[15] However the cost of reducing Rvp may not be a linear function. Therefore, utilizing the Petroleum Market Model, a methodology based on marginal costs was developed to compute an Rvp specification to represent the annual average. The PMM was configured to run two separate cases for summer and winter using the appropriate product specifications and demands for each season. The summer and winter marginal costs for gasoline obtained from the two runs were averaged (weighted by demand) to produce a target annual cost. The PMM (re-configured for annual demands) was then run iteratively, varying Rvp until the model produced marginal gasoline costs that were significantly similar to the target cost. The resulting Rvp specifications were then reduced by 0.3 psi to reflect pipeline requirements which are tighter than the EPA limits. The Rvp specifications used in the PMM are shown in Table F10. The lower Rvp specifications in PADD V reflect more stringent California limits which are imposed statewide.

---

[15]The summer weight of 0.396 and winter weight of 0.604 were provided by Dave Korrotney of EPA (313-668-5507).

Table F10. Estimated Annual Reid Vapor Pressure

Gasoline Market/Type	Simple Average		Annual Rvp in PMM	
	PADD I-IV	PADD V	PADD I-IV	PADD V
Conventional	10.2	9.2	9.6*	9.2
Oxygenated	10.2	9.2	11.0	9.2
Reformulated	9.1	8.7	8.5	7.9

*Originally 10.0, adjusted to reflect "boutique fuels" with lower Rvp requirements in some areas.

Complex Model Standards for Motor Gasoline

The Environmental Protection Agency (EPA) has promulgated new regulations for reformulated motor gasoline that are designed to lower vehicle emission pollutants as required by the amended Clean Air Act of 1990[16]. The reformulated gasolines are designed to reduce vehicle emissions of toxic and ozone-forming compounds. Reformulated gasoline must be sold in certain regions where there are severe ozone problems as well as in areas with less severe ozone problems which opt into the program. Conventional gasoline may be sold elsewhere but it must not be more polluting than it was in 1990. These areas are discussed elsewhere in the documentation. Although the EPA has established some conventionally treated specifications, namely minimum oxygen content and maximum benzene content, the new conceptual aspect of the emission standards is that the reformulated gasoline must be blended in such a way that it meets maximum allowable emissions of volatile organic compounds (VOCs), nitrous oxides (NO_x), and toxics. These new motor gasoline standards are calculated by complex formulae based upon key properties of the gasoline blend. The regulations cover Phase I (1 January 1995 through 31 December 1999) and Phase II (1 January 2000 and indefinitely afterwards). The model uses a set of specifications that meet emissions requirements for Phase II of the Complex. Also, the refiner may meet the requirements for VOCs and NO_x on either a per gallon basis or on an average basis although some per gallon constraints still apply. The average basis has been incorporated into the model.

The NO_x and toxics emission standards for reformulated gasoline apply year-round whereas the VOCs standards apply only in the summer. The NO_x standard varies depending upon whether the VOCs standards apply, i.e. depending upon whether it is summer or winter. The VOCs standard for the north[17] is different from the VOCs standard applying to the south, greater volatility is allowed in the north. The

---

[16]Federal Register, Environmental Protection Agency, <u>Regulation of Fuels and Fuel Additives;Standards for Reformulated and Conventional Gasoline; Final Rule</u>, Part II, 40 CFR Part 80, (Washington, DC, 16 February 1994)

[17]For the sake of simplicity, we use the terms south and north to refer to EPA regions 1 and 2 respectively. Region 1 is covered by ASTM Class B while Region 2 is covered by Class C.

Complex Model Averaged Standards are shown below in Table F11.

Table F11. Complex Model Standards

	Phase I 1995 - 1999	Phase II 2000+
VOC Reduction, %		
South	≥ 36.6	≥ 29.0
North	≥ 17.1	≥ 27.4
NO$_x$ Reduction, %		
Summer	≥ 1.5	≥ 6.8
Winter	≥ 1.5	≥ 1.5
Toxics Reduction, %	≥ 16.5	≥ 21.5
Oxygen, wt%	≥ 2.1	≥ 2.1
Benzene, %	≤ 0.95	≤ 0.95

These standards were translated into conventionally configured specifications for blending motor gasoline. First, two winter specifications were developed, one for Phase I and one for Phase II. Of course, the VOCs standard was excluded from consideration. Then four summer specifications were created, a south set and a north set for Phase I and similarly for Phase II. Specifications for Phase I were used in prior forecasts for years up to 1999. PMM currently uses only the Phase II specifications as 2001 is the initial forecast year. The sulfur specification is adjusted to reflect the regulations requiring the reduction of sulfur in gasoline. RFG is assumed to reach the target of 30 ppm sulfur by 2004.

These sets were developed by use of a spreadsheet, developed by EPA, which calculates the VOCs, NO$_x$, and Toxics of a reformulated gasoline as a function of the 'conventional' properties of the gasoline, i.e. as a function of Rvp, sulfur content, oxygen content, aromatics content, olefins content, benzene content, percent evaporation at 200 degrees Fahrenheit (E200), and percent evaporated at 300 degrees Fahrenheit (E300). The approach was to start with 'best informed guess' properties and use trial and error to gradually expand the allowable property limits. The blend properties cited as typical fuels in an EPA presentation[18] served as the starting values for both Phases I and II. The same starting point was used for

---

[18]C.L. Gray, "Reformulated Gasoline Final Rulemaking and Renewable Oxygenate Proposal," Proceedings of The World Conference on Refinery Processing and Reformulated Gasoline, March 22-24, 1994, Information Resources, Inc.

both winter and summer. Table F12, following a chart developed by the EPA,[19] indicates the directional sensitivities of the properties on the standards. Of course, a more rigorous approach is possible in establishing the specification sets. For instance, one might perform incremental changes over the reformulated gasoline properties followed by computer runs to establish minimum cost specifications. However, this approach was not implemented due to resource constraints.

Table F12. Directional Emission Effects of Gasoline Property Changes

Property	VOC	NO$_x$	Air Toxics
Rvp ↓	↓↓↓	–	↓
Sulfur ↓	↓	↓↓↓	↓↓
Aromatics ↓	↓	↓	↓↓
Olefins ↓	–	↓	–
E200 ↑	↓	↑	↓
E300 ↑	↓	–	–
Oxygen ↑	–	–	↓↓
Benzene ↓	–	–	↓↓↓

The PMM is an annual model, i.e. it does not have seasonality. A decision was made to develop, for PADDs I-IV, a single reformulated gasoline specification for Phase I simulation and a single specification for Phase II. This required several actions. The two summer sets for Phase I were linearly blended by compositing the projected gasoline sales-weighted south specifications to the appropriately weighted specifications of the north. The resulting two sets of specifications for Phase I, one for summer and one for winter, were then composited after weighting them according to summer sales and winter sales respectively. The Phase II specifications were collapsed to a single set in the same manner. The composites were calculated in a spreadsheet maintained by the Oil and Gas Division. This specification was adapted from the presentation made by Charles L. Gray at the conference cited above. The resulting reformulated gasoline specifications are shown in Table F13. It is, of course, a simple matter to convert the PMM blending stock distillation temperature values as needed.

---

[19]Ibid.

Table F13. PMM Reformulated Gasoline Specifications

	Phase I PADDs I-IV	Phase II PADDs I-IV	Phase II with Reduced Sulfur PADDs I-IV
Max Rvp, psia	8.7	8.5	8.5
Max S, ppm	305	108.75	30
Max Aro, %	25.0	25.0	25.0
Max Ole, %	12.0	12.0	12.0
Min E200, %	49.0	49.0	49.0
Min E300, %	87.0	87.0	87.0
Min Oxy, wt%	2.1	2.0	2.0
Max Ben, %	0.95	0.95	0.95

Data represent 2001 specifications to meet Complex Model standards. PMM adopted specifications in each forecast year based on the regulations in effect at the time. Therefore, in 2004 when the Tier 2 regulation kicks in, the maximum sulfur content is reduced to 30 ppm. The sulfur specification on the Complex Model is adjusted to meet Tier 2 gasoline requirements.

F.8 Estimation of Gasoline Market Shares

Within the PMM, total gasoline demand is disaggregated into demand for conventional, 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 actual 1999 level. The Census Divisions 3 and 4 market shares were adjusted because St. Louis, Missouri, joind the Federal reformulated gasoline program in the summer of 1999.

In 2003, the Census Division 9 market share for RFG is separated into two different catagories which represent CARB3 gasoline without an oxygen requirement (RFH) and CARB3 gasoline with the Federal oxygen requirement(RFG). This breakout into another product is needed to represent the planned MTBE ban in California in the absence of a waiver to the Federal RFG oxygen requirement.   As no waiver had been granted prior to AEO2001, PMM assumes the Federal oxygen requirement will remain intact in the three areas of California bound by the Federal requirement; Los Angeles, Sacramento, and San Diego. In effect, these areas must use ethanol to meet the oxygen requirement.. The market shares assume that 46 percent of the gasoline in Census Division 9 will continue to meet the Federal 2.0 percent oxygen requirement, and 27 percent will meet California specifications with no oxygen requirement.

Legislation to ban/limit the use of MTBE in California and seven other States is modeled as a requirement to produce ethanol blended gasoline in the CHGDMDS subroutine. Ethanol blends are assumed to account for the following market percentages:

> 33.8 percent of RFG in Census Division 1
> 36.3 percent of RFG in Census Division 2
> 99.9 percent of RFG in Census Division 8
> 100.0 percent of RFG(with 2.0 percent oxygen requirement) in Census Division 9
> 100.0 percent of oxygenated gasoline in Census Division 4
> 32.9 percent of oxygenated gasoline in Census Division 9

Although the shares are assumed to remain constant after 2003, 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.

F.9 Estimation of Low-Sulfur Diesel Market Shares

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 1999* (online: http://www.eia.doe.gov/oil_gas/petroleum/data_ publications/fuel_oil_and_kerosene_sales/foks.html, September 2000). Since about 15 percent of current demand in the transportation sector is off highway, 85 percent of transportation demand for distillate fuel is assumed to be low sulfur. Consumption of low-sulfur distillate also occurs in the industrial sector where it is assuemd to be 50 percent of the market.

F.10 Low-Sulfur Diesel Specifications

In order to account for CAAA90 diesel desulfurization regulations, low-sulfur diesel is differentiated from other distillates. Specifications for sulfur, aromatics content, and API gravity are included in the PMM. Diesel fuel in Census Divisions 1 through 8 is assumed to meet Federal specifications including a maximum sulfur content of 500 parts per million (ppm) and a maximum aromatic content of 35 percent by volume.[20] Diesel fuel in Census Division 9 is assumed to meet California Air Resources Board (CARB) standards which limit sulfur content to 500 ppm and aromatics to 10 percent by volume.[21]

F.11 Estimation of Regional Conversion Coefficients

Differing regional definitions necessitate the conversions of certain variables from one regional structure to another. Regional conversions are not extensive in the PMM, but are needed for three refinery input prices, refinery fuel consumption, and cogeneration information. The factors are used to convert prices consumption, or cogeneration from other regions to the PADD level since the PMM was originally constructed by PADD. The PADD level information is applied to the current PMM regional configuration where PADD I is equivalent to PMM Region I, PADD 2, 3, and 4 are included in PMM Region II, and PADD V is equivalent to PMM Region III.

Conversions for Prices of Refinery Inputs

PMM receives prices for refinery inputs of natural gas in other regional configurations and must convert these into PADD level prices. Due to the proximity of refineries in PADDs 2, 3, and 4 to the sources of natural gas supply, prices in these PADDs reflect wellhead natural gas prices in the corresponding Oil

---

[20] Federal regulations require either a maximum 35 percent (volume) aromatics or a cetane index of 40.
[21] http://arbis.arb.ca.gov/diesel/diesregs.pdf

and Gas Production Regions. PADDs 1 and 5 use industrial prices in the corresponding Census divisions in order to capture the additional costs of moving the natural gas to the refineries. Table F14 shows the source of PADD level natural gas prices:

Table F14. Source of PMM Natural Gas Prices

Correlation of Prices	
PADD	Input Price
1	Census Division 2 industrial price (PGIIN)
2 - 4	Oil and Gas Production Region 3 and 5 wellhead prices (OGWPRNG), and quantity weighted average of Oil and Gas Production Regions 2,4, & 8 wellhead price (OGWPRNG)
5	Census Division 9 industrial price (PGIIN)

PMM receives prices for refinery inputs of electricity by Census division. PADD level prices are derived by assuming prices in intersecting Census divisions. Table F15 shows the correlation between PADD and Census division electricity input prices:

Table F15. Source of PMM Electricity Prices

Correlation of Prices	
PADD	Input Price
1	Census Division 2 industrial prices (PELIN)
2 - 4	Census Division 3, 7, and 8 industrial prices (PELIN)
5	Census Division 9 industrial prices (PELIN)

Conversions for Refinery Fuel Consumption

Refinery fuel consumption must be converted from the PADD to the Census division level. Each Census division consumption number will equal the consumption in the overlapping PADDs times a factor. The

factors were developed using State-level refinery operating capacity and are shown in Table F16. The factors are interpreted as follows: The 0.8434 at the intersection of Census Division 2 and PADD I indicates that 84.3 percent of the PADD I refinery fuel consumption is estimated (using refinery operating capacity as estimator) to occur in Census Division 2. These values will change by small amounts as refinery capacities change, but the impact on model results will be small.

Example: Census Division 7 fuel consumption =
(PADD II consumption * .12) + (PADD III consumption * .93)

Table F16. PADD to Census Division Conversion Factors

	Census Division									
	1	2	3	4	5	6	7	8	9	SUM
PADD 1		0.84			0.16					1.00
PADD 2			0.60	0.19		0.09	0.12			1.00
PADD 3						0.07	0.93			1.00
PADD 4								1.00		1.00
PADD 5									1.00	1.00

Conversions for Cogeneration

Information including cogeneration levels (RFCGGEN(CD)), cogeneration capacity (RFCGCAP(CD)), refinery fuel consumption (RFCGFUEL(CD)), self-generation (RFCGSELF(CD)), and generation for grid (RFCGGRID(CD)) must also be converted from PADD level to Census divisions. The same factors and methodology developed for refinery fuel consumption (Table F16) are used to convert the cogeneration data.

Conversion coefficients for refinery fuel consumption and cogeneration information are estimated using &6007PRJ.PMM.CAPACITY.COEFS. Manual updates to the data file were made using data from Oil and Gas Journal survey and making some minor adjustments to the program that reads the data.

F.12 Unfinished Oil Imports Methodology

PADDs I and III are the primary recipients of unfinished oil imports into the United States. Of the four categories that EIA publishes, light gas oils are practically nil and will not be modeled in PMM.

The Oil Market Module used the most recent known values for imports of unfinished oils, which remained fixed throughout the forecast period. While simplistic, this methodology was difficult to improve on.

In the methodology described below, unfinished oil imports are estimated as a function of crude oil input to refineries. Only six observations were available for this equation (1989 was an outlier and was not used), so this methodology should be reviewed later, possibly re-estimating the equation using quarterly data. Total U.S. unfinished oil imports are estimated from the equation, then the PADD I and III values are shared out.

U.S. Unfinished Oil Imports = $-2856.7 + (0.2447 *$ Crude Inputs)
t-stats: (-157.5) (8.97)
R-squared: .95

PADD III Unfinished Oil Imports = U.S. Unfinished Oil Imports $* 0.61$
   PADD III Naphthas = PADD III Total $* 0.24$
   PADD III Heavy Gas Oils = PADD III Total $* 0.33$
   PADD III Residuum = PADD III Total $* 0.43$

PADD I Unfinished Oil Imports = U.S. Unfinished Oil Imports $* 0.38$
   PADD I Naphthas = PADD I Total $* 0.12$
   PADD I Heavy Gas Oils = PADD I Total $* 0.68$
   PADD I Residuum = PADD I Total $* 0.20$

F.13 Product Pipeline Capacities and Tariffs

Two sources were used to obtain the product pipeline data; (1) The NPC study [22] and (2) The North American Crude Oil Distribution (NACOD) model prepared by ICF for the Office of Strategic Petroleum Reserves (OSPR) during 1990-91. The NACOD data was received in LOTUS.WK3 spreadsheet format from Don Buck of OSPR.

NACOD data for the year 2000 were used for the petroleum product pipeline capacities and tariffs

---

[22]National Petroleum Council, *Petroleum Storage and Distribution, Volume 5, Petroleum Liquids Transportation*, (April 1989).

(1991$). The NPC study was used for LPG and NGL pipeline capacity data. The NACOD model defines 15 crude oil demand regions (including Canada and Puerto Rico/Virgin Islands) and the NPC study uses PADD regions. The links needed for PMM, as shown in Table F17, are based on PADDs for refining regions and Census divisions for demands.

Many of the arcs shown in Table F18 and Table F19 represent more than one pipeline. In some cases, we have retained more than one arc from a source to a destination in order to have a better representation of product movements.

Table F17. NACOD Regions and NEMS/PMM Census Regions

NACOD Regions		NEMS/PMM Regions	
Code	Locations	Code	Locations
1	New England	1	NE, New England
2	Includes MD,DE	2	MA, excludes MD,DE
3	WV to FL	5	SA, includes MD,DE
4	KS, OK	7	WSC, includes OK,KS
5	PADD II	3, 4	WNC,ENC, and KY, TN from 6
6	Texas Gulf Coast	7	WSC
7	LA Gulf Coast	7	WSC
8	West Texas, NM	7	WSC, excludes NM
9	AR, No. LA, No. MS, AL	6, 7	ESC,AR,LA,MS,AL
10	PADD IV, North- ID, MT	8	MNT
11	PADD IV, South- WY,UT,CO	8	MNT
12	Alaska		
13	Hawaii		
14	PADD V,	9	PAC, excludes NV,AZ

The product pipeline capacities, excluding LPG/NGL service, are shown in Table F19. The matrix formulation used in PMM allows for separate arcs for product movements. For example, to deliver a barrel of gasoline to Dorsey, Maryland (in Census Region 2) from PADD III, (Census Region 7), requires flow on the arc from Region 7 to Region 6 (capacity of 2280 Mbbl/cd) at a cost of $0.31/bbl, flow on the

arc from Region 6 to Region 5 (capacity of 2526 Mbbl/cd) at a cost of $0.74/bbl, and flow on the arc from Region 5 to Region 2 (capacity of 1392 Mbbl/cd) at a cost of $0.16/bbl. The total tariff is $1.21/bbl or 2.88 cents/gallon.

Table F18. Petroleum Product Pipeline Capacities and Tariffs[23]

Census region			
From	To	Capacity (Mbbl/cd)	Rate (Wt. avg $/bbl)
ENC, 3	MA, 2	157	1.32
ENC, 3	SA, 5	20	1.40
SA, 5	MA, 2	1392	0.16
ESC, 6	SA, 5	2526	0.74
WSC, 7	ENC, 3	328	0.56
WSC, 7	WNC, 4	280	0.86
WSC, 7	WNC, 4	717	0.80
WSC, 7	ESC, 6	2280	0.31
WSC, 7	MNT, 8	81	0.74
WSC, 7	MNT, 8	58	0.73
MNT, 8	WNC, 4	44	0.99
MNT, 8	PAC, 9	73	0.99

[23]Capacities and tariffs from NACOD model. Tariffs shown reflect 1987 dollars so that it's consistent throughout the PMM.

The LPG/NGL pipelines are shown in Table F19.

Table F19. LPG/NGL Pipelines Capacities and Tariffs[24]

Census Region			
From	To	Capacity (Mbbl/cd)	Rate (Wt. avg $/bbl)
ENC, 3	MA, 2	61	2.18
WNC, 4	ENC, 3	56	0.99 (estimated)
WNC, 4	SA, 5	57	0.99 (estimated)
ESC, 6	SA, 5	109	0.65
WSC, 7	ESC, 6	120	0.28
WSC, 7	WNC, 4	225	0.65
WSC, 7	WNC, 4	65	1.14
WSC, 7	MNT, 8	47	0.84
MNT, 8	WNC, 4	12	1.15

F.14 Cogeneration Methodology

Electricity consumption in the refinery is a function of the throughput of each unit. Sources of electricity consist of refinery power generation, utility purchases, refinery cogeneration, and merchant cogeneration. Power generators and cogenerators are modeled in the PMM Linear Program (LP) as separate units which are allowed to compete along with purchased electricity.

Refinery Cogeneration

The refinery cogeneration unit in the PMM LP was modeled using historical data as a guideline. Cogeneration activity for each refinery was aggregated to the PADD level for incorporation into the PMM LP. Cogeneration capacity, fuel consumption, and percent sales to the utility grid were estimated from the EIA-860B, Annual Nonutility Power Producer Report for 1998. The data covers all of SIC 29, not just SIC 2911. Cogeneration investment and operating costs were derived from the 1980 Office of Technology Assessment (OTA) report "Industrial Cogeneration."

---

[24]Capacities from NPC study, tariffs from NACOD model data

Cogeneration capacity (including planned capacity) for each refining region was derived from the EIA-860B historical data base. It should be noted that the capacity provided in the data base is summertime capability and not nameplate capacity. The LP limits utilization to 90 percent of the summertime capability. Cogeneration capacity is allowed to expand when the value received from the additional product exceeds the investment and operating costs of the new unit. The value of adding capacity includes revenues from sales to the utility grid and the displacement of purchases of electricity. Investment costs are derived from the OTA report. The capacity expansion methodology is described in detail in Chapter 4.

Refinery cogeneration fuel consumption was derived from the NEMS Industrial Model for small cogeneration systems. A 1,000 kw capacity unit was assumed with an overall heat rate of 14,217 btu/kwh. Converted to fuel oil equivalent, consumption of 2.26 barrels of fuel oil produces approximately 1,000 kwh of electricity and 6,530 lbs of steam. Since the LP refinery consumes fuel in barrels of fuel oil equivalent, shares of individual fuels were determined from the historical data and computed post process. The shares are allocated as follows:

Oil   6.0%
Natural Gas   68.1%
Other Gaseous Fuels   25.2%
Other   0.7%.

In the past, shares of all petroleum based fuels were aggregated under Petroleum Products. This category has now been divided into Oil and Other Gaseous Fuels.

In general, refinery cogeneration units tend to be small, designed to supply the refinery's steam and electricity needs, with a small amount of leftover capacity sold to the grid. However, if it is profitable to sell cogeneration electricity, the LP will sell all of it. Likewise if it is not profitable, it will sell none of it. To model the situation more realistically, sales to the grid were modeled using percentages derived from the historical data base. The percentage of sales to the grid for each refining region (PADD) was calculated from the 1998 data as follows:

REGION	PERCENT SOLD TO GRID
1 (PADD I)	56.9
2 (PADD's II, III, and IV)	4.3
3 (PADD V)	20.1

The LP is forced to sell electricity back to the grid in these percentages at a price equal to the average price of electricity.

Fixed operating costs are calculated in the model as a function of cogeneration capacity while variable operating costs are determined as a function of electricity generated. The following rates were determined from the OTA report.

Annual Fixed Cost $7.32/kw
Variable Cost $0.00565/kwh

Data from the EIA-860B report obtained from an Access query by Alan Beamon. The resulting data were manipulated in COGENALL.XLS and saved into COGEN.HISTORY.PRN which is read by the SAS program &PRJ6007.PMM.HIST.COGEN00. This program manipulates the data to get it into the format need by the LP. Note: cogenaration capacity by PADD from the last historical year is multiplied by 24 for input into the PMM file COGENER.DAT.

Merchant Cogeneration

Merchant cogeneration is also modeled in the PMM. Merchant cogenerator's are defined as non-refiner owned facilities located near refineries to provide energy to the open market and to the neighboring refinery. The PMM merchant cogeneration model parameters are based on the Central & South West Energy Inc. (CSWE) facility located adjacent to the Phillips Petroleum Company in Sweeny, Texas. CSWE supplies all of the refinery's steam and electricity requirements and receives up to three quarters of their fuel from refinery waste gases.[25] Electricity not used by Phillips, about two-thirds of total capacity, is sold on the open market.

Fuel consumption parameters for the PMM merchant plant are based on the Sweeny facility. The PMM merchant cogeneration unit consumes 1.90 barrels of fuel oil equivalent to produce 1,000 kwh of electricity and 5,200 lbs. of steam.

Initial capacity in PMM region 2 (PADD's II, III, and IV) is 330 Mw (Sweeny plant). Base capacity in all other regions is zero. Capacity expansion methodology is the same as in the refinery cogeneration model. Investment cost for a new cogeneration facility is $580 per kw of capacity. Annual fixed cost and variable operating cost are the same as for the refinery cogeneration model.

Unlike refinery cogeneration units, merchant facilities tend to be large units designed to sell a large portion of their electricity to the grid. The PMM merchant cogeneration model assumes 67 percent of electricity generated is sold to the grid in all regions, based on the Sweeny facility. The sale price is equal to the average of the generation price and the industrial price of electricity for each PMM region. Electricity prices are obtained from the Electricity Market Model.

---

[25]CarolAnn Giovando June 1998. *1998 Powerplant Awards Sweeny Cogeneration Facility*, Power.

F.15 Natural Gas Plant Fuel Consumption

The consumption of natural gas by natural gas processing plants is modeled as a function of dry gas production. Natural gas consumed at gas processing plants is calculated as a percentage of dry gas production using data from the *Natural Gas Annual 1992*. The ratios are calculated by PADD, except for PADD V where Alaska is computed separately from the rest of PADD V.

PADD I	1.36
PADD II	2.50
PADD III	2.43
PADD IV	2.61
PADD V	2.25
ALASKA	8.93

F.16 Crude Oil Exports/Total and Alaskan

Exports of crude oil have been historically linked to the level of domestic production. Crude oil exports are represented in the PMM by the following equation:

$$\text{Exports} = -179.23 + .043 \, (\text{Totprod})$$
$$(-5.03) \quad (6.14)$$

$$\text{R squared} = 0.60$$

where Totprod = total United States crude oil production in thousands of barrels per day.

In November 1995, the ban on exports of Alaskan North Slope (ANS) oil was lifted. Exports began in the spring of 1996. Since that time ANS exports have represented approximately 60 percent of total crude oil exports from the United States. Therefore the PMM methodology assumes that 60 percent of crude oil exports are from ANS.

F.17 Technology Improvement Option

A number of mechanisms for representing technological progress for key PMM refinery processing units has been implemented in the PMM. The first option allows the PMM to represent process technology improvements which will impact operating costs on any or all active processing units and/or processing modes. Thus, the user defines the processing unit(s), corresponding processing mode(s), and percentage

change in variable operating cost (OVC) (positive or negative), along with a range of years over which these are phased in. The second option allows the user to define a set of processing units and corresponding output streams whose yields would change due to technology improvements. The year in which the technology will come on and the corresponding yields are also included in the input data. The third option allows the user to upgrade the properties of intermediate streams beginning in any user-specified year. The user defines the stream ID, the spec ID(s), and the new spec value(s), along with the activation year for this change. The design for each of these options is modular in that the control data are located in a file separate from the current PMM refinery technology database, and the user defines the information needed to drive the technology change. Each of these options are summarized below.

For the first option, the user has the option to change the OVC data for all processing units (global), for any number of user-defined processing units, for both (with the user-defined unit data over riding the global data), for any set of processing modes, or for nothing at all. The user defines the period over which the OVC change is phased in, as well as the total percentage change (- for a decrease and + for an increase) that is desired over the period. For the user-specified option, the user also includes the 3-digit processing unit ID(s). The last record of data in the user-specified option must begin with a # symbol to signal the end of the list. To turn off either or both options, the phase-in begin and end years must be set to 0. The control data are located at the bottom of the PMM QDCRDCF data file. The format of this control data is as follows:

```
C Data for Global changes to reflect Technological Progress
C       |  Phase-in Period  | Chng over period
C       | BeginYR    EndYR  | Percent Chng
@       |    Y1        Y2   | TPCT_CHNG
             0         0       0.0000

C Data for Process Unit changes to reflect Technological Progress
C       | Phase-in Period   | Chng over period  | Name of ProcUnit/ Mode
C       | BeginYR    EndYR  | Percent Chng      | Three-letter ID
@       |    Y1        Y2   | TPCT_CHNG         | UNAMID      MNAMID
x            0         0       0.0000              FCC   75H
x            0         0       0.0000              ALK        C4A
#            0         0       0.0             ---         ---
```

To activate the option to *change stream yields* for a processing unit and mode of operation, the user is required to define the processing unit(s), mode(s) and stream(s) being affected, the corresponding new yield level(s), and an activation year (not phased in for this version). The number of processing units, modes, and streams must be included in the data file to act as controls for reading and processing the data. Up to ten modes and ten streams per mode can be changed for each processing unit defined. To deactivate this option, the number of processing units is set to zero. During the processing effort, the original yield and gain levels associated with the processing unit/mode combination are first retrieved from the LP matrix. Next, the yields corresponding to streams specified by the control data are updated based on the input data. Finally, the gain is recalculated and updated in the matrix. The data format representing an activated list of new yield levels is presented below:

```
C Data for Yield improvement to reflect Technological Progress
C   | Num/Name |      |       |     MAX MODES = 10
C   | ProcUnit | Tech | # of  |    1  new  |      2  new  |      3  new  |      4  new
C   | 3-let ID | Year | modes | mode, coeff | mode, coeff | mode, coeff | mode, coeff|
@   | -------- | ---- | ----- | ----  ----- | ----  ----- | ----  ----- | ----  -----|
      1
      FCC       2005    2       80S            75H
                                 4              8
                                RC8    .635     UC4    .064
                                LC8    .099     UC3    .050
                                UC4    .089     ZR8    .286
                                COX    .051     ZR7    .286
                                ---    .000     ZC7    .040
                                ---    .000     ZC8    .040
                                ---    .000     LC1    .054
                                ---    .000     LC2    .055
```

To activate the option to *change spec values* of intermediate streams, the user is required to define the stream(s), spec ID(s), new spec levels, and an activation year (not phased in for this version). The number of streams and spec IDs must also be included in the data file to act as controls for reading and processing the data. Up to ten spec types can be changed for each stream defined. To deactivate this option, the number of streams is set to zero. During the processing effort, the coefficients corresponding to the product component stream columns (B* and F*) and the product spec requirement rows (Q*) are updated using the stream spec data. Note, however, that a special algorithm must be used when changing the gravity and sulfur specs for streams used for blending into products. The gravity spec (GRX) must be converted using the following equation before being used to update the LP matrix:

$$\text{coef}_{\text{gravity}} = 141.5 / (131.5 + \text{CHNGSPC}_{\text{gravity}})$$

The sulfur spec (SLX) data for streams used in blending gasoline simply must be divided by 100 (to convert from percent to decimal), while that used in blending distillate product must be converted based on the sulfur spec data, the gravity spec data, and a distillate sulfur adjustment factor (DISTSUL). Thus, the following equation is used to define the coefficient corresponding to the distillate component stream column (F*) and the distillate sulfur requirement (Q*) row:

$$\text{coef}_{\text{sulfur}} = (\text{CHNGSPC}_{\text{sulfur}} - \text{DISTSUL}) * 141.5 / (131.5 + \text{CHNGSPC}_{\text{gravity}})$$

The data format representing an activated list of new spec levels for intermediate streams is presented below:

```
C Data for Spec improvement to reflect Technological Progress
C
C   SELECT FROM THE FOLLOWING LIST OF SPEC IDS:
C       GASO: R0N, M0N, RVX, E2N, E3N, SLX, OLX, ARX, BZX, PON, POX
C       DIST: SLX, GRX, VBX, LMX, FLX, FZX, ARX
```

```
C  REQUIRED: WHEN CHANGING SLX, MUST ALSO CHANGE GRX, AND VICE VERSA
C
C  |      |          |       |    MAX NUM OF SPECS = 10
C  | Tech |  Stream  | # of  |    1  new |    2  new |    3  new |    4  new|
C  | Year | 3-let ID | specs | spec, value | spec, value | spec, value | spec, value|
@  | ---- | -------- | ----- | ----  ----- | ----  ----- | ----  ----- | ----  -----|
              5
     2005      ZL8       2      BZX  2.50     RVX  10.00
     2005      8LR       3      BZX  2.40     RVX  10.00     ARX  10.00
     2005      ZR8       3      BZX  0.88     GRX  65.00     SLX 200.00
     2005      OR8       3      BZX  2.56     GRX  75.00     SLX  80.00
     2005      BR8       3      BZX  0.18     GRX  50.00     SLX 320.00
```

APPENDIX G

Matrix Generator Documentation

APPENDIX G. Matrix Generator Documentation

G.1 Introduction

The purpose of this appendix is to describe the program which runs the Multi-Refining Model (MRM) (3-regions) and the Enhanced Refinery Model (ERM) (single region); and to provide detail on how it works. The program allows the user to simulate a single region (ERM) or a 3-region (MRM) representation of the entire refining industry in the United States.

The ERM model simulates a single PADD (Petroleum Administration for Defense District) and has no transportation of crude oil to the refinery region nor product from the refinery region. Instead, crude oil is supplied directly to the refinery gate and product demands are satisfied at the refinery gate. The ERM projects petroleum product prices, product demands, crude oils, alcohols, ethers, natural gas and fuel consumption, and capacity expansion in a PADD.

The 3-region MRM simulates multiple PADD regions. It is a collection of ERMs linked by a transportation network. It simulates the entire refining industry in the United States. The MRM simulates the operation of petroleum refineries in the United States, including the supply and transportation of crude oil to refineries, the regional processing of these raw materials into petroleum products, and the distribution of petroleum product to meet regional demands. In addition to the quantities that an ERM produces, the MRM identifies sources of supply for domestic and imported crude oils, alcohols, ethers and natural gas. The 3-region MRM models the 5 U.S. PADDs, aggregated into 3 regions and labeled as follows: E = PADD I; B = PADDs II, III, IV; W = PADD V.

The program generates the matrix for the linear programming model representation of the ERM or MRM, solves it, writes the solution, reports, and packs the matrix for use by the analyst using the ANALYZE software.

G.2 Code

The program is written in Fortran and makes use of the OML (Optimization and Modeling Libraries) to read in the data files, generate the matrix representation of the model, solve the problem, store the solution, and pack the matrix for use with ANALYZE. In addition to the above, the program produces reports.

The program is data driven and the user provides key information such as the model he chooses to run, the location of the input data files, and some other options.

G.2.a Variables and Constraints

The model consists of variables or activities (columns), constraints (rows), and bounds on activities. A unique name has been assigned to each variable and constraint. In the naming of the variables and rows, indices were used. The following table displays the index set name and the number of elements in the set, gives a brief description of the set, and provides a partial listing of the set members.

Index	No. of Values	Description	Members
@	1	represents all regions	@
c	2	Constraint type	X: for max N: for min
d	9	Census divisions	1: New England 2: Mid Atlantic 3: East North Central 4: West North Central 5: South Atlantic 6: Est South Central 7: West South Central 8: Mountain 9: Pacific
e	2	Emission source	C: Emission from fuel combustion N: Emission from process unit
m	15	Transportation mode, function of material and means of movement	4: U.S. flag residual oil 5: South Atlantic node W: crude pipeline from supply reg 3 to PADD III B: Barge residual oil I: West Texas to PADD II J: U.S. flag light products O: U.S. flag LPG R: PADD III loop to PADD II S: PADD III capeline to PADD II T: Light product pipeline U: LPG, C4, CC5 pipeline V: Barge residual oil X: Local transportation Y: Pipeline PADD II to demand region 6 Z: Psudo link

Index	No. of Values	Description	Members
o	8	OGSM regions	0: OGSM 1A East Coast 1: OGSM 1B East West part 2: OGSM 2 Gulf Coast 3: OGSM 3 Midcontinent 4: OGSM 4 Permian Basin 5: OGSM 5 Rocky Mountain 6: OGSM 6 West Coast A: OGSM A Alaska North
r	3	Refining regions	E: PADD I B: PADD II, PADD III, PADD IV W: PADD V
t	2	Type of transportation	V: Vessel P: Pipeline
x	5	Exporting regions	2: Export cd for PADD I (region E) 3: Export cd for PADD II (region B) 7: Export cd for PADD III (region B) 8: Export cd for PADD IV (region B) 9: Export cd for PADD V (region W)
Nn	3	Negative shift in demand	N1, N2, N3
On	8	Natural Gas refinery supply steps	N1, N2, N3, N4, P5, P6, P7, P8
Pn	3	Positive shift in demand	P1, P2, P3
qm	11	Quality code for gasoline blending	AR: Aromatics BZ: Benzene E2: E 200 E3: E 300 M0: Motor octane PO: Percent oxygen OL: Olefine R0: Research octane RV: Reid vapor pressure SL: Sulfur RE: renewables component (due to required minimum contribution to oxygenates)
qd	7	Quality code for distillate	AR: Aromatics FL: Flash point FZ: Freezing point GR: Gravity LM: Luminometer number SL: Sulfur VB: Viscosity
Qs	3	Step label for crude oil imports	Q1, Q2, Q3

Index	No. of Values	Description	Members
Rs	9	Step label for product imports	R1, ..., R9,
S1	1	Step label for product demands	S1
SX	1	Product exports	SX
Z9	1	Distress imports and exports	Z9
crt	12	Crude groups by quality and origin	ALL: Alaskan, API 25-66, S<0.5, B<15 AMH: Alaskan, API 21-32, S<1.1, B>15 DLL: Domestic, API 25-66, S<0.5, B<15 DMH: Domestic, API 21-32, S<1.1, B>15 DHL: Domestic, API 29-56, S<1.99, B<15 DHH: Domestic, API 23-35, S<3.0, B>15 DHV: Domestic, API<23, S>0.7, B>15 FLL: Foreign, API 25-66, S<0.5, B<15 FMH: Foreign, API 21-32, S<1.1, B>15 FHL: Foreign API 29-56, S<1.99, B<15 FHH: Foreign, API 23-35, S<3.0, B>15 FHV: Foreign, API<23, S>0.7, B>15
dfo	5	Distillate fuel oil blends	JTA: Jet fuel N2H: Number 2 oil DSL: Low sulfur diesel N6I: Low sulfur resid N6B: High sulfur resid
emu	6	Emission type	CAR: Total carbon CO1: Carbon monoxide CO2: Carbon dioxide NOX: Nitrous oxides SOX: Sulfur oxides VOC: Volatile organic compounds
ist	783	Refinery intermediate streams	LNI: Light naphtha, (175-250) intermediate LNN: Light naphtha, (175-250) naphthenic LNP: Light naphtha, (175-250) paraffinic
mgb	2	Gasoline blends	TRG: Conventional gasoline RFG: Reformulated gasoline
mod	many	Operating mode	C2A: Ethyl alkylate C3A: Propyl alkylate C4A: Butyl alkylate

Index	No. of Values	Description	Members
ncr	10	Non crude purchase	ARB: Atmospheric resid of type B CC3: Propane ETH: Ethanol HGM: Heavy gas oil medium sulfur IC4: Isobutane MET: Methanol MTB: M.T.B.E. NAT: Natural gasoline NC4: Normal butane NPP: Paraffinic naphtha
pol	36	Policy type	LOS: Lost OVC: Other variable cost MSD: Maximum distillation feed, cat cracker MSR: Maximum low sulfur resid, cat cracker SVR: Maximum severity, cat cracker H00: Maximum 100 severity, HP reformer H05: Maximum 105 severity, HP reformer
prd	18	Products	AST: Asphalt COK: Coke DSL: Low sulfur diesel E85: 85% Ethanol and 15% TRG JTA: Jet fuel LPG: Liquefied petroleum gas M85: 85% Methanol and 15% TRG N2H: Number 2 oil N67: Low sulfur resid to utilities N68: High sulfur resid to utilities N6B: High sulfur resid N6I: Low sulfur resid OTH: Other PCF: Petrochemical feed stock RFG: Reformulated gasoline RFH: Reformulated high oxygen gasoline TRG: Conventional gasoline TRH: Conventional high oxygen gasoline
pri	12	Product imports	DSL, JTA, LPG, MET, MTB, N2H, N6B, N6I, OTH, PCF, RFG, TRG, SSR
prx	10	Product exports	COK, DSL, JTA, LPG, N2H, N6B, N6I, OTH, PCF, TRG
px9	16	Distress exports	AST, COK, DSL, JTA, LPG, N2H, N67, N68, N6B, N6I, OTH, PCF, RFG, RFH, TRG, TRH

Index	No. of Values	Description	Members
pi9	18	Distress imports	AST, COK, DSL, E85, JTA, LPG, M85, N2H, N67, N68, N6B, N6I, OTH, PCF, RFG, RFH, TRG, TRH
unf	3	Unfinished oil	ARB: Atmospheric residual bottom type B HGM: Heavy gas oil medium sulfur NPP: Medium naphtha paraffin
uns	72 (mrm) 56 (erm)	Process unit (excludes merchant & gas plant in ERM)	ACU: Atmospheric crude distillation See Appendix A.3 for complete list of processes
uuu	3	Utility	KWH: Kilo-watt hour NGF: Natural gas liquids STM: Steam

In the naming of the columns and rows, the limit is a maximum of eight characters per name. The following two tables give the name of the variable (activity) and the row (constraint) represented.

The general name structure for columns is (v)(r)(abc)(def), where v is key code, r is region code, abc and def are 3 character names.

MRM	ERM	Name	Activity Represented
x	x	B(r)(mgb)(ist)	Blend stream (ist) to gasoline grade (mgb) in (r)
x		C(d)ETCR(s)	Ethanol from cellulose supply step (s) in (d)
x		C(d)ETHR(s)	Ethanol from corn supply step (s) in (d)
x		D@METS1	Total US demand for methanol
x	x	D(d)(prd)S1	Product (prd) demand in (d)
x		D(d)(prx)SX	Product (prx) exports from (d)
x		D(d)(px9)Z9	Distress product (px9) export from (d)
x	x	E(r)(uns)INV	Investment in new capacity for process (uns) in (r)
x	x	F(r)(dfo)(ist)	Blend stream (ist) to distillate fuel oil (dfo) in (r)
x		G(r)DGR	Dry gas residue in (r)
x		G(r)GPL01	Gas plant operations mode 01 in (r)
x		G(r)(ist)(prd)	Gas plant output transfer of stream (ist) to product (prd) in (r)
x		G(r)MOH01	Methanol plant operations in (r)
x		G(r)(ist)RFN	Transfer of gas plant stream (ist) to refinery in (r)
x		G(r)METDEM	Methanol production from methanol plant in (r)
x		G(r)SC2CC1	Shift of ethane to natural gas in gas plant in (r)
x		G(r)SC3CC1	Shift of propane to natural gas in gas plant in (r)
x		H(r)(uns)(mod)	Production of mode (mod) for process (uns) at merchant plant in (r)
x		H(r)(aa)(bb)(ist)*	Transfer from (aa) to (bb) of stream (ist) in (r)
x		I(d)(pi9)Z9	Distress product (pi9) imports to (d)
x		I(r)(pri)R(s)	Imported product (pri) step (s) to region (r)
x	x	K(r)(uns)CAP	Existing capacity for process (uns) in (r)
x	x	L(r)(uns)BLD	Addition to capacity for process (uns) in (r)
	x	N(r)(ncr)	Purchase noncrude and additives (ncr) in (r)
x		N(r)DGP	Dry gas supply in (r)
x		N(r)NGKN(s)	Alaska NG supply curve step (s) for GTL production for region (r)

MRM	ERM	Name	Activity Represented
x		N(r)NGRF(On)	Natural gas to refinery supply step (On) in (r)
x		NZAMH(On)	Export supply step (on) for Alaskan crude
x		O@CRDEXP	Alaskan crude exports
x		O@CRDSPR	SPR fill in US
x		P(o)DCRQ1	Domestic crude in (o)
	x	P(r)(crt)	Supply of crude (crt) to (r)
x		P(r)(crt)(Qs)	Supply step (Qs) of imported crude (crt) to (r)
x		PANGLQ1	Supply of natural gas liquids from Alaska North slope
x	x	Q(r)(mgb)	Spec vector, total volume for (mgb) in (r)
x	x	Q(r)(dfo)	Spec vector, total volume for (dfo) in (r)
x	x	R(r)ACU(crt)	Volume of crude (crt) processed by the ACU unit in (r)
x	x	R(r)(uns)(mod)	Refinery process (uns) operation for mode (mod) in (r)
x	x	R(r)CGNCGN R(r)CGXCGN	Refinery (CGN) and Merchant (CGX) cogeneration plant operation in region (r)
x	x	T(r)(ist)(ist)	transfer of stream (ist) to stream (ist) in (r)
x		T@UNFTOT T(r)UNF(ist)	Total unfinished oils in US Unfinished oils from stream (ist) in region (r)
x		TAAMHXZ	Volume of AMH crude transported from Alaska to Valdez
x	x	T(r)CBNTAX	Carbon tax in (r)
x		T(r)OVCOBJ	Refinery plant operating variable costs in region (r)
x		T(r)GPLOVC	Gas pland operating variable costs in region (r)
x		T(r)MCHOVC	Merchant plant operating variable costs in region (r)
x	x	U(r)(uuu)	Utility (uuu) purchased in (r)
x		VTVC(m)CP	Crude vessel transportation capacity for mode (m)
x		VTVP(m)CP	Product vessel transportation capacity for mode (m)
x		VTPC(r)(m)(d)	Crude pipeline transportation capacity from (r) to (d) using mode (m)
x		VTPP(r)(m)(d)	Product pipeline transportation capacity from (r) to (d) using mode (m)
x		VTPL(r)(m)(d)	LPG pipeline transportation capacity from (r) to (d) using mode (m)
x		W(r)(prd)(m)(d)	Product (prd) transportation from (r) to (d) using mode (m)
x		W(d)(prd)(m)(r)	Product (prd) transportation from (d) to (r) using mode (m)

MRM	ERM	Name	Activity Represented
x		X(d)(prd)SPG	Recipe blends of product (prd) for oxygenated fuels and electric utility residual oils in (d)
x	x	X(r)(ist)(prd)	Recipe blends of product (prd) from stream (ist) in region (r)
x		X(d)(ist)(prd)	Splash blending of (prd) from stream (ist) in (d)
x		X(r)(yyyy)**	Recipe blends (yyyy) in region (r)
x		Y(o)(crt)(m)(r)	Crude (crt) transportation from (o) to (r) using mode (m)
x		Z(d)ETCTAX	Total supply of ethanol from cellulose in (d) for adding tax credit to objective function
x		Z(d)ETHTAX	Total supply of ethanol from corn in (d) for adding tax credit to objective function
x		Z(r)FLO(uns)	Total flow through processing unit (uns) in region (r)
		Z(r)RFGOXY	Total OXY in RFG in region (r)
x		Z@TOTCRD	Total foreign crude imports
x		ZZAMHTOT	Total export volume of Alaskan crude oil

* : (aa), (bb) = MP, GP, RF, where MP = Merchant plant, GP = Gas plant, RF = Refinery. For (ist), first and last character of (ist).

**: (yyyy) = recipe blends for categories of products such as AST, PCF, OTH.

The general name structure for rows is: (v)(r)(abc)(def), where v is key code, r is region code, abc and def are 3 character names.

MRM	ERM	Name	Constraint Represented
x		A(d)(prd)	Product demand accounting row in (d) for (prd)
x		A(d)RFG(yyy) A(d)TRG(yyy)	Gasoline blending accounting row in (d) for mogas (yyy)
x		A(x)PRDEXP A@PRDEXP	Product export accounting row in (x) and US
x		A(d)ETHTAX A(d)ETCTAX	Ethanol tax credit accounting row in (d)
x	x	A(r)INVST A@INVST	Investment accounting row in (r) and US
x	x	A(r)(prd)	Product (prd) refined accounting row in (r)
x	x	A(r)CRX(crt)	Crude oil (crt) accounting row in (r)
x		A@CRDAKA	Alaskan crude oil accounting row in US
x		A@CRDDCR	Domestic crude oil accounting row in US
x		A@CRDEXP	Crude oil export accounting row in US
x	x	A(r)CRDFCR A@CRDFCR	Foreign crude oil accounting row in (r) and US
x		A@CRDL48	Lower 48 crude oil accounting row in US
x		A@CRDSPR	SPR crude oil accounting row in US
x	x	A@CRDTOT	Total crude oil accounting row in US
x		A(r)ETHRFN	Ethanol to refinery accounting row in (r)
x	x	A(r)FUEL A@FUEL	Fuel use accounting row in (r) and US
x	x	A(r)FUM(xx) A@FUM(xx)	FUM accounting row in (r) for (xx) and US
x	x	A(r)FXOC A@FXOC	Fixed cost accounting row in (r) and US
x		A(d)GO8(yyy)	Gasoline blending accounting row in (d) for mogas (yyy)
x	x	A(r)G(I)(xxx) A@G(I)(xxx)	Gasoline blend components accounting row in (r) for (xxx); US total
x	x	A(r)GAIN A@GAIN	Gain accounting row in (r)
x	x	A@KWHRFN	Refinery KWH usage accounting row in US

MRM	ERM	Name	Constraint Represented
x		A(r)METIMP A@METIMP	Methanol imports accounting row in (r); US total
x		A@METDEM	Methanol demand accounting row in US
x		A@METM85	Accounting of methanol used for M85 splash blending in US
x		A@METPRD	Methanol production accounting row in US
x	x	A(r)METRFN	Accounting of methanol consumption by ETH refinery unit in (r)
x		A(r)MTBRFN	MTB refinery imorts accounting row in (r)
x	x	A(r)NGFTOT A@NGFTOT	Natural gas purchase accounting row in (r); US total
x		A(r)NGLRFN A@NGLRFN	Accounting of NGL transfer from gas plant to refinery in (r); US total
x	x	A(r)NGLPRD A@NGLPRD	NGL accounting in (r); US total
x	x	A(r)NGSH2P A@NGSH2P	Accounting of NGS consumption by H2P refinery unit in (r); US total
x		A(r)NGSMER A@NGSMER	Accounting of methanol transfer from gas plant to refinery in (r); US total
x		A(r)NGSMET A@NGSMET	Methanol plant production accounting row in (r); US total
x	x	A(r)NGSRFN	Accounting of NGF stream transfer to NGS stream in (r)
x	x	A(r)PETCOK A@PETCOK	Accounting of high & low sulfur coke production from recipe blending in (r) and US
x	x	A(r)SULSAL A@SULSAL	Accounting of sulfur production from recipe blending in (r) and US
x	x	B(r)(ist)	Balance for intermediate stream (ist) in (r)
x		C(o)(crt)	Crude balance for crude type (crt) in (o)
x	x	C(r)(crt)	Crude balance for crude type (crt) in (r)
x		CZAMH	Alaskan crude exports
x	x	D(d)(prd)	Final demand for product (prd) in (d)
x		D@MET	Total demand for methanol
x		E(r)(emu)(e)	Emission of (emu) from source (e) in (r)
x		F(r)UNF(unf)	Unfinished oil balance for (unf) in (r)
x	x	F@TOTCRD	Total crude balance for unfinished oil constraint in US
x		G(r)(ist)	Gas plant balance for stream (ist) in (r)

MRM	ERM	Name	Constraint Represented
x		G(r)(pol)	Gas plant policy (pol) accounting row in (r)
x		H(r)(ist)	Merchant oxygenate plant balance row for (ist) in (r)
x		H(r)FUMCAP	Merchant oxygenate fuel balance row in (r)
x		H(r)(pol)	Merchant oxygenate plant policy (pol) accounting row in (r)
x	x	L(r)(uns)CAP	Process (uns) capacity in (r)
x	x	M(r)(prd) M(d)(prd)	Final product (prd) demand at refinery (r) or CD (d)
x		O(o)(crt)	Domestic crude oil (crt) accounting in (o)
x	x	OBJ	Objective function
x	x	P(r)(pol)	Policy (pol) constraint in (r)
x	x	P(r)CBNTAX	Carbon tax accounting row in (r)
x	x	Q(r)(prd)(qd)(c) Q(r)(prd)(qm)(c)	Product (prd) specification for quality (qd) constraint type (c) in (r) Product (prd) specification for quality (qm) constraint type (c) in (r)
x	x	S(r)(mgb)E	Sum row for blending gasolines (mgb) in (r)
x	x	S(r)(dfo)E	Sum row for blending fuel oils (dfo) in (r)
x	x	S(r)RFGOXY	Constraint on renewable OXY limits in (r)
x		TVC(m)CP	Crude oil vessel transportation capacity limits for mode (m)
x		TVP(m)CP	Product vessel transportation capacity limits for mode (m)
x		TPC(r)(m)(d)	Crude pipeline transportation capacity balance row
x		TPL(r)(m)(d)	LPG pipeline transportation capacity balance row
x		TPP(r)(m)(d)	Product pipeline transportation capacity balance row
x	x	U(r)(uuu)	Utilities (uuu) in region r
x	x	Z(r)CAP(uns)	Balance row for total capacity of (uns) in (r)
x		Z(r)NGFSUM	Sum row for natural gas to refineries in (r)
x		ZZAMHSUM	Sum row for Alaskan crude export
x	x	Z@WOP	Current world oil price in value of RHS
x	x	Z@CRDTOT	Sum row for total crude in US
x	x	Z@YRITER	Iteration year
x		Z@IRACX	Sum row to force average refinery crude cost within specified range
x		Z@IRACN	Sum row to force average refinery crude cost within specified range
x	x	ZD(mmddyy)	Month, day, year of matrix generation

(I) = 00, 01, 02, ... , 12

(xx) = LPG, N2H, N6B, N6I, NGS, OTH, STG

(xxx) = TRG and RFG

(yyy) = TRG, TRH, and/or RFG, RFH

There are several other accounting rows.

The following Table gives the dimensions of each model:

Model	Columns		Rows	
	Total	Fixed	Total	Fixed
MRM (3 regions)	10227	419	4009	3162
ERM (single region)	2274	38	914	709

The general structure for the model is as follows:

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

MRM Model Block Diagram

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

G.2.b Subroutines

The program consists of several subroutines and a main program. The subroutines can be grouped as those that setup the OML environment, read in the data tables, form parts of the matrix representation of the model, solve the model, retrieve needed information for report writing, and write the reports. All the subroutines that generate part of the matrix representation of the model use input from data files in an OML format. These files have a .dat extension. Some subroutines use ASCII files as input and some others don't use any. The following table shows the subroutine names, the input data file names, the purpose of the subroutines, and the model that uses them.

Source Code	Data file	Purpose	Models
accunit.f	accunit.dat	Represents ACU unit	All
akaexp.f	akaexp.dat	Represents Alaskan exports	MRM
avoids.f	avoids.dat	Represents the avoids	MRM
cogener.f	cogener.dat cogenere.dat	Represents the cogeneration	MRM ERM
crdimprt.f	crdimprt.dat	Represents crude imports	MRM
demand.f	demand.dat	Represents demands	MRM
distblnd.f	distblnd.dat	Represents distillate blending	All
distress.f	distress.dat	Represents the distress imports and exports	MRM
domcrude.f	domcrude.dat	Represents crude inputs	MRM
emish.f	emish.dat	Represents emissions	MRM
ermcrude.f	ermcrude.dat	Represents crude inputs	ERM
ermother.f	ermother.dat	Represents non-crude inputs	ERM
ermprod.f	ermprod.dat	Represents product demands	ERM
ethanol.f	ethanol.dat	Represents ethanol supply and prices	MRM
fixcol.f	fixcol.dat	Fixes some columns	All (not used)
fuelmix.f	fuelmix.dat	Simulates fuel mixing	All
gasoblnd.f	gasoblnd.dat	Simulates gasoline blending	All
limpol.f	limpol.dat	Puts limits on policy rows	All
lplookup.f		Retrieves solution	MRM (5-reg only)
mrm.f	mrmparam, mrmpath main.dat ermparam pathe maine.dat	Program MPS2ANAL: Sets up the OML environment, reads in some main data, controls the program, calls subroutines to form matrix, solves problem, stores solution, writes reports, basis and packs matrix.	MRM ERM

Source Code	Data file	Purpose	Models
mchproc.f	mchproc.dat	Simulates the merchant plant	MRM
ngprod.f	ngprod.dat	Provides gas supply steps to refinery	MRM
nrfplant.f	nrfplant.dat	Simulates the non refinery plant activities	MRM
output.f		Prints a report	MRM (5-reg only)
prdexp.f	prdexp.dat	Simulates the product exports	MRM
prdimprt.f	prdimprt.dat	Simulates the product imports	MRM
recipes.f	recipes.dat	Specifies product recipe blends	All
refproc.f	refproc.dat	Simulates the refinery	All
setrows.f	setrows.dat	Sets some rows	All
splash.f	splash.dat	Simulates splash blending	MRM
stream.f	stream.dat	Simulates stream transfers	All
tabread.f		Reads data tables	All
transit3.f	transit.dat	Simulates the product and crude oil transportation for the 3-region representation of MRM	MRM
unfinished.f	unfinish.dat	Provide for unfinished oil imports	MRM
utility.f	utility.dat	Simulates utility purchased	MRM
utilitye.f	utilitye.dat	Simulates utility purchased	ERM

Most of the subroutines that constitute the program generate part of the matrix representation of the model. The following gives a representation of the submatrix generated by each subroutine in table form. Columns of the tables correspond to activities (variables), and rows of the tables to constraints. The symbols x, -x or +-x represent matrix coefficients.

accunit.f: This subroutine simulates the ACU unit. It creates the following submatrix:

	R(r)ACU(crt)
C(r)(crt)	-x
L(r)ACUCAP	x
A(r)CRDFCR*	x
A(r)STM	-x
A@CRDFCR*	x
A(r)CRX(crt)	x
A@CRDTOT	x
Z@CRDTOT*	x

	R(r)ACU(crt)
F@TOTCRD	x
B(r)(ist)	+-x
U(r)(uuu)	-x
P(r)(pol)**	+-x

* for (crt) = FLL, FMH, FHL, FHH, and FHV
** for (pol) = OVC, FRL

Bounds: None

akaexp.f: This subroutine simulates the Alaskan exports. It creates the following submatrix:

	NZAMH(i)	ZZAMHTOT	TAAMHXZ	PANGLQ1
OBJ	+-x*	x	-x	-x
CAAMH			-x	
CZAMH		-x	x	
BW(ist)				x
ZZAMHSUM	x	-x		
A@AKAEXP		x		
A@CRDEXP		x		
AANGLPRD				x
A@NGLPRD				x
AWNGLRFN				x

(i) = N1, N2, N3, P4, P5, P6
* : -x if i = N1, N2, N3; x if i = P4, P5, P6

Bounds: PANGLQ1, NZAMH(i)

avoids.f: This subroutine simulates the avoids. It is turned off. It creates the following submatrix:

	D(d)(prd)N(i)	D(d)(prd)P(i)
D(d)(prd)	x	-x
OBJ	-x	-x
A(d)(prd)	-x	x
A@PRDDEM	-x	x

	D(d)(prd)N(i)	D(d)(prd)P(i)
A@AVDNEG	x	
A@AVDPOS		x

(i) = 1, ..., 3

Bounds: D(d)(prd)N(i) and D(d)(prd)P(i)

cogener.f: This subroutine simulates the cogeneration unit. It creates the following submatrix

	E(r)CGNINV	K(r)CGNCAP	L(r)CGNBLD	R(r)CGNCGN
B(r)FUL				-x
L(r)CGNCAP	-x	-x	-x	x
OBJ	-x		-x	x
P(r)OVC				-x
U(r)(uuu)				x
A@FXOC	x		x	
A(r)FXOC	x		x	
A@INVST	x			
A(r)INVST	x			
A@KWHRFN				x

	E(r)CGXINV	K(r)CGXCAP	L(r)CGXBLD	R(r)CGXCGN
B(r)FUL				-x
L(r)CGXCAP	-x	-x	-x	x
OBJ	-x		-x	x
P(r)OVC				-x
U(r)(uuu)				x
A@FXOC	x		x	
A(r)FXOC	x		x	
A@INVST	x			
A(r)INVST	x			
A@KWHRFN				x

Bounds: E(r)CGNINV, K(r)CGNCAP, L(r)CGNBLD, E(r)CGXINV, K(r)CGXCAP, L(r)CGXBLD

crdimprt.f: This subroutine simulates the crude imports into the United States. It creates the following matrix:

	P(r)(crt)(Qs)
C(r)(crt)	x
OBJ	-x
Z@IRACN	x
Z@IRACX	x

(Qs) = supply step Q1,Q2,Q3

Bounds: P(r)(crt)Q(s)

demand.f: This subroutine simulates product demands. It creates the following submatrix:

	D(d)(prd)S1	D@METS1
D(d)(prd)	-x	
OBJ	x	
A(d)(prd)*	x	
A@METDEM		x
A@PRDDEM	x	
D@MET		-x

* for (prd) not equal to E85 or M85

Bounds: D@METS1 and D(r)(prd)S1

distblnd.f: This subroutine simulates the distillate blending. It creates the following matrix:

	F(r)(dfo)(ist)	Q(r)(prd)*
B(r)(ist)	+-x	
M(r)(prd)*		x
Q(r)(prd)*(qd)(c)	+-x	-x
S(r)(dfo)E	x	-x
U(r)STM		-x
A(r)(prd)*		x

	F(r)(dfo)(ist)	Q(r)(prd)*
A(r)STM		-x
A@PRDRFN		x

* for (prd) = (dfo) only

Bounds: None

distress.f: This subroutine simulates product distresses. It creates the following submatrix:

	I(d)(pi9)Z9	D(d)(px9)Z9
OBJ	-x	-x
D(d)(pi9)	x	
A@ZZIMP	x	
D(d)(px9)		-x
A@ZZEXP		x

Bounds: None

domcrude.f: This subroutine simulates domestic crudes. It creates the following submatrix:

	P(o)DCRQ1	PADCRQ1	O@CRDEXP	O@CRDSPR
OBJ	-x	-x		
C(o)(crt)	x			
CAALL		x		
CAAMH		x	-x	
CBFHL				-x
A@CRDDCR	x	x		
A@CRDAKA		x		
A@CRDL48	x			
A@CRDEXP			x	
A@CRDSPR				x
A@CRDFCR				x
O(o)(crt)	x	x		

(o) : except A

Bounds: P(o)DCRQ1, PADCRQ1, O@CRDEXP, O@CRDSPR

emish.f: This subroutine simulates emissions. It creates the following submatrix:

	K(r)(uns)CAP	R(r)FUM(ist)
E(r)(emu)N	x	
E(r)(emu)C		x

Bounds: None

ermcrude.f: This subroutine simulates domestic crudes for ERM. It creates the following submatrix:

	P(r)(crt)*
C(r)(crt)*	x
OBJ	-x

* (crt) = FHH, FHL, FHV, FLL, FMH, DLL, DMH, DHL, DHH, DHV.
(r) = region G only (i.e., single region)

Bounds: P(r)(crt)

ermother.f: This subroutine simulates the non-crude inputs for ERM. It creates the following submatrix:

	N(r)(ist)*
B(r)(ist)*	x
OBJ	-x
A(r)(ist)*	x

* (ist) = (ncr) only
(r) = region G only (i.e., single region)

Bounds: N(r)(ist)

ermprod.f: This subroutine simulates product demands for ERM. It creates the following submatrix:

	D(r)(prd)S1
M(r)(prd)	-x
OBJ	x

(r) = region G only (i.e., single region)

Bounds: D(r)(prd)S1

ethanol.f: This subroutine represents ethanol supply and prices. It creates the following submatrix:

	C(d)ETCR(i)	Z(d)ETCTAX	C(d)ETHR(i)	Z(d)ETHTAX	X(d)ETHE85
D(d)ETH	x		x		
OBJ	-x	x	-x	x	-x
A(d)ETH	x		x		
A(d)ETHTAX			x	-x	
A@ETHPRD	x		x		
A(d)ETCTAX	x	-x			
A@ETCPRD	x				

i = 1, ..., 4

Bounds: C(d)ETHR(i), C(d)ETCR(i)

fixcols.f: This subroutine fixes some variables or activity. No submatrix is generated

Bounds: R(r)FCC(ist)

fuelmix.f: This subroutine simulates fuel mixing. It creates the following submatrix:

	R(r)FUM(mod)	T(r)CBNTAX	K(r)FUMCAP
OBJ		-x	
P(r)CBNTAX		x	
A(r)FUM(mod)	x		
A@FUM(mod)	x		
A(r)FUEL			x
A@FUEL			x

Bounds: None

gasoblnd.f: This subroutine simulates gasoline blending. It creates the following submatrix:

	B(r)(mgb)(ist)	Q(r)(mgb)	Z(r)RFGOXY
B(r)(ist)	-x		
M(r)(prd)		x	
Q(r)RFGREN			-x

	B(r)(mgb)(ist)	Q(r)(mgb)	Z(r)RFGOXY
Q(r)(prd)(qq)(c)	x	-x	
S(r)(mgb)E	x	-x	
S(r)RFGOXY			-x
U(r)KWH		-x	
A(r)(xxx)(mgb)	x		
A(r)(prd)*		x	
A@(xxx)(mgb)	x		
A@PRDRFN		x	

* (prd) = (mgb) only; (xxx) = GO1, ..., G12

Bounds: B(r)RFG(ist) and B(r)TRG(ist) where ist= ETB, MTB, TAE, TAM, THE, THM

limpol.f: This subroutine defines policy conditions. It creates the following submatrix:

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	Z(r)FLO(uns)
Z(r)CAP(uns)	x	x	x	-x
P(r)(pol)				-x

(uns) = specific units underpolicy controls (i.e., FCC, KRF,...)

Bounds: None

lplookup.f: Retrieves solution values and stores them in arrays.

main.f: This subroutine reads in the mrmparam file that has the information relative to the model to run; initializes the OML subroutine library environment; opens the database; specifies a problem in the database for processing; initializes the matrix processing; reads in the path file, the main.dat file that contains some global variables such as the refinery, the exporting, and demand regions code; calls the subroutines that generate the matrix; ends the matrix processing; writes out the MPS file; inserts the advanced basis; solves the matrix; puts the solution in output; writes the optimal basis; prints reports; packs the matrix; and closes the database.

mchproc.f: This subroutine represents the merchant plant. It creates the following submatrix

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	K(r)FUXCAP	H(r)(uns)(mod)
H(r)FUMCAP				x	x
L(r)(uns)CAP	-x	-x	-x		x

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	K(r)FUXCAP	H(r)(uns)(mod)
OBJ		-x	-x		
A@FXOC		x	x		
A(r)FXOC		x	x		
A@INVST		x			
A(r)INVST		x			

mchproc.f (Continued)

	H(r)(uns)(mod)	H(r)KWHMCH	H(r)(aa)(bb)(ist)*	T(r)MCHOVC	N(r)NGKN(s)
H(r)(ist)	+-x		+-x		x
H(r)(uuu)	+-x				
H(r)(pol)	+-x				
G(r)(ist)			+-x		
B(r)(ist)			+-x		
H(r)KWH		x			
H(r)OVC				x	
OBJ		-x	-x	-x	-x

*: first and last character of (ist); (aa) and (bb) = MP, GP, RF
   where MP = Merchant plant, GP = Gas plant, and RF = Refinery

Bounds: K(r)(uns)(CAP, E(r)(uns)INV, L(r)(uns)BLD, H(r)GPMP(ist) and H(r)RFMP(ist) = 0;
N(r)NGKN(s)

ngprod.f: This subroutine represents the gas supply steps to refinery. It creates the following submatrix

	N(r)NGRF(ij)*
OBJ	+-x**
Z(r)NGFSUM	x

* (ij) = N1, N2, N3, N4, P5, P6, P7, P8
** +x for N1, N2, N3, N4 and -x for P5, P6, P7, P8

Bounds: N(r)NGRF(ij)

nrfplant.f: This subroutine simulates the non refinery plant. It creates the following submatrix:

	G(r)DGR	G(r)GPL01	T(r)GPLOVC	N(r)DGP
G(r)OVC	-x		x	
G(r)DGP	x	-x		
G(r)LOS	-x	-x		
G(r)(xxx)		x		
G(r)CC1	-x			x
OBJ			-x	

nrfplant.f (Continued)

	G(r)NATOTH	G(r)NATPCF	G(r)(xxx)*LPG	G(r)(xxx)**RFN
G(r)(xxx)	-x	-x	-x	-x
OBJ	-x	-x	-x	-x
A(r)GPL(xxx)***	x	x	x	
A(r)NGLRFN				x
A@NGLRFN				x
B(r)(xxx)**				x
M(r)(prd)***	x	x	x	
A(r)NGLPRD	x	x	x	x
A@NGLPRD	x	x	x	x

nrfplant.f (Continued)

	G(r)SC2CC1	G(r)SC3CC1	G(r)METRFN	G(r)METDEM
G(r)CC1	x	x		
G(r)CC3		-x		
G(r)LOS	x	x		
G(r)PGS	-x			
OBJ	x	x	-x	-x
A(r)NGSMER			x	
A@NGSMER			x	
B(r)MET			x	

	G(r)SC2CC1	G(r)SC3CC1	G(r)METRFN	G(r)METDEM
G(r)MET			-x	-x
D@MET				x

nrfplant.f (Continued)

	E(r)MOHINV	L(r)MOHBLD	K(r)MOHCAP	G(r)MOH01
L(r)MOHCAP	-x	-x	-x	x
G(r)MET				x
G(r)OVC				-x
U(r)NGF				-x
U(r)KWH				-x
A(r)NGSMET				x
A@NGSMET				x
A@METPRD				x
OBJ	-x	-x		
A(r)INVST	x			
A@INVST	x			
A(r)FXOC	x	x		
A@FXOC	x	x		

(xxx) : PGS, CC3, IC4, NC4, NAT
* : (xxx) except NAT ; **: (xxx) except PGS, CC3; *** LPG, OTH, PCF

Bounds: G(r)SC3CC1, N(r)DGP, E(r)MOHINV, K(r)MOHCAP, L(r)MOHBLD
output.f: This subroutine prints reports.

prdexp.f: Simulates product exports. It creates the following submatrix:

	D(z)(prx)*SX	D(z)COKSX	D(z)ASTSX
D(z)(prx)	-x	-x	-x
OBJ	x	x	
A@COKEXP		x	
A(d)PRDEXP	x		x
A@PRDEXP	x		x

*: All (prx) except COK and AST; (z) = export demand regions (d) 2,3,7,8,9

Bounds: D(z)(prx)SX, except for (prx) = COK

prdimprt.f :   This subroutine simulates product imports. It creates the following submatrix:

	I(r)(pri)*R(s)	I(r)(pri)**R(s)
A@(pri)*IMP	x	
A(r)(pri)*IMP	x	
B(r)(pri)*	x	
A(r)(pri)RFN	x***	
A(r)PRDIMP		x
A@PRDIMP		x
M(r)(pri)**		x
OBJ	-x	-x

* : for (pri) = MET and MTB; **: for all (pri) except MET and MTB;
*** for (pri) = MTB only; (s) = import steps 1-3 or 1-9

Bounds: I(r)(pri)R(s)

recipes.f: This subroutine simulates product recipe blending. It creates the following submatrix:

	X(r)(xxx)(yyy)	X(r)(yyyy)
B(r)(ist)	-x	-x
M(r)(yyy)	x***	x
OBJ	x	-x*
U(r)STM		-x**
A(r)STM		-x**
A(r)(yyy)	x***	x
A(r)SULSAL	x****	
A@SULSAL	x****	
A(r)PETCOK	x***	
A@PETCOK	x***	
A@PRDRFN	x***	x

(xxx) = AST, AVG, CKH, CKL, GOP, SUL ; (yyy) = AST, OTH, COK, PCF, SAL
(yyyy) = AST0, AST1, AVG0, GOP0;

: for (yyyy) = AVG; **: for (yyyy) = AST0; ***: for (yyy) = COK; **** for (yyy) = SAL

refproc.f: This subroutine simulates the refinery processes. It creates the following submatrix:

	E(r)(uns)INV	K(r)(uns)CAP	L(r)(uns)BLD	T(r)OVCOBJ	R(r)(uns)(mod)
OBJ	-x		-x	-x	
B(r)(ist)					+-x
L(r)(uns)CAP	-x	-x	-x		x
U(r)(uuu)					+-x
P(r)(pol)				x*	+-x
P(r)CBNTAX					-x
M(r)(mod)					-x
A(r)INVST	x				
A@INVST	x				
A(r)FXOC	x		x		
A@FXOC	x		x		
A(r)GAIN					+-x
A@GAIN					+-x
A(r)METRFN					x**
A(r)NGSH2P					x***
A@NGSH2P					x***
A@MTBPRD					x****
A(r)STM					-x

*: when (pol) = OVC; **: when (uns) = ETH; ***: when (uns) = H2P; ****: when (uns) = ETH and (mod) = MTB

Bounds: K(r)(uns)CAP, E(r)(uns)INV, L(r)(uns)BLD, R(r)(uns)(mod)

setrows.f: This subroutine sets the row types (G, L, E, N) for rows P(r)(pol).

splash.f: This subroutine simulates splash blending. It creates the following submatrix:

	X(d)ETH(xxx)	X(d)METM85	X(d)(www)SPG	B(r)RFG(sss)	B(r)RFG(rrr)
D(d)(xxx)	x	-x****			
D(d)ETH	-x				

	X(d)ETH(xxx)	X(d)METM85	X(d)(www)SPG	B(r)RFG(sss)	B(r)RFG(rrr)
D(d)(yyy)	-x				
D(d)M85		x			
D(d)MET		-x			
A(d)G08(xxx)	x*				
A@ETH(xxx)	x				
A@METM85		x			
A(d)RFG(xxx)** not linked to col					
A(d)TRG(xxx)	x***				
D(d)(www)			x		
D(d)(ttt)			-x		
Q(r)RFGREN	x**			x	
S(r)RFGOXY	x**				x

(rrr) = ETB, MTB, TAE, TAM, THE, THM; (sss) = ETB, TAE, THE;
(ttt) = N6B, N6I; (www) = N67, N68; (xxx) = E85, RFG, RFH, TRH, TRG;
(yyy)=SSR when (xxx)=RFG, RFH and (yyy)=SST when (xxx)=TRH and
(yyy)=SSE when (xxx)=TRG;
*: (xxx) not E85; **: (xxx)=RFG, RFH only;
:(xxx)=TRG, TRH only; *:(xxx)=TRG only
Bounds: none.

stream.f: This subroutine simulates stream transfers. It creates the following submatrix:

	T(r)(ist)(ist)	T(r)(ist)(prd)
B(r)(ist)	+-x	-x
M(r)(prd)		x
A(r)(prd)		x
A@PRDRFN		x

tabread.f: This subroutine prints the data file names, the number of tables and lists the tables names that are read.

transit3.f: This subroutine simulates the transportation network for MRM 3-region

	Y(o)*(crt)(m)(r)	W(d)ETH(r)	W(r)MET(d)	W(s)(prd)(d)	V(xxxxxx)
C(o)(crt)	-x				
C(r)(crt)	+-x				

	Y(o)*(crt)(m)(r)	W(d)ETH(r)	W(r)MET(d)	W(s)(prd)(d)	V(xxxxxx)
OBJ	-x	-x	-x	-x	
TVC(m)CP	x				
TPC(o)*(m)(r)	x				
B(r)ETH		x			
D(d)ETH		-x			
D(r)ETH		x**			
A(r)ETHRFN		x			
B(r)MET			-x		
D(d)MET			x		
M(s)(prd)				-x	
M(d)(prd)				x	
TPL(s)(m)(d)				x****	
TPP(s)(m)(d)				x***	
D(d)(prd)				x	
TVP(m)CP				x	
(xxxxxx)					-x

* OGSM supply (o) and refinery (r) regions; ** for (r)=Census Division
*** for (prd) different than MET, ETH; **** for (prd) = LPG and PCF;
(s) : refinery (r) and demand (d) regions; (xxxxxx) = TVC5CP, TVPJCP, ...

Bounds: V(xxxxxx)

unfinished.f: This subroutine simulates the unfinished oil process. It creates the following submatrix:

	T(r)UNF(ist)	T@UNFTOT	RHS
B(r)(ist)	x		
F(r)UNF(ist)	-x	x	
OBJ	-x		
A(r)UNF	x		
A@UNFIMP	x		
A(r)UNFIMP	x		
F@TOTCRD		-x	x

utility.f: This subroutine represents the utility. It creates the following submatrix:

	U(r)(uuu)	R(r)KWGPGN	T(r)NGFNGS
U(r)(uuu)	x		-x***
OBJ	-x		
A@KWHRFN	x*	x	
B(r)NGS			x
A(r)NGSRFN			x
A@NGFTOT	x***		
A(r)NGFTOT	x***		
Z(r)NGFSUM	-x***		

*: for (uuu) = KWH ;***: for (uuu) = NGF

utilitye.f: This subroutine is the same as utility.f, except that it is for ERM, and (r)=refinery region G only (i.e., single region).

All the Fortran files are located on the EIA RS-6000 in the directory /default/source/ .

G.2.c Common Blocks

Variables shared by several subroutines are set up in common. There are four files that contain the common blocks used by the program. Some of the files consist of several common blocks.

The following table lists the common block names, gives a brief description and the location of the block.

Common	Description	Location
IPMMREAL	Common for real variables shared by subroutines that generate submatrices	/default/includes/ipmmtest
IPMMINT	Common for integer variables shared by subroutines that generate submatrices	/default/includes/ipmmtest
IPMMCHAR	Common for character variables shared by subroutines that generate submatrices	/default/includes/ipmmtest
LPTAB	Common used for solution retrieval and report writing	/refine/pmm_lp_gen/includes/lpout
OMLREAL	Common for real variables used to set LP mrmory size	/default/includes/omlspace
OMLINT	Common for integer variables used to set LP mrmory size	/default/includes/omlspace
DFINC2	Common for OML database functions	/default/includes/dfinc2

Common	Description	Location
WCR	Common for the WHIZ optimizer	/default/includes/wfinc2

A list of the common blocks and the variables that constitute them is given in Appendix G-D.

G.3 Data

Most of the data that the program uses is provided in files with a .dat extension. There is a one to one correspondence between the Fortran files that form part of the matrix and the .dat data files (ex accunit.f gets its input from accunit.dat) . In each of the .dat files, the data is arranged in an OML format that consists of tables. Each table consists of a table name; row or stub and column or head names; and values at the intersection of rows and columns. In addition there are ASCII files. These ASCII files are for control of the program. The following is the description of each input file.

G.3.a Data sets

.dat files

accunit.dat

Table Name	Columns	Rows	Description
ACUCUTS	(crt)	(ist)	Crude distillation yield
ACUPOL	OVC, LOS	(crt)	ACU policy table
ACUUTI	(uuu)*	(crt)	ACU utility consumption
INVLIM	MAX	(r) , @	Maximum investment

* except NGF

akaexp.dat

Table name	Columns	Rows	Description
EXPAKA	P, Q	N1, N2, N3, P4, P5, P6	Price and quantity of Alaskan crude exports.
NGLAKA	PER	PGS, CC3, NC4, IC4, and NAT	Yield of NGL
PRQAKA	VOL, TRP, EXPPRC	A	Volume, and transportation and expected cost for Alaskan crude exports

avoids.dat   (no longer used)

Table	Columns	Rows	Description
SADELPX	FACTORS	N1, N2, N3, P1, P2, P3	Price differentiate

Table	Columns	Rows	Description
PRDAVOID	DUMMY	(prd)	Product list
SADELQ	N1, N2, N3, P1, P2, P3	(prd)	Demand shift quality fraction

cogener.dat

Table	Columns	Rows	Description
CGNCAP	CAP, PUL, BLD	(r)	Refinery cogeneration capacity, %utilization and build
CGNINV	INV, FXOC, CAPREC	(r)	Refinery cogeneration investment, fixed cost and capital recovery
CGNPOL	OVC	CGN	Refinery cogeneration policy
CGNREP	CGN	FUL	Refinery cogeneration yields
CGNUTI	(uuu)*	(r)	Refineiry cogeneration utility usage
SELCGN	SOLD	(r)	% cogeneration sold to grid from Refinery
VEPLAS	(r)	(year)	Electric utililty prices for Refinery cogen (87$/kwh)
CGXCAP	CAP, PUL, BLD	(r)	Merchant plant cogeneration capacity, %utilization and build
CGXINV	INV, FXOC, CAPREC	(r)	Merchant plant cogeneration investment, fixed cost and capital recovery
CGXPOL	OVC	CGN	Merchant plant cogeneration policy
CGXREP	CGX	FUL	Merchant plant cogeneration yields
CGXUTI	(uuu)*	(r)	Merchant plant cogeneration utility usage
SELCGX	SOLD	(r)	% cogeneration sold to grid from Merchant plant
VEPLWS	(r)	(year)	Electric utililty prices for Merchant cogen (87$/kwh)

* except NGF

cogenere.dat

Table	Columns	Rows	Description
CGNCAP	CAP, PUL, BLD	G	Cogeneration capacity, %utilization and build
CGNINV	INV, FXOC, CAPREC	G	Cogeneration investment, fixed cost and capital recovery
CGNPOL	OVC	CGN	Cogeneration policy

Table	Columns	Rows	Description
CGNREP	CGN	FUL	Cogeneration yields
CGNUTI	(uuu)*	G	Cogeneration utility usage
SELGEN	SOLD	G	% cogeneration sold to grid

* except NGF

crdimprt.dat

Table	Columns	Rows	Description
CRUDETYPE	DUMMY	(crt)*	Foreign crude types
ICR(crt)*(r)	C1, Q1, C2, Q2, C3, Q3	(year)	Price and quantity available for crude imports.

*: for (crt) = FLL, FMH, FHL, FHH, FHV (i.e. foreign crudes)

demand.dat

Table	Columns	Rows	Description
CKSMIX	CKL, CKH	OBJ, CKL, CKH, COK	Coke price and conversion factor
PRODLIST	DUMMY	(prd)	List of products
(prd)*	(d)	(year)	Product (prd) demand
DEMMET	CHEM	(year)	MET demand

* RFH mapping and corresponding table renamed to RFHA due to duplicate table name elsewhere.

distblnd.dat

Table	Columns	Rows	Description
Q(r)DFO	(dfo)	(spec)	Distillate fuel oil blend specs
DFOUTI	STM	(dfo)	Distillate blend steam use.
DCC	(dfo)*	(ist)	Distillate recipe blend.
DCB	spec categories **	(ist)	Distillate blend intermediate stream quality specification.

 * from Z:MAPDFOPD
** from Z:MAPDFOSP

distress.dat

Table	Columns	Rows	Description
ZPX	Value	(prd)	Distress code for pricing

domcrude.dat

Table	Columns	Rows	Description
DCRSUP	(o)	Y96	Historical crude supplies by OGSM region
DCRSHR	(o)	(crt)*	Domestic crude share by OGSM region
CREXP	CRDEXP, CRDSPR	VOL	Crude exports and SPR

*: (crt) except FLL, FMH, FHL, FHH, FHV

emish.dat

Table	Columns	Rows	Description
EMUNS	(emu)*	Process unit	Emission by process unit
EMFUM	(emu)	Fuel stream burned	Emission by fuel burned

* except CO_2

ermcrude.dat

Table	Columns	Rows	Description
CRUDEG	CST, MIN, MAX	(crt)	Crude cost and volume limits

ermother.dat

Table	Columns	Rows	Description
OTHERG	CST, MIN, MAX	(ncr)	Non crude cost and volume limits

ermprod.dat

Table	Columns	Rows	Description
PRODUCTG	REV, MIN, MAX	(prd)	Product revenue and volume limits

ethanol.dat

Table	Columns	Rows	Description
SUPETH(d)	C1, R1, C2, R2, C3, R3, C4, R4	(year)	Ethanol supply curves
ETHTAX	TAXETH, TAXE85	(year)	Ethanol taxes; tax subsidy

fixcols.dat   (no longer used)

Table	Columns	Rows	Description
FIXCOL	R	Dummy	First letter of column to fix
(r)RCOL	FCC	(mod)	Column to fix to zero

fuelmix.dat

Table	Columns	Rows	Description
GROUP	DUMMY	Fuel stream	List of fuel stream

gasoblnd.dat

Table	Columns	Rows	Description
Q(r)GSL	TRG, RFG	(spec)	TRG, RFG specs
(r)SSR	Y1, Y2, Y3, Y4, Y5	RFG(spec); YEAR	Gasoline specs for subspec SSR ; year of data
(r)SST	Y1, Y2, Y3, Y4, Y5	TRG(spec); YEAR	Gasoline specs for subspec SST; year of data
(r)SSE	Y1, Y2, Y3, Y4, Y5	TRG(spec); YEAR	Gasoline specs for subspec SSE; year of data
(r)RFH	Y1, Y2, Y3, Y4, Y5	RFG(spec); YEAR	Gasoline spec for RFH; year of data
(r)TRH	Y1, Y2, Y3, Y4, Y5	TRG(spec); YEAR	Gasoline spec for TRH; year of data
Z:GASGROUP	TEXT(1)	(ist)	List of blending streams specially grouped
GCB	Quality codes	(ist)	Gasoline blend intermediate stream quality specification.
GCC	Gasoline type	(ist)	Gasoline recipe blend.
MCO	Motor octane codes*	(ist)	Gasoline component base octane ratings
(xxx)BV	Motor octane codes**	(ist)	Gasoline component blending values
GSLUTI	KWH	(prd), SSE, SST, SSR	Gasoline utility use.
GSPETH	RE	RFGN	Gasoline specs for ETH

(spec) = 2 character quality code followed by X (maximum) or N (minimum).
(xxx) = many exist, however, PMM uses UNC and RFM defined by Z:MAPGSLPD (representing TRG and RFG, respectively).
* R00, R05, R15, R30, M00, M05, M15, M30, of which only R00 and M00 are used by the PMM.
** same as *, except column TEL added (but not used by the PMM).

limpol.dat

Table	Columns	Rows	Description
UNITPOL	DUMMY	(uns)	List of processes that have a limit on POL
LIM(uns)(r)	(ist)	DUM	Limit on (ist)

main.dat

Table	Columns	Rows	Description
EXPROD	DUMMY	(prx)	List of product exports
INVFACT	LOC, ENV	(r)	Location and environment factors
TRSOVC	OVC	(r)	Conversion factor for operating cost
FORCRD	DUMMY	(crt)*	List of foreign crudes
YRDOLLAR	1991	1987	Conversion factor
ZIRACFAC	Delta	ZIRAC	Range of price differential for IRAC
WOP	WOP	(year)	World oil price
RFNREG	PAD	(r)	List of PADDs
RFNEXP	RFID	Linked list of refinery and export regions	List of exporting regions
DEMNDREG	REGION	Linked list of refinery and demand regions	List of demand region
USERYEAR	YEAR	YR96	Year to run model

* FFL, FMH, FHL, FHH, FHV

maine.dat

Table	Columns	Rows	Description
EXPROD	DUMMY	(prx)	List of product exports
INVFACT	LOC, ENV	G	Location and environment factors
TRSOVC	OVC	G	Conversion factor for operating cost
FORCRD	DUMMY	(crt)*	List of foreign crudes
YRDOLLAR	1991	1987	Conversion factor
ZIRACFAC	Delta	ZIRAC	Range of price differential for IRAC
WOP	WOP	(year)	World oil price
RFNREG	REFINERY	G	List of PADDs

Table	Columns	Rows	Description
DEMNDREG	REGION	GG	List of demand region
USERYEAR	YEAR	YR95	Year to run model

* FFL, FMH, FHL, FHH, FHV

mchproc.dat

Table	Columns	Rows	Description
MCHINV	INV, FXOC, CAPREC	(uns)	Merchant plant investment, fixed cost and capital recovering
(r)CAPMCH	CAP, PUL, BLD	(uns)	Merchant plant processes capacity, % utilization and build.
(uns)POL*	(pol)	(ist)	Merchant plant processes policy
(uns)CAP*	(uns)CAP	(ist)	Merchant plant process capacity
(uns)REP*	(ist)	(ist)	Merchant plant process yields
(uns)UTI*	(uuu)	(ist)	Merchant plant process utility usage
TRANSFER	Dummy	GP, MP, RF	Transfer allowed
RFTRANS	MP	(ist)	Refinery transfer to merchant plant
GPTRANS	MP	(ist)	Gas plant transfer to merchant plant
MPTRANS	GP, RF	(ist)	Merchant plant transfer to gas plant and refinery
(r)UAP	CST	(uuu)	Utility purchases

* uns defined by T:MCHINV

ngprod.dat

Table	Columns	Rows	Description
SPNGF	ALLREG	N1, .., N4, P5, ..., P8	Price steps for gas supply
SQNGF	MAX, MIN	N1, .., N4, P5, ..., P8	Quantity steps for gas supply
SCVAL	(r)	VOL	Volume limits on each step

nrfplant.dat

Table	Columns	Rows	Description
INVMOH	INV, CAPREC, FXOC	MOH	Non refinery plant process investment, capital recovery, and fixed cost.

Table	Columns	Rows	Description
MOHPLT	(r)01	CC1, MET, OVC, KWH	Production of methanol
MOHCAP	(r)01	CAP	Methanol capacity
GASPLT	(r)01	(ist), (pol)	Yield from gas plant
GASSHFT	SC2, SC3	CC1, LOS, OBJ	Shift from ethane and propane to methane
GASCAP	(r)01	FAC, CAP, LIM, PCU	Gas plant capacity limits
CC1CAP	(r)01	(year)	Dry gas production capacity

prdexp.dat

Table	Columns	Rows	Description
(x)PRDEXP	MINY1, MAXY1, MINY2, MAXY2, ... MINY5, MAXY5	(prx), YEAR	Limit on volume to export; year of data
EXPLIM	YRPC, FIX	1995	Limit on volume and yearly increase
MULTEXPR	MULT	PRICE	Price for exports as function of imports

(x) = export regions (CDs 2,3,7,8,9).

prdimprt.dat

Table	Columns	Rows	Description
PRODTYP	DUMMY	(pri)	List of product import
IMPLIM	MAX	@	Maximum imports into USA
IPR(pri)(r)	C1, R1, ..., C3, R3	(year)	Product import supply curve
NEMSRSD	R1B, R1PR	R1, ..., R9	Resid import supply curve

recipes.dat

Table	Columns	Rows	Description
RCPEIA	A, CST, JTA, N2H, SLP, CKH, CKL	KERSPG, SULSAL, CKHCOK, CKLCOK	Cost of sulfur and coke; kerosene split; unit conversions.
RCP	A, CST, component stream, STM	Recipe blended products	Recipe blends.

refproc.dat

Table	Columns	Rows	Description
(r)CAP	CAP, PUL, BLD	(uns)	CAP, PUL and BLD values
(uns)	(mod)	(ist), (uuu), CAP, (pol)	Refinery process yields, utility usage, capacity factor, policy
MATBAL	A	(ist)	Streams requiring material balance
INV	INV, FXOC, CAPREC	(uns)	Refinery processes investment, fixed cost and capital recovery

setrows.dat

Table	Columns	Rows	Description
(r)POL	TYPE	(pol)	Row type

splash.dat

Table	Columns	Rows	Description
HOXETH	TRH, RFH, RFG,TRG	Gasoline stream	Ethanol recipe for splash blending
BLNSP(d)	KER, N67, N68	JTA, N2H, KER, N6I, N6B, N67, N68	Blend composition recipe
BLOX(d)YXX	E85, M85, TRH, RFH, RFG, TRG	Gasoline stream	Recipe blend composition
XETH	PO	XETH	Oxygen content of ethanol
SCB	PO	Oxygenate stream	Oxygen content of oxygenates

stream.dat

Table	Columns	Rows	Description
XSALE	DUMMY	(ist)(prd)	Linked list of stream transfer to products
TRS	MIN, MAX, CST	(ist)(ist)	Linked list of stream to stream transfers

transit.dat

Table	Columns	Rows	Description
MVCCAP	MAX	TVC(m)CP, TVP(m)CP	Marine vessel capacity for crude & product
BVPCAP	MAX	TVP(m)CP	Marine barge capacity for product
PLCCAP	MAX	TPC(o)(m)(r) TPP(r)**(m)(d) TPL(r)**(m)(d)	Pipeline capacity for (C) crude (P) product (L) LPG

Table	Columns	Rows	Description
TPCRLIST	DUMMY	(o)	Crude supply regions for transportation
TPCR(o)	(crt)	(m)(r)	Crude oil transportation cost from supply region (r)
PLCRLIST	DUMMY	(o)	List of crude oil supply regions for pipeline
PLCR(o)	(crt)	(m)(r)	Crude pipeline transportation cost from (r)
BVPR(r)	(prd)	(m)(d)	Product barge/truck transportation cost from (r) to (d)
TPPR(r)	(prd)	(m)(d)	Product marine transportation cost from (r) to (d)
TPME(r)	MET	(m)(d)	Methanol transportation cost from (r) to (d)
TPETLIST	DUMMY	(d)	List of Census Divisions for ethanol transportation source
TPET(d)	ETH	(m)(r)**	Ethanol transportation cost from (d) to (r)
PLPRLIST	DUMMY	(d)	List linked census divisions for product pipeline from region B to East Coast
PLPR(r)**	(prd), SSE, SST, SSR	(m)(d)	Product pipeline transportation cost from (r)** to (d)
PLLB(r)	LPG, PCF	(m)(d)	LPG transportation cost from (r) to (d)
PLNKLIST	DUMMY	(r)**	List of product pipeline originations.
PLNK(r)**	(prd), SSE, SST, SSR	(m)(r)**	Product pipeline transport connections and costs from (r)** to (r)**

** refinery (r) and/or demand (d) regions

unfinish.dat

Table	Columns	Rows	Description
UNFOIL	E, B, PD	streams: NPP, HGM, ARB	Types (3) of unfinished oil imports into the U.S.
UNFEQT	SLOPE, CONST	XYZ	eq. parameters that correlate unfinished oil imports to crude input

utility.dat

Table	Columns	Rows	Description
UTITRS	COEF	NGFNGS	BFOE natural gas.
(r)UAP	CST	(uuu)	Utility costs.

Table	Columns	Rows	Description
VALPNG	(r)	(year)	Industrial price of natural gas.
VPELIN	(r)	(year)	Industrial elec utility prices (87$/kwh)

utilitye.dat

Table	Columns	Rows	Description
UTITRS	COEF	NGFNGS	BFOE natural gas.
GUAP	CST	(uuu)	Utility costs.

G.3.b Other input files

1. **mrmparam** file

The mrmparam file[1] is a control file read by main.f to map input and output file names and instructions. In the mrmparam, the user chooses the model that he wants to run; the names for the actproblem, solution, path file, basis, mps file, and packed matrix; the model title; and the location and name of the starting basis and optimal basis. The following table lists the information that is to be supplied in the mrmparam file.

Variable name	Variable length	Variable purpose	Restrictions
MODELN	8	Model to be run	MRM3, ERM
ACTPROB	8	Act problem	
SOLNAME	8	Solution name	
PATHNF	7	Name of file where data files paths are stored.	
TITLE	40	Problem title	
INBASISN*	40	Location and name of advanced basis	
OUTBASIS	8	Name of optimal basis	
BASISN	8	Basis name	
MPSOUTN**	8	MPS file name	
PAKCN**	8	Packed matrix file name	.PCK extension

*: If no name or a file does not exist, the program will operate without an advanced basis.
**: if "NULL" or "null" is provided, the program will skip the part of the program that generates the file.

---

[1]Note that the default file used for the MRM is named "mrmparam," while that used for the ERM is named "ermparam." Before an ERM execution can be run, the ermparam name must be renamed to mrmparam.

The above variables have to be provided in the order they are listed in the above Table and should start at column 18. Appendix G-A provides an example of an mrmparam file. The mrmparam file has to be in the subdirectory where the model is executed.

2. **mrmpath** file:

In this file the user provides the program with the location and name of the data files. The order in which the names appear is important. See Appendix G-B for an example of a path file. The path file has to be in the directory from which the model is executed. This file format is that of an OML table.

3. **Advanced basis** file:

In this file the user provided an advanced basis to the model. If the user does not provide one or provides one whose name does not coincide with the basis name provided in the mrmparam, the program will not use it.

G.4 Submission of a Run

In order to run the model, one has to first compile and link the different FORTRAN source files to form an executable. Once the executable is created, the user submits a run in conjunction with an mrmparam and a path file. The execution of the program will solve the problem and create:

- An ACTFILE file
- An MPS file
- A SYSPRINT file (solution)
- An out basis file
- A packed matrix file
- Reports (only for MRM5)
    The following are the files created by a run:

	ERM	MRM
ACTFILE	ACTFILE.act	ACTFILE.act
MPS file	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Solution file	SYSPRINT	SYSPRINT
Out basis	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Packed matrix	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Report	None	reports5, fort.75

All the files used for MRM and ERM matrix generation reside within the NEMS default directories on EIA's NEMS NT servers, as defined next. The source files that encompass the program are on n:/default/source/, and the object codes are on n:/default/objects/. The user must link the object files to form the mrm executable to be located in the user's directory. The *Developer's Studio* (a debugging

package for the PC) is used by the user to compile, link, execute, debug, and manage files. Instructions on how use this package, in connection with the mrm, is defined below.

The mrmparam file and the mrmpath file used for the MRM model are located in the n:/default/scripts/ directory. The ermparam file and the ermpath file used for the ERM model are located in the n:/default/input/ directory. To run each of the models, their respective param and path files must be copied to the user's Debug directory. Also remember that the ermparam file must be renamed to mrmparam in the user directory prior to model execution. The path files point to the default data files (*.dat) that are stored in n:/default/input/ directory.

Runs

First, connect to the NEMS-F5 via a terminal server client, and open a korn shell. You are now operating within a unix environment. All runs will be made using the *Developer's Studio*.

1. Set up and run the default (no changes):
    a.   Create a scenario directory in your user directory, then create the following directories within the scenario directory: Source, Data, Debug
    b.   In the Debug directory, *nemsco* the appropriate **param** and **path files.** (If running ERM, rename the ermparam to **mrmparam**.)
    c.   In the Debug directory, copy the following 4 files from the n:/default/oml/DLL directory: OMLDB32.DLL, OMLLIB32.DLL, OMLLP32.DLL, and OMLWIN32.DLL (or *32.DLL).
    d.   In the scenario directory, *nemsco* mrmmps.dsp (a *Developer's Studio* project file).
    e.   Double-click the *Developer's Studio* icon on your NEMS-F5 terminal server desktop.
         -- from the FILE, OPEN menu, set file type to *.dsp, and select the mrmmps.dsp file. (This creates two more files in the scenario directory: mrmmps.dsw and mrmmps.opt.)
         -- from the PROJECT, SETTINGS menu, click on the Debug tab. Highlight the path defined in the "Executable for debug session" display, and copy it to the "Working directory" display just below. HOWEVER, go to the "Working directory" display and delete "\mrmmps.exe" portion of the path. Click OK.
    f.   To compile and link all default mrm code and DLLs, go to the BUILD menu, and select "Rebuild All." A message will appear in the lower window that the executible has been created.
    g.   To execute the default, go the the BUILD menu, and select "Execute." A pop-up window will show the progress of the mrm run. When finished, the pop-up window will instruct the user to press any key to continue.
    h.   The resulting mps file will be called mrm3mps (as defined in the mrmparam) and will be located in the Debug directory.

2. Make changes to a mrm data file and rerun mrm:
    a.   In the Data directory, *nemsco* the data file you want to change.
    b.   Edit, change, and resave.
    c.   In the Debug directory, edit the **mrmpath** file.
         -- modify the path of the updated data file to point to the new location in the Data directory, and resave
         -- delete (remove) the following two files that were created from a previous mrm run: ACTFILE.act and SYSPRINT
    d.   Double-click the *Developer's Studio* icon on your NEMS-F5 terminal server desktop.

-- from the FILE, OPEN menu, set file type to *.dsw, and select the mrmmps.dsw file from your scenario directory (created in step 1e above)

   e. To execute [assuming source code has already been compiled], go the the BUILD menu, and select "Execute." A pop-up window will show the progress of the mrm run. When finished, the pop-up window will instruct the user to press any key to continue.

   f. The resulting mps file will be called mrm3mps (as defined in the mrmparam) and will be located in the Debug directory.

3. Make changes to a mrm source code and rerun mrm:

   a. In the Source directory, *nemsco* the source code you want to change.

   b. Edit, change, and resave.

   c. In the Debug directory, delete (remove) the following two files that were created from a previous mrm run: ACTFILE.act and SYSPRINT

   d. Double-click the *Developer's Studio* icon on your NEMS-F5 terminal server desktop.
   -- from the FILE, OPEN menu, set file type to *.dsw, and select the mrmmps.dsw file from your scenario directory (created in step 1e above)

   e. [Need to do only once.] In the workspace window, double-click on the **mrmmps files** listing, and then on the **Source Files** listing.
   -- find the source code filename, right-click on the filename, and select **Properties** from this sub-menu: a pop-up window entitled "Source File Properties" appears
   -- within the pop-up window, modify the path of the source code (in the "Persist as" line) to point to the new location in the source directory
   -- close the pop-up window by clicking on the 'x' in this window

   f. To recompile updated code and link to other code, go to the BUILD menu, and select "Rebuild All." A message will appear in the lower window that the executible has been created.

   g. To execute, go the the BUILD menu, and select "Execute." A pop-up window will show the progress of the mrm run. When finished, the pop-up window will instruct the user to press any key to continue.

   h. The resulting mps file will be called mrm3mps (as defined in the mrmparam) and will be located in the Debug directory.

Appendix G-A: Example of an mrmparam file.

mrmparam:

```
MODELN    'MRM3    '                                                  !8
ACTPROB       'OMLMRM3 '                                              !8
SOLNAM        'MRM3SOL '                                              !8
PATHNF        'mrmpath'                                               !7
TITLE     'MRM3 MULTI  REGION  REFINERY                '         !48
INBASISN 'inbasis3                                      '         !48
OUTBASISN     'outbasis3'                                             !9
BASISN        'MRM3    '                                              !9
MPSOUTN       'mrm3mps '                                              !9
PACKN     'NULL      '                                                !9
```

ermparam:

```
MODELN        'ERM     '                                              !8
ACTPROB       'OMLERM  '                                              !8
SOLNAM        'ERMSOL  '                                              !8
PATHNF        'pathe  '                                               !7
TITLE     'ERM  SINGLE REGION  REFINERY               '          !48
INBASISN '/refine/pmm_lp_gen/data/erm/inbasise           '      !48
OUTBASISN     'outbasise'                                             !9
BASISN        'ERM     '                                              !9
MPSOUTN       'ermGmps '                                              !9
PACKN     'ERM2.PCK '                                                 !9
```

The mrmparam file will run the 3-region MRM model and the ermparam file will run the single region ERM model; the act problem will be "OMLMRM3" for the MRM model and "OMLERM "for the ERM model; the solution name will be "MRM3SOL" for the MRM model and "ERMSOL" for the ERM model; the data files path will be read from the file "mrmpath" for the MRM model and "pathe" for the ERM model; the title of the MRM model will be "MRM3, MULTIPLE REGIONS REFINERY" and the ERM model will be "ERM, SINGLE REGION REFINERY;" the advanced basis will be read from "inbasis3" for the MRM model and "inbasise" for the ERM model along the path defined; the optimal basis will be stored in the file "outbasis3" for the MRM model and "outbasise" for the ERM model; both the advanced and optimal basis will be named "MRM3" for the MRM model and "ERM for the ERM model; the mps file will be stored in "mrm3mps" for the MRM model and "ermGmps" for the ERM model; and the packed matrix will not be created (NULL) for the MRM model, but will be stored in "ERM2.PCK" for the ERM model.

Remember that the "ermparam" file must be **renamed** to "mrmparam" before an ERM execution can be run.

Appendix G-B: Example of a path file

mrmpath:

```
NAME            PATHDATA
        DATA    Z:PATHNAME
**      TEXT(6)
accunit     /default/input/accunit.dat.v1.6
avoids      /default/input/avoids.dat.v1.1
cogener     /default/input/cogener.dat.v1.7
crdimprt    /default/input/crdimprt.dat.v1.4
demand      /default/input/demand.dat.v1.4
distblnd    /default/input/distblnd.dat.v1.3
distress    /default/input/distress.dat.v1.2
domcrude    /default/input/domcrude.dat.v1.2
emish       /default/input/emish.dat.v1.1
ethanol     /default/input/ethanol.dat.v1.4
fixcols     /default/input/fixcols.dat.v1.3
fuelmix     /default/input/fuelmix.dat.v1.2
gasoblnd    /default/input/gasoblnd.dat.v1.7
main        /default/input/main.dat.v1.4
ngprod      /default/input/ngprod.dat.v1.2
nrfplant    /default/input/nrfplant.dat.v1.7
prdimprt    /default/input/prdimprt.dat.v1.3
recipes     /default/input/recipes.dat.v1.2
refproc     /default/input/refproc.dat.v1.18
setrows     /default/input/setrows.dat.v1.4
splash      /default/input/splash.dat.v1.4
stream      /default/input/stream.dat.v1.3
transit     /default/input/transit.dat.v1.6
utility     /default/input/utility.dat.v1.5
mchproc     /default/input/mchproc.dat.v1.5
limpol      /default/input/limpol.dat.v1.3
unfinished  /default/input/unfinish.dat.v1.2
prdexp      /default/input/prdexp.dat.v1.2
akaexp      /default/input/akaexp.dat.v1.1
foreign1
foreign2
fsu
intsetup
epsetup
bldhead
bldstub
ENDATA
```

pathe:

```
NAME            PATHDATA
         DATA      Z:PATHNAME
**         TEXT(6)
accunit     /default/input/accunit.dat.v1.4
avoids
cogener     /default/input/cogenere.dat.v1.1
crdimprt
ermprod     /default/input/ermprod.dat.v1.1
distblnd    /default/input/distblnd.dat.v1.2
distress
ermcrude    /default/input/ermcrude.dat.v1.1
emish
ethanol
fixcols
fuelmix     /default/input/fuelmix.dat.v1.2
gasoblnd    /default/input/gasoblnd.dat.v1.4
main        /default/input/maine.dat.v1.1
ngprod
ermother    /default/input/ermother.dat.v1.1
prdimprt
recipes     /default/input/recipes.dat.v1.2
refproc     /default/input/refproc.dat.v1.14
setrows     /default/input/setrows.dat.v1.3
splash
stream      /default/input/stream.dat.v1.3
transit
utility     /default/input/utilitye.dat.v1.1
mchproc
limpol      /default/input/limpol.dat.v1.2
unfinished
prdexp
akaexp
foreign1
foreign2
fsu
intsetup
epsetup
bldhead
bldstub
ENDATA
```

Appendix G-C:Makefile

(not part of the Developer's Studio Methodology)

```
FLAGS= -c -g -C -qcharlen=16384 -qmaxmem=-1 -qnoprint \
     -qflttrap=zerodivide -qsave
INC= -I/refine/pmm_lp_gen/includes/ -I/default/includes
LIBS= -lwhiz -ldb -lutil -L/usr/lpp/MPS/oml/lib
DIR= /default/objects/
SIR= /default/source/
LIR= /default/objects/
OMLSPA = /refine/pmm_lp_gen/includes/omlspace \
     /refine/pmm_lp_gen/includes/ipmmtest
OBJS= $(LIR)mrm.v1.2.o \
     $(LIR)extpnt.v1.2.o \
     $(LIR)epadjust.v1.2.o \
     $(LIR)bldhead.v1.2.o \
     $(LIR)bldstub.v1.2.o \
     $(LIR)intsetup.v1.2.o \
     $(LIR)foreign.v1.2.o \
     $(LIR)fsu.v1.2.o \
     $(LIR)akaexp.v1.2.o \
     $(LIR)prdexp.v1.4.o \
     $(LIR)unfinished.v1.2.o \
     $(LIR)lplookup.v1.2.o \
     $(LIR)output.v1.2.o \
     $(LIR)ermcrude.v1.2.o \
     $(LIR)ermother.v1.2.o \
     $(LIR)ermprod.v1.2.o \
     $(LIR)tabread.v1.2.o \
     $(LIR)limpol.v1.2.o \
     $(LIR)mchproc.v1.4.o \
     $(LIR)crdimprt.v1.2.o \
     $(LIR)accunit.v1.6.o \
     $(LIR)refproc.v1.6.o \
     $(LIR)nrfplant.v1.5.o \
     $(LIR)stream.v1.2.o \
     $(LIR)distblnd.v1.3.o \
     $(LIR)gasoblnd.v1.4.o \
     $(LIR)domcrude.v1.3.o \
     $(LIR)demand.v1.3.o \
     $(LIR)utility.v1.3.o \
     $(LIR)utilitye.v1.2.o \
     $(LIR)cogener.v1.4.o \
     $(LIR)fuelmix.v1.2.o \
     $(LIR)recipes.v1.2.o \
     $(LIR)ethanol.v1.9.o \
     $(LIR)ngprod.v1.2.o \
     $(LIR)setrows.v1.2.o \
     $(LIR)fixcols.v1.2.o \
     $(LIR)transit3.v1.4.o \
     $(LIR)transit5.v1.2.o \
     $(LIR)prdimprt.v1.2.o \
     $(LIR)splash.v1.3.o \
     $(LIR)distress.v1.2.o \
     $(LIR)avoids.v1.2.o \
     $(DIR)omlanal.v1.6.o \
     $(LIR)emish.v1.2.o \
```

```
mrm: $(OBJS)
        xlf -o mrm -g -C $(OBJS) $(LIBS) -bloadmap:loadmap

$(LIR)mrm.v1.3.o: $(SIR)mrm.f $(OMLSPA)
        xlf $(FLAGS) -o $(LIR)mrm.v1.3.o $(INC) $(SIR)mrm.f
$(LIR)extpnt.v1.2.o: $(SIR)extpnt.f
        xlf $(FLAGS) -o $(LIR)extpnt.v1.2.o $(INC) $(SIR)extpnt.f
$(LIR)epadjust.v1.2.o: $(SIR)epadjust.f
        xlf $(FLAGS) -o $(LIR)epadjust.v1.2.o $(INC) $(SIR)epadjust.f
$(LIR)bldhead.v1.2.o: $(SIR)bldhead.f
        xlf $(FLAGS) -o $(LIR)bldhead.v1.2.o $(INC) $(SIR)bldhead.f
$(LIR)bldstub.v1.2.o: $(SIR)bldstub.f
        xlf $(FLAGS) -o $(LIR)bldstub.v1.2.o $(INC) $(SIR)bldstub.f
$(LIR)intsetup.v1.2.o: $(SIR)intsetup.f
        xlf $(FLAGS) -o $(LIR)intsetup.v1.2.o $(INC) $(SIR)intsetup.f
$(LIR)foreign.v1.2.o: $(SIR)foreign.f
        xlf $(FLAGS) -o $(LIR)foreign.v1.2.o $(INC) $(SIR)foreign.f
$(LIR)fsu.v1.2.o: $(SIR)fsu.f
        xlf $(FLAGS) -o $(LIR)fsu.v1.2.o $(INC) $(SIR)fsu.f
$(LIR)akaexp.v1.2.o: $(SIR)akaexp.f
        xlf $(FLAGS) -o $(LIR)akaexp.v1.2.o $(INC) $(SIR)akaexp.f
$(LIR)prdexp.v1.4.o: $(SIR)prdexp.f
        xlf $(FLAGS) -o $(LIR)prdexp.v1.4.o $(INC) $(SIR)prdexp.f
$(LIR)unfinished.v1.2.o: $(SIR)unfinished.f
        xlf $(FLAGS) -o $(LIR)unfinished.v1.2.o $(INC) $(SIR)unfinished.f
$(LIR)lplookup.v1.2.o: $(SIR)lplookup.f
        xlf $(FLAGS) -o $(LIR)lplookup.v1.2.o $(INC) $(SIR)lplookup.f
$(LIR)output.v1.2.o: $(SIR)output.f
        xlf $(FLAGS) -o $(LIR)output.v1.2.o $(INC) $(SIR)output.f
$(LIR)limpol.v1.2.o: $(SIR)limpol.f
        xlf $(FLAGS) -o $(LIR)limpol.v1.2.o $(INC) $(SIR)limpol.f
$(LIR)tabread.v1.2.o: $(SIR)tabread.f
        xlf $(FLAGS) -o $(LIR)tabread.v1.2.o $(INC) $(SIR)tabread.f
$(LIR)mchproc.v1.4.o: $(SIR)mchproc.f
        xlf $(FLAGS) -o $(LIR)mchproc.v1.4.o $(INC) $(SIR)mchproc.f
$(LIR)ermcrude.v1.2.o: $(SIR)ermcrude.f
        xlf $(FLAGS) -o $(LIR)ermcrude.v1.2.o $(INC) $(SIR)ermcrude.f
$(LIR)ermother.v1.2.o: $(SIR)ermother.f
        xlf $(FLAGS) -o $(LIR)ermother.v1.2.o $(INC) $(SIR)ermother.f
$(LIR)ermprod.v1.2.o: $(SIR)ermprod.f
        xlf $(FLAGS) -o $(LIR)ermprod.v1.2.o $(INC) $(SIR)ermprod.f
$(LIR)crdimprt.v1.2.o: $(SIR)crdimprt.f
        xlf $(FLAGS) -o $(LIR)crdimprt.v1.2.o $(INC) $(SIR)crdimprt.f
$(LIR)accunit.v1.6.o: $(SIR)accunit.f
        xlf $(FLAGS) -o $(LIR)accunit.v1.6.o $(INC) $(SIR)accunit.f
$(LIR)refproc.v1.6.o: $(SIR)refproc.f
        xlf $(FLAGS) -o $(LIR)refproc.v1.6.o $(INC) $(SIR)refproc.f
$(LIR)nrfplant.v1.5.o: $(SIR)nrfplant.f
        xlf $(FLAGS) -o $(LIR)nrfplant.v1.5.o $(INC) $(SIR)nrfplant.f
$(LIR)stream.v1.2.o: $(SIR)stream.f
        xlf $(FLAGS) -o $(LIR)stream.v1.2.o $(INC) $(SIR)stream.f
$(LIR)distblnd.v1.3.o: $(SIR)distblnd.f
        xlf $(FLAGS) -o $(LIR)distblnd.v1.3.o $(INC) $(SIR)distblnd.f
$(LIR)gasoblnd.v1.4.o: $(SIR)gasoblnd.f
        xlf $(FLAGS) -o $(LIR)gasoblnd.v1.4.o $(INC) $(SIR)gasoblnd.f
$(LIR)domcrude.v1.3.o: $(SIR)domcrude.f
        xlf $(FLAGS) -o $(LIR)domcrude.v1.3.o $(INC) $(SIR)domcrude.f
$(LIR)demand.v1.3.o: $(SIR)demand.f
        xlf $(FLAGS) -o $(LIR)demand.v1.3.o $(INC) $(SIR)demand.f
$(LIR)utility.v1.3.o: $(SIR)utility.f
```

```
        xlf $(FLAGS) -o $(LIR)utility.v1.3.o $(INC) $(SIR)utility.f
$(LIR)utilitye.v1.2.o: $(SIR)utilitye.f
        xlf $(FLAGS) -o $(LIR)utilitye.v1.2.o $(INC) $(SIR)utilitye.f
$(LIR)cogener.v1.4.o: $(SIR)cogener.f
        xlf $(FLAGS) -o $(LIR)cogener.v1.4.o $(INC) $(SIR)cogener.f
$(LIR)fuelmix.v1.2.o: $(SIR)fuelmix.f
        xlf $(FLAGS) -o $(LIR)fuelmix.v1.2.o $(INC) $(SIR)fuelmix.f
$(LIR)recipes.v1.2.o: $(SIR)recipes.f
        xlf $(FLAGS) -o $(LIR)recipes.v1.2.o $(INC) $(SIR)recipes.f
$(LIR)ethanol.v1.9.o: $(SIR)ethanol.f
        xlf $(FLAGS) -o $(LIR)ethanol.v1.9.o $(INC) $(SIR)ethanol.f
$(LIR)ngprod.v1.2.o: $(SIR)ngprod.f
        xlf $(FLAGS) -o $(LIR)ngprod.v1.2.o $(INC) $(SIR)ngprod.f
$(LIR)setrows.v1.2.o: $(SIR)setrows.f
        xlf $(FLAGS) -o $(LIR)setrows.v1.2.o $(INC) $(SIR)setrows.f
$(LIR)fixcols.v1.2.o: $(SIR)fixcols.f
        xlf $(FLAGS) -o $(LIR)fixcols.v1.2.o $(INC) $(SIR)fixcols.f
$(LIR)transit3.v1.4.o: $(SIR)transit3.f
        xlf $(FLAGS) -o $(LIR)transit3.v1.4.o $(INC) $(SIR)transit3.f
$(LIR)transit5.v1.2.o: $(SIR)transit5.f
        xlf $(FLAGS) -o $(LIR)transit5.v1.2.o $(INC) $(SIR)transit5.f
$(LIR)prdimprt.v1.2.o: $(SIR)prdimprt.f
        xlf $(FLAGS) -o $(LIR)prdimprt.v1.2.o $(INC) $(SIR)prdimprt.f
$(LIR)splash.v1.3.o: $(SIR)splash.f
        xlf $(FLAGS) -o $(LIR)splash.v1.3.o $(INC) $(SIR)splash.f
$(LIR)distress.v1.2.o: $(SIR)distress.f
        xlf $(FLAGS) -o $(LIR)distress.v1.2.o $(INC) $(SIR)distress.f
$(LIR)avoids.v1.2.o: $(SIR)avoids.f
        xlf $(FLAGS) -o $(LIR)avoids.v1.2.o $(INC) $(SIR)avoids.f
$(LIR)emish.v1.2.o  : $(SIR)emish.f
        xlf $(FLAGS) -o $(LIR)emish.v1.2.o $(INC) $(SIR)emish.f
```

Appendix G-D: Common Blocks

File: ipmmtest

C $Header: /default/includes/RCS/ipmmtest,v 1.6.1.11 1995/07/17 19:59:11 db6 Exp $
```
    COMMON /IPMMREAL/MAX, MIN, VALUE, INFINITY,
    +      WOP,
    +      REALURYR, YRDOLLAR, ENV, LOC, OVCOST
    REAL*8     MAX(1000)
    REAL*8     MIN(1000)
    REAL*8     VALUE(1000)
    REAL*8     INFINITY
    REAL*8     WOP(26)
    REAL*8     REALURYR
    REAL*8     YRDOLLAR
    REAL*8     ENV(5)
    REAL*8     LOC(5)
    REAL*8     OVCOST(5)
    COMMON /IPMMINT/COUNT, DUMMY,
    +      I, IRET, IROWS, J, JCOLS, K, KROWS, NUMREG,EXPREGSS,
    +      USERYEAR, DMDREG, NUMYRS, DBPROBG, COMTAB1, COMTAB2
    INTEGER*4   COUNT
    INTEGER*4   DUMMY
    INTEGER*4   I
    INTEGER*4   IRET
    INTEGER*4   IROWS
    INTEGER*4   J
    INTEGER*4   JCOLS
    INTEGER*4   K
    INTEGER*4   KROWS
    INTEGER*4   NUMREG
    INTEGER*4   EXPREGSS
    INTEGER*4   USERYEAR
    INTEGER*4   DMDREG
    INTEGER*4   NUMYRS
    INTEGER*4   DBPROBG(22)
    INTEGER*4   COMTAB1(13)
    INTEGER*4   COMTAB2(13)
    COMMON /IPMMCHAR/HEAD, STUB, PROCESS, BND, CNAME,
    +  DECKNAME, LRNAME, OBJ, RHS, RNAME, RCHAR5, REGION,
    +  EXPREG, DEMNDREG, DEMNDPAD, PATH, FRCRD, EXPRD
    CHARACTER*8  HEAD(1000)
    CHARACTER*8  STUB(1000)
    CHARACTER*8  PROCESS(1000)
    CHARACTER*8  BND
    CHARACTER*8  CNAME
    CHARACTER*8  DECKNAME
    CHARACTER*8  LRNAME
    CHARACTER*8  OBJ
    CHARACTER*8  RHS
    CHARACTER*8  RNAME
    CHARACTER*5  RCHAR5
    CHARACTER*1  REGION(5)
    CHARACTER*2  EXPREG(5)
    CHARACTER*1  DEMNDREG(9)
    CHARACTER*1  DEMNDPAD(9)
```

```
      CHARACTER*48 PATH(40)
      CHARACTER*8 FRCRD(5)
      CHARACTER*8 EXPRD(11)
```

File: lpout

Common block used for report writing

```
C  LPOUT COMMON BLOCK FOR USE IN OML MATRIX SOLUTION
                             !
      REAL        PRDPRC(9,18)
      REAL        BASECAP(5,27)
      REAL        BASEUTL(5,27)
      REAL        INVCAP(5,27)
      REAL        INVUTL(5,27)
      REAL        TOTCAP(5,27)
      REAL        TOTUTL(5,27)
      REAL        TOTSUP(6)
      REAL        PUTL(5,27)
      REAL        RFCRDCR(6)
      REAL        RFCRDAKA(6)
      REAL        RFCRDL48(6)
      REAL        RFQICRD(6)
      REAL        RFIMCR(6)
      REAL        RFQISPR(6)
      REAL        RFIMTP(6)
      REAL        RFQEXCRD(6)
      REAL        RFPQNGL(6)
      REAL        RFQNGLRF(6)
      REAL        NGLRF(6)
      REAL        NGLMK(6)
      REAL        RFQPRCG(6)
      REAL        RFPQIPRDT(6)
      REAL        RFPQUFC(6)
      REAL        RFQEXPRDT(6)
      REAL        RFQPRDDM(11)
      REAL        QCDUPD(6)
      REAL        RFQDINPOT(6)
      REAL        RFETHD(6)
      REAL        RFMTBI(6)
      REAL        RFMETI(6)
      REAL        RFMETD(6)
      REAL        RFMETCHM(6)
      REAL        RFMETM85(6)
      REAL        RFMETETH(6)
      REAL        RFETHE85(6)
      REAL        RFETHETB(6)
      REAL        RFETHMGS(6)
      REAL        RFCRDOTH(6)
      REAL        OTHOXY(6)
      REAL        QPRDIMD(11,23)
      REAL        QPRDEXD(6,23)
      COMMON/LPTAB/PRDPRC,BASECAP,BASEUTL,INVCAP,INVUTL,TOTCAP,
     +TOTUTL,PUTL,RFCRDDCR,RFCrtAKA,RFCrtL48,RFQICRD,RFIMCR,
     +RFQEXCRD,RFPQNGL,RFQNGLRF,NGLRF,NGLMK,RFQPRCG,RFPQIPRDT,
     +RFPQUFC,RFQEXPRDT,RFQPRDDM,QCDUPD,RFQDINPOT,RFETHD,RFMTBI,
     +RFMETI,RFMETD,RFMETCHM,RFMETM85,RFMETETH,RFETHE85,TOTSUP,
     +RFQISPR,RFIMTP,RFETHETB,RFETHMGS,OTHOXY,QPRDIMD,QPRDEXD,
     +RFCRDOTH
```

File: DFINC2

Common block used for OML database functions

C $Header: /default/includes/RCS/dfinc2,v 1.1 1995/03/14 16:22:27 dln Exp $
C
C   DATABASE.FH   FORTRAN FUNCTION DECLARATIONS
C
C$INCLUDE DWCPRAG.FH
C
     INTEGER DFINIT
     INTEGER DFOPEN
     INTEGER DFEND
     INTEGER DFCLOSE
     INTEGER DFDEL
     INTEGER DFLIST
C
     INTEGER DFPINIT
     INTEGER DFPDEL
     INTEGER DFPCPY
     INTEGER DFPLIST
     INTEGER DFPTDEL
     INTEGER DFPTCPY
     INTEGER DFPMDEL
     INTEGER DFPMCPY
     INTEGER DFPSDEL
     INTEGER DFPSCPY
     INTEGER DFPRTBI
C
     INTEGER DFTINIT
     INTEGER DFTNEW
     INTEGER DFTDIM
     INTEGER DFTDEL
     INTEGER DFTCPY
     INTEGER DFTSNDX
     INTEGER DFTHNDX
     INTEGER DFTNDX
     INTEGER DFTGET
     INTEGER DFTPUT
     INTEGER DFTSADD
     INTEGER DFTHADD
     INTEGER DFTSDEL
     INTEGER DFTHDEL
     INTEGER DFTDISP
C
     INTEGER DFMINIT
     INTEGER DFMEND
     INTEGER DFMSTAT
     INTEGER DFMCRTP
     INTEGER DFMCRSC
     INTEGER DFMCCSC
     INTEGER DFMCVAL
     INTEGER DFMMVAL
     INTEGER DFMCRHS
     INTEGER DFMCRNG
     INTEGER DFMCBND
     INTEGER DFMRRTY
     INTEGER DFMRRSC

```
        INTEGER DFMRCSC
        INTEGER DFMRVAL
        INTEGER DFMRRHS
        INTEGER DFMRRNG
        INTEGER DFMRBND
        INTEGER DFMIROW
        INTEGER DFMICOL
        INTEGER DFMIRHS
        INTEGER DFMIRNG
        INTEGER DFMIBND
        INTEGER DFMNROW
        INTEGER DFMNCOL
        INTEGER DFMNRHS
        INTEGER DFMNRNG
        INTEGER DFMNBND
        INTEGER DFMLROW
        INTEGER DFMLCOL
        INTEGER DFMLRHS
        INTEGER DFMLRNG
        INTEGER DFMLBND
        INTEGER DFMLVAL
        INTEGER DFMTAB
C
        INTEGER DFSINIT
        INTEGER DFSROW
        INTEGER DFSCOL
C
        INTEGER DFNCMP
C
```

File: WFINC2

Common block used for the WHIZ optimizer

```
C  $Header: /default/includes/RCS/wfinc2,v 1.1 1995/03/14 16:22:45 dln Exp $
C
C     WHIZ.FH
C
C THIS FILE DEFINES A COMMON AREA NAMED WCR AND SUPPLIES THE TYPES FOR
C ALL OF THE VARIABLES IN THE CR USED BY OML OPTIMIZATION.
C IT ALSO SUPPLIES DECLARATIONS FOR THE INTEGER WF... FUNCTIONS.
C
C$INCLUDE WWCPRAG.FH
C    USE _WCR FOR WATCOM
C    COMMON /_WCR/
C    USE WCR OTHERWISE (E.G., 370)
     COMMON /WCR/
    * XNAME, XCORE, XCORELEN,
    * XACTCASE, XACTFILE, XACTPROB, XBOUND, XCHOBJ, XCHRHS, XCMASK,
    * XDATA, XINSERT, XLOADB, XMINMAX, XOBJ., XPUNCH, XRANGE, XRHS,
    * XRMASK, XRNGFILE, XRNGPRNT, XSAVEB, XSOLFILE, XSOLPRNT,
    * XSOLSTAT, XEPS, XFUNCT, XINTGOAL, XMAXVAR, XPARAM, XPENCOST,
    * XPHI, XRSTOP, XSIF, XSSCALE, XTHETA, XTOLCHK,
    * XTOLCHZR, XTOLCKRW, XTOLCLRT, XTOLDJ, XTOLERR,
    * XTOLFSTM, XTOLINV, XTOLLMAX, XTOLPERT, XTOLPIV, XTOLREL,
    * XTOLRMAX, XTOLRWRT, XTOLUREL, XTOLV, XTOLZE, XZERO,
    * XCHECKSW, XCLOCKSW, XCOMPERR, XCOMPSW, XCRASHSW,
    * XCYCLESW, XDEGEND, XDEGMAX, XDEMAND, XDETAIL,
    * XDOATTN, XDODELTM, XDOFEAS, XDOFREQ1, XDONFS, XDOUNB,
```

```
    *  XDUAL, XEQUIL, XFEAS, XFREQINV, XFREQLOG, XFREQSAV,
    *  XFREQSUM, XINVERT, XITERNO, XJ, XLUDENSE,
    *  XLUFILL, XLUINV, XM, XMAJERR,
    *  XMAXITER, XMAXPASS, XMAXTIME, XMINERR, XNEGDJ,
    *  XNIF, XNOWT, XRUNMODE, XRYANOSB, XSCALESW, XSCRNSW,
    *  XSLPNZ, XTIMESAV, XTRACE, XTRAN, XUNBDNDX, XUSEFREE
C
    CHARACTER*8 XNAME
    INTEGER    XCORE
    INTEGER    XCORELEN
C
    CHARACTER*8 XACTCASE
    CHARACTER*8 XACTFILE
    CHARACTER*8 XACTPROB
    CHARACTER*8 XBOUND
    CHARACTER*8 XCHOBJ
    CHARACTER*8 XCHRHS
    CHARACTER*8 XCMASK
    CHARACTER*8 XDATA
    CHARACTER*8 XINSERT
    CHARACTER*8 XLOADB
    CHARACTER*8 XMINMAX
    CHARACTER*8 XOBJ
    CHARACTER*8 XPUNCH
    CHARACTER*8 XRANGE
    CHARACTER*8 XRHS
    CHARACTER*8 XRMASK
    CHARACTER*8 XRNGFILE
    CHARACTER*8 XRNGPRNT
    CHARACTER*8 XSAVEB
    CHARACTER*8 XSOLFILE
    CHARACTER*8 XSOLPRNT
    CHARACTER*8 XSOLSTAT
    REAL*8     XEPS
    REAL*8     XFUNCT
    REAL*8     XINTGOAL
    REAL*8     XMAXVAR
    REAL*8     XPARAM
    REAL*8     XPENCOST
    REAL*8     XPHI
    REAL*8     XRSTOP
    REAL*8     XSIF
    REAL*8     XSSCALE
    REAL*8     XTHETA
    REAL*8     XTOLCHK
    REAL*8     XTOLCHZR
    REAL*8     XTOLCKRW
    REAL*8     XTOLCLRT
    REAL*8     XTOLDJ
    REAL*8     XTOLERR
    REAL*8     XTOLFSTM
    REAL*8     XTOLINV
    REAL*8     XTOLLMAX
    REAL*8     XTOLPERT
    REAL*8     XTOLPIV
    REAL*8     XTOLREL
    REAL*8     XTOLRMAX
    REAL*8     XTOLRWRT
    REAL*8     XTOLUREL
    REAL*8     XTOLV
```

```
    REAL*8      XTOLZE
    REAL*8      XZERO
    INTEGER     XCHECKSW
    INTEGER     XCLOCKSW
    INTEGER     XCOMPERR
    INTEGER     XCOMPSW
    INTEGER     XCRASHSW
    INTEGER     XCYCLESW
    INTEGER     XDEGEND
    INTEGER     XDEGMAX
    INTEGER     XDEMAND
    INTEGER     XDETAIL
    INTEGER     XDOATTN
    INTEGER     XDODELTM
    INTEGER     XDOFEAS
    INTEGER     XDOFREQ1
    INTEGER     XDONFS
    INTEGER     XDOUNB
    INTEGER     XDUAL
    INTEGER     XEQUIL
    INTEGER     XFEAS
    INTEGER     XFREQINV
    INTEGER     XFREQLOG
    INTEGER     XFREQSAV
    INTEGER     XFREQSUM
    INTEGER     XINVERT
    INTEGER     XITERNO
    INTEGER     XJ
    INTEGER     XLUDENSE
    INTEGER     XLUFILL
    INTEGER     XLUINV
    INTEGER     XM
    INTEGER     XMAJERR
    INTEGER     XMAXITER
    INTEGER     XMAXPASS
    INTEGER     XMAXTIME
    INTEGER     XMINERR
    INTEGER     XNEGDJ
    INTEGER     XNIF
    INTEGER     XNOWT
    INTEGER     XRUNMODE
    INTEGER     XRYANOSB
    INTEGER     XSCALESW
    INTEGER     XSCRNSW
    INTEGER     XSLPNZ
    INTEGER     XTIMESAV
    INTEGER     XTRACE
    INTEGER     XTRAN
    INTEGER     XUNBDNDX
    INTEGER     XUSEFREE
C
    INTEGER     WFINIT
    INTEGER     WFDEF
    INTEGER     WFSET
    INTEGER     WFMPSIN
    INTEGER     WFMPSOU
    INTEGER     WFLOAD
    INTEGER     WFOPT
    INTEGER     WFEND
C
```

```
      INTEGER    WFCVAL
      INTEGER    WFCRHS
      INTEGER    WFCRNG
      INTEGER    WFCBND
C
      INTEGER    WFRVAL
      INTEGER    WFRRHS
      INTEGER    WFRRNG
      INTEGER    WFRBND
C
      INTEGER    WFRNAME
      INTEGER    WFCNAME
      INTEGER    WFRMASK
      INTEGER    WFCMASK
      INTEGER    WFSROW
      INTEGER    WFSCOL
      INTEGER    WFRROW
      INTEGER    WFRCOL
C
      INTEGER    WFRLVAL
      INTEGER    WFRLIST
      INTEGER    WFCLIST
      INTEGER    WFSPRT
      INTEGER    WFSFILE
      INTEGER    WFRCORD
      INTEGER    WFRPRT
      INTEGER    WFRFILE
C
      INTEGER    WFSAVEB
      INTEGER    WFLOADB
      INTEGER    WFPUNCH
      INTEGER    WFINSRT
C
      INTEGER    WFMGDMP
      INTEGER    WFMGLOD
      INTEGER    WFCRGET
      INTEGER    WFCRPUT
C
```

Appendix G-E: MRM Data Conversion

The current data used in the MRM (and ERM) were updated for the AEO2001 using the 2000 WORLD model data (referred to as ENSYS00) provided by EnSys Co. Due to the differences in data format (OMNI vs OML) and naming conventions, the ENSYS00 data had to undergo convertion and new mapping data tables had to be added to the MRM files prior to being used by the MRM.

The following provides a summary of the effort it took to convert the ENSYS00 OMNI tables into OML RTB tables (to be read by the matrix generation code).

1. The code to convert the OMNI tables to RTB tables is found in directory /refine/prj/ensys/source95/... on the EIA RS-6000 computer (not yet moved to the EIA NT server) with the following name: omni2rtb.c

2. To compile and execute the omni2rtb type:
   - compile: cc -o <exec filename> <source code filename>
   - execute: <exec filename> <input data path/filename> <output filename>

   For example, if all files are in the same directory:
   cc -o omniexec omni2rtb.c
   omniexec v0.ensrymeq.gdb omniout

3. Technology database development since 1994, according to ENSYS:

   • Implementation of weight balancing on every process vector

   • Implementation of rigorous sulfur balancing on every process vector (down to the ppm level)

   • Conversion of the technology database to spreadsheet basis (Excel)

   • Implementation of model compositing system. This current task is directed to RYM-type regional/prototypical refinery fuels/regulatory studies and takes advantage of the fact that, in any one case, crude slate is essentially fixed. This enables a much smaller matrix to be generated, with yields and qualities crude slate dependent, from the un-composited model tables. Resulting model matrix has far fewer prototypical streams, less susceptibility to over-optimization (and attendant criticism), more manageable when ratio controls are used. (The task to develop this system is proving to be a rigorous diagnostic on model structure, non-composited and composited, and as such is helping eliminate any errors.)

4. New processing units related to technology improvements included in refproc.dat:
   • Atmospheric Residuum Desulfurization (ARD)
   • Catalitic Desulfurization (CDT)
   • Low Conversion Hydrocracker (HCL)
   • Catalytic Naphtha Hydrotreater (SYG)
   • Hydrodesulfurizer 1 (HD1)
   • Hydrodesulfurizer 2 (HD2)
   • Hydrocracker (partial) (MAK)
   • Catalytic Fluidized Bed (MOD)

- Middle Distillate Hydro (MDH, orignally identified by Ensys as MOH)
- Catalytic Fixed-Bed Hydroprocessor (OCT)
- Caustic SOx Scrubber (SOX)
- Methanol to Olefins Fluid Bed (MTO)
- Shell Middle Distillate (SMD)
- Syntroleum GTL Process (SOD)

5. Other updates and error corrections in the Ensys99 database include:

T:TCG	-- corrected sign on fuel component from + to - for all modes
T:RFC	-- removed RFN consumption and corrected consumption of RFI (from 1.1 to 1) in mode 1L1; removed production of R90 and corrected production of R10 (from .8438 to .843) in mode 1L1
T:PHI	-- corrected typo (7.. to 7.) for FUL component in mode NC6
T:FUM	-- added 0.999 coef to FUL component in mode HH2
T:FCC	-- changed coef for OVC component (-9999. to -.141) in modes B85, 70A, 85A, 70B, 85B, 65S
T:FDS	-- multiplies coef by 100 for HH2 component in all modes
T:ARD	-- removed components RR1, RR2, RR3 in all modes
T:OCT	-- removed component G32 in mode F30; changed sign of FUL component (from 9999.0 to -9999.0) in mode F31

6. FOR THE RECORD: errors found in the original ENSYS95 v0.ensrymeq.gdb tables (and corrected in the v0.ensrymeq.mod version) include:
    a)   v0.ensrymeq.gdb
        - all references to "Total C5+ YIELD" should be commented using an "* " at the beginning of each line (only one needed fixing)
        - Table ALK -- change "- 500" to " -500"
            Row: [STM] STEAM, LB/BBL
            Col: [C3A]
        - Table HCR -- remove comment to activate the 0.4 in
            Row: [DDL] HYCK DIESEL
            Col: [DIE] & [MLD]
        - Table ALK -- change "-.03" to "-.030"
            Row: [FUL] FUEL, FOE/BBL
            Col: [N5A]

    b)   - In accordance with a memo from Will McCullers (5-29-96) related to the ENSYS95 conversion effort, an RTB table (T:RCPEIA) was added to allow the continued use of EIA-specific recipes which are necessary to produce petroleum coke in the matrix.
        - Additional mapping tables were added to the following *.dat files to change naming convention conflicts between the WORLD model and the PMM:
            gasoblnd.dat   Z:MAPGSLPD & Z:MAPGSLSP
            distblnd.dat   Z:MAPDFOPD & Z:MAPDFOSP

    c)   Of the tables updated using the ENSYS95 data (listed below), the following additional changes were made to selected tables:

        refproc.dat:

T:FUM --	all FUL coef changed from 1.0 to .999 so that the coef could be changed in memory.
T:OLE --	FUL coef changed from .071 to -.003 for mode PGU; LOS coef changed from -.007 to -.067 for mode PGU; removed comment from NGS stub to connect to mode PGU
T:SUL --	STM coef changed from -877.6 to 590.0 for all modes (update from MAPLES)
T:STG --	FUL,CAP,STM,KWH,OVC coef changed

FUL	-.204	old:-4.93
CAP	1000.	old: 1.0
STM	1000.	old: 1.0
KWH	-3.92	old:-.094
OVC	-.0458	old:-.555

T:SCL --	FUL, OVC coef (.001) removed for mode STG
T:FCC --	FUL,KWH coef changed from 0 to -.012 and -0.4 for (respectively) for modes: A70,A85,B70,B85,C70,C85,D70,D85,E70,E85,F70,F85,G70,G85,H71,H85,I70, I85,J70,785,K70,K85,70A,85A,70B,85B,70C,85C,70D,85D,70E,85E,70F,85F, 80G,85G,71H,85H,70I,85I,70J,85J,70K,85K
T:ETH --	removed modes TAM,THM,TAE,THE; changed coef on modes ETB & MTB:

	DATA	T:ETH
**	ETB	MTB
MTB	0.0000	1.0000
ETB	1.0000	0.0000
ETH	-0.4310	0.0000
MET	0.0000	-0.3410
I4E	-0.6940	-0.7940
HH2	-0.0000	-0.0000
LOS	0.1250	0.1350
OVC	-0.1570	-0.1570
KWH	-2.8100	-2.5500
STM	-384.0	-384.00
CAP	1.0	1.0

*

| T:ETM -- | new table added: |

	DATA	T:ETM		
**	TAE	TAM	THE	THM
TAE	1.0000	0.0000	0.0000	0.0000
THE	0.0000	0.0000	1.0000	0.0000
ETH	-0.3820	0.0000	-0.3430	0.0000
MET	0.0000	-0.3030	0.0000	-0.2690
R5E	-0.6940	-0.8770	0.0000	0.0000
R6E	0.0000	0.0000	-0.6980	-0.8210
TAM	0.0000	1.0000	0.0000	0.0000
THM	0.0000	0.0000	0.0000	1.0000
HH2	-0.0078	-0.0078	-0.0078	-0.0078
LOS	0.0838	0.1878	0.0488	0.0978
OVC	-0.1730	-0.1730	-0.1900	-0.1900
KWH	-6.3500	-6.0900	-6.3500	-6.0900
STM	-1060.0	-1062.0	-1062.0	-1062.0

```
                    CAP      1.0          1.0          1.0          1.0
                    ETM      1.0                       1.0
```

gasoblnd.dat:
  -Added SSE Spec for Splash Blending TRG: T:GSSE, T:ESSE, T:CSSE, T:WSSE, T:MSSE
  -Added stub SSE to T:GSLUTI with coef of 0.2

mchproc.dat:
  -added ETB mode to ETX at merchant plant;
  -added transfer connect of ETH from RF to MP;
  -added transfer connect of ETB from MP to RF.

d) The following list of *.dat and tables were updated using the new ensys95 data:

```
distblnd.dat:   DATA    T:DCC
                DATA    T:DCB
gasoblnd.dat:   DATA    T:MCO
                DATA    T:UNCBV
                DATA    T:RFMBV
                DATA    T:GCB
                DATA    T:GCC
recipes.dat:    DATA    T:RCP
refproc.dat:    DATA    T:MATBAL
                DATA    T:HLO
                DATA    T:RST
                DATA    T:SDA
                DATA    T:KRD
                DATA    T:KRF
                DATA    T:VBR
                DATA    T:NDS
                DATA    T:DDS
                DATA    T:FDS
                DATA    T:RDS
                DATA    T:RFH
                DATA    T:RFL
                DATA    T:RFC
                DATA    T:SPL
                DATA    T:HCN
                DATA    T:OLE
                DATA    T:DHT
                DATA    T:JFP
                DATA    T:FCC
                DATA    T:FGS
                DATA    T:TCG
                DATA    T:TCN
                DATA    T:TCV
                DATA    T:HCR
                DATA    T:HCV
```

```
                    DATA    T:ETS
                    DATA    T:C24
                    DATA    T:H56
                    DATA    T:C4T
                    DATA    T:FEX
                    DATA    T:HDN
                    DATA    T:JPS
                    DATA    T:DEW
                    DATA    T:ALK
                    DATA    T:CPL
                    DATA    T:DIP
                    DATA    T:ETH
                    DATA    T:CYC
                    DATA    T:ALM
                    DATA    T:DIM
                    DATA    T:ARP
                    DATA    T:RES
                    DATA    T:LUB
                    DATA    T:PHI
                    DATA    T:TRI
                    DATA    T:C4I
                    DATA    T:C4S
                    DATA    T:H2P
                    DATA    T:H2X
                    DATA    T:SUL
                    DATA    T:VCU
                    DATA    T:KWG
                    DATA    T:STG
                    DATA    T:REL
                    DATA    T:PFA
                    DATA    T:SCL
                    DATA    T:FUM
stream.dat:         DATA    T:TRS
```

Appendix G-F: Refinery Processes

Refinery Process	Abbreviation
Atmospheric crude distillation	ACU
Alkylation	ALK
Alkynax	ALM*
Atmospheric Residuum Desulfurization	ARD****
Aromatic recovery	ARP
Catalytic Distillation Technology	CDT
Cogeneration unit	CGN**
Polymerization	CPL
Cyclar	CYC
Butane isomerization	C4I
Butane splitter	C4S**
Akylation feed butene isomerizer	C4T*
Butane isomerization	C4X***
C2E to C4E dimerization	C24*
Distillate desulfurizer	DDS
Dimersol	DIM
Gas oil dewaxer	DEW
Di-isopropyl ether	DIP*
Etherol	ETH, ETM
Cryogenic C2 fractionation	ETS*
Etherrol unit	ETX***
FCC gasoline fractionation units	FGS
FCC feed hydrofiner	FDS
Fluid cat cracker	FCC
Mid-distillate furfural treating	FEX
Fuel plant	FUM**
Fuel plant	FUX***
Gas oil hydrocraker	HCR
Residum hydrocracker	HCV
Low Conversion Hydrocracking	HCL****

Refinery Process	Abbreviation
Naphta hydrocracker	HCN
Hydrodesulfurizer 1	HD1****
Hydrodesulfurizer 2	HD2****
High density jet fuel hydrotreating	HDN
Hydogen/fuel gas reformer hydrogen	HLO**
H2-stream reformer	H2P
H2-partial oxidizer	H2X
Hydrogeneration normal pentenes/hexenes	H56*
High density jet fuel prefactionation	JFP
Recut for JTA	JPS**
Delayed-coker	KRD
Fluid/flexi-coker	KRF
Power generation	KWG**
Lub and wax	LUB
Hydrocracker (partial)	MAK
Olefin Saturation Process	MDH****
Catalytic Fluidized Bed	MOD****
Methanol to Olefins Fluid Bed Process	MTO****
Naphta hydrotreater	NDS
OCTGAIN Catalytic Hydroprocessor	OCT
C2-C5 dehydrogenation	OLE*
C2-C5 dehydrogenation	OLX***
Pentane/hexane isomerization	PHI
Residuum desulfurizer	RDS
HP semi-regenerative reformer	RFH
LP cyclic reformer	RFL
LP continuous reformer	RFC
Solvent deasphalting	SDA
Shell Middle Distillate	SMD
Syntroleum GTL Process	SOD
Caustic SOx Scrubber	SOX****
Naphta splitter	SPL
Steam generation, lbs/hr	STG**

Refinery Process	Abbreviation
Steam generation, lbs/hr	STX***
Sulfur, short tons/day	SUL
Mid-distillate deep hydrotreater	SYD
Catalytic Naphtha Hydrotreater	SYG****
Thermal cracker C2-C4 feed	TCG*
Thermal craker naphta feed	TCN*
Thermal craker gas oil feed	TCV*
Total recycle isomerization	TRI*
Vaccum distillation	VCU
Visbreaker/thermal craker	VBR

* : Processes involved in reformulated gasoline manufacturing
**: Utilities and pseudo-units
***: Processes represented in OXY-Refineries
****: Not made available for *AEO2001*-- new, not ready for production

APPENDIX H

Historical Data Processing

APPENDIX H. Historical Data Processing

H.1 Processing Data for PMM History File

Data Dump Programs:

1) PSA Query: In Access97 open c:\OGIRS3.5\modify ogirs. Click on Aget PSADATA.@ This runs a query and produces AtblStacey@. To add or delete elements in the query change AtblParkListStacey@ and rerun. Pull AtblStacey@ into Excel (PSADATA.XLS) and modify the year format(try year(date)col), delete old year column, and File Output To, space delimited text file (PSA99.PRN). In FTP/TCP download ASCII file to mainframe to be read by SAS files. (May need to save as card on mainframe.)

   The last version of OGIRS was missing some of the elements of refinery production: nfrpp1-p5(naphtha feedstocks), otrpp1-p5 (other oils for feedstock), msrpp1-us(miscellaneous products for nonfuel use), pfrpp1-us(total petrochemical feedstocks), msgrpus 92 (still gas).

2) PRJ6007.NEMS.MARKUP.PRICE.HISTFILE: reads markup and tax files and creates a file of historical end-use prices.

Input files:	PRJ6007.NEMS.MARKUP.SASDB
	PRJ6007.NEMS.TAX.SASDB
Output file:	PRJ6007.PRICES.HIST.SASDB:PBTU9099

3) PRJ6007.NEMS.READ.SEDS: reads flat-file of SEDS sectoral consumption data, converts to thousand barrels per day, estimates Aother@ consumption, and outputs to a SASDB.

Input files:	PRJ6007.SEDS97A.DATA provided by EMEU (Roy Stanley)
	PRJ6007.SEDS97A.DATA
	PRJ6007.NEMS.MARKUP.SASDB
Output file:	PRJ6007.HISTORY.SASDB:SEDS.

4) Manually update PRJ6007.FUELUSED from fuel consumption data in Table 47. of the PSA. Natural gas and coal consumption have been published only every 2 years. The table will be published every year starting in 2000.

5) Update PFPRICES.WK4 to estimate petrochemical feedstock prices (see SEPER APPENDIX).

p naphtha= 1.23* WOP and other = 1.607 * WOP, uses 1999 prices weighted by 1993 volumes to estimate average pf price.

6) Manually update PRJ6007.ELCG.FLATFILE.DATA(MSPRICE) using estimates from PFPRICES.WK4.

7) Crude oil Wellhead Production and Prices are provided by the OGSM modeling team and are added to the history file during STEO data processing (see Section H.2).

8) Updated cogeneration data provided by the EMM modeling team and added during STEO data processing (Section H.2).

Data Processing Files:

1) PRJ6007.PMM.PROCESS.PSADATA - loads PRJ6007.PSA99.PRN which is created from a query of OGIRS(See PSA Query). The data is transposed, manipulated, and put data into SASDB.

       Input files: PRJ6007.PSA99.PRN
       Output file: PRJ6007.PMM.HISTORY.DATA.SASDB:PSDATA

2) PRJ6007.PMM.PROCESS.RFFUEL - reads refinery fuel consumption data and outputs to SASDB.

       Input files: PRJ6007.FUELUSED manually updated
                  and PRJ6007.PMM.MISCELL.SASDB:BTU1

       Output file: PRJ6007.PMM.MISCELL.HIST.SASDB:RFFUELCD   in BTU's

3) PRJ6007.PMM.PROCESS.PRCDATA - reads prices and petrochemical prices, transposes for regional headings and puts in SASDB. Data set "test1" must be updated for current year for CD4 and CD8. Adds a 2 cents per gallon (nominal) local gasoline tax. Currently uses a two-digit year. Will be modified to read a 4 digit year when year 2000 becomes a historical year.

       Input files: PRJ6007.PRICES.HIST.SASDB:PBTU9099
                  PRJ6007.ELCG.FLATFILE.DATA(MSPRICE)

       Output file: PRJ6007.PRICES.HIST.SASDB:PRDPRIC

4)   PRJ6007.PMM.PROCESS.WPRCDATA - reads wholesale prices transposes for regional
        headings and puts in SASDB. Data set "test1" must be updated for current year for CD4 and
        CD8. Currently uses a two-digit year. Will be modified to read a 4 digit year when year 2000
        becomes a historical year.

                Input files: PRJ6007.PRICES.HIST.SASDB:PBTU9099

                Output file: PRJ6007.PRICES.HIST.SASDB:WPRDPRIC

5)   PRJ6007.PMM.PROCESS.DEMAND - reads sectoral demand from SEDS, estimates most recent
        2 year's sectoral demand by using current PSA total demand times the sector ratios. Type in PSA
        total product supplied number from Table 3.

                Input files: PRJ6007.HISTORY.SASDB:SEDS

                Output File: PRJ6007.PRODTN.HIST.SASDB:DEMAND

6)   PRJ6007.PMM.PROCESS.MISCELL - includes data for miscellaneous inputs, to be manually
        updated each year. See ETHBLND.XLS for ethanol blending (RFETHMGS).

                Output file: PRJ6007.PMM.MISCELL.SASDB:MISCELL

Creating PMM Flat-file:

1)   PRJ6007.PMM.MAKE3.HIST.FLATFILE - reads SASDBs and STEO estimates and outputs
        them to a flat-file. Must run STEO programs in Appendix H.2 to update STEO benchmarking.

                Input files: PRJ6007.PMM.HISTORY.DATA.SASDB:PSDATA
                                  PRJ6007.MISCELL.HIST.SASDB:RFFUELCD
                                  PRJ6007.PRODTN.HIST.SASDB:CRDOGSM (updated manually later)
                                  PRJ6007.PRODTN.HIST.SASDB:DEMAND
                                  PRJ6007.PRICES.HIST.SASDB:CRDPRIC (updated manually later)
                                  PRJ6007.PMM.HISTORY.DATA.SASDB:COGEN (updated later)
                                  PRJ6007.PRICES.HIST.SASDB:PRDPRIC
                                  PRJ6007.PMM.MISCELL.SASDB:MISCELL
                                  PRJ6007.NEMSSTEO.COMP.BASE
                Output file: PRJ6007.RFHIST6
**   lrecl=120
The crude oil and cogeneration information is usually updated later via cut and paste.

Cogeneration Data Processing:

Historical cogeneration data is derived from the EIA-860B, Annual Nonutility Power Producer Report. The data is obtained from an Access query by Alan Beamon of the Electricity Market Modeling team. The data is provided in the form of an Excell spreadsheet COGENALL.XLS which contains refinery cogeneration capacity, generation, fuel consumption, and sales to grid data as well as planned new capacity by census division. The spreadsheets are converted to .PRN text file COGEN.HISTORY.PRN which is then transported to the EIA mainframe computer and read by the SAS program &PRJ6007.PMM.HIST.COGEN00. The program manipulates the data to get it into the format needed by the LP and outputs to &PRJ6007.PMM.HISTORY.DATA.SASDB:COGEN9098. Note: cogeneration capacity by PADD from the last historical year is multiplied by 24(hours) for input into the PMM file COGENER.DAT.

H.2 Processing Data for STEO Years

The *Short-Term Energy Outlook* (STEO) published by the Energy Information Administration provides quarterly projections 2 years into the future. Since the STEO is EIA's official forecast during this period, the Petroleum Market Model was set up to produce numbers that very closely match the STEO when a switch in the PMM is turned on. The information in this section describes the programs that are used to generate this data for the PMM. The data is then added to the input file that contains the history data described in Section H.1.

The files below are on mainframe account 6007, PRJ, unless otherwise stated. Input data are read from and output data are written to
&PRJ6007.NEMSSTEO.COMP.BASE.SASDB
unless otherwise indicated. Files 1 and 2 only need to be updated once a year when new historical price and supply data are available. The other files can be updated with data from any STEO projection. Note that some files produce output for other files, so the order of execution is important. For example, program 6 inputs data from programs 3 and 5.

1. NEMS.HIST.PRICES.MARGINS

This file creates a data file ARETMARG@ which contains historical product prices, crude prices, and margins.

       Intput files: many   from PRJ6007.NEMS.MARKUP.SASDB

	many	from PRJ6007.NEMS.TAX.SASDB
	many	from PRJ6007.A.SASDB

Output file: RETMARG   to PRJ6007.A.SASDB

2. NEMSSTEO.HISTMARG

This file calculates differentials that are used to estimated regional prices from U.S. average STEO prices. Differentials are also calculated from crude oil prices for those fuels that STEO does not price.

Input file: RETMARG   from PRJ6007.A.SASDB

Output files: RCSPRD88
                 CDSPRD88
                 RFSPRD88

3. NEMSSTEO.HISTFACT

This file calculates factors from petroleum supply data which are used to apportion U.S. data to the PADD level.

Input file: PSDATA   from PRJ6007.PMM.HISTORY.DATA.SASDB

Output file: SUPPFACT

4. NEMSSTEO.PRICE.DATA

STEO prices are typed in to this program and the differentials from file 1 are input, then regional PMM product prices are estimated.

Input files: CDSPRD88   from PRJ6007.NEMSSTEO.COMP.BASE.SASDB
                 RCSPRD88
                 RFSPRD88
                 GDP87CH   from PRJ6007.NEMS.MARKUP.SASDB
Output files: PRICES
                 RRAC87

5. NEMSSTEO.READ.STEODB.OTHINP

This program reads in data from the STEO database and outputs data needed for later processing (monyy = sep00).

Input files:	ALLBBB	from PRJ6489.STIFSIII.monyy.SASDATA
Output files:	CAPUTIL	(STEO capacity and utilization rates)
	OTHIMP	(imports of unfinished oils, ethers, and gasoline blending components)
	OTHINPUT	(other input data)

6. NEMSSTEO.SUPPLY.PUBDATA

In this file, supply data are typed in from the STEO publication.

Input files:	SUPPFACT	from PRJ6007.NEMSSTEO.COMP.BASE.SASDB
	OTHIMP	
	CAPUTIL	
Output files:	USSUP	
	CRUDEINP	
	CRDPROD	
	PADSUP	

7. NEMSSTEO.READ.STEODB.PRODSUP

This program uses data from the STEO database and file 5, and develops product supplied data for the PMM (monyy = sep00).

Input files:	ALLBBB	from PRJ6489.STIFSIII.monyy.SASDATA
	USSUP	from PRJ6007.NEMS.COMP.BASE.SASDB
Output files:	PRODSUP	
	PRODSECT	

8. NEMSSTEO.READ.STEODB.REFPROD

This program uses data from the STEO database and file 2, and develops refinery production numbers (monyy = sep00).

Input files: ALLBBB   from PRJ6489.STIFSIII.monyy.SASDATA
                     SUPPFACT   from PRJ6007.NEMS.SCOMP.BASE.SASDB
Output: REFPROD

9. NEMSSTEO.RFFUEL

This program estimates refinery fuel consumption based on historical values and STEO crude input estimates.

Input: CRUDEINP   from PRJ6007.NEMS.COMP.BASE.SASDB
                     RFFUELCD   from PRJ6007.FUELUSE.HIST.SASDB
Output: FUELUSE

10. NEMSSTEO.WELLPR.D091100

This file estimates regional crude wellhead prices based on wellhead price equations in the PMM provided by the Oil and Gas Supply Team and STEO's world oil price projections.

Input: GDP87CH   from PRJ6007.NEMS.MARKUP.SASDB
                     flatfile   PRJ6007.WELLPR.D091100
                     flatfile   PRJ6007.WELLPROD.D091100
Output: WELLREG
                     CRDPROD

11. NEMSSTEO.INPUT.DSTCAP.DSTADD

This file updates historical and STEO year distillation capacity and additions.

Input: ADDHCAP   from data input cards
                     ADDHADD   from data input cards
                     STEOCAP   from data input cards
                     STEOADD   from data input cards
Output: HCAP   to PRJ6007.PMM.HISTORY.DATA.SASDB
                     HADD
                     ELCGCAP
                     ELCGADD

12. NEMSSTEO.ALLDATA

This program reads in all the relevant data created by the previous programs, drops the last historical year,[1] and writes out the data needed to input into the PMM history file.

Input:	Output:
PADSUP	SPADSUP
REFPRD	SREFPRD
USSUP	SUSSUP
OTHINPUT	SOTHINP
PRODSUP	SPRODSUP
PRODSECT	SPRDSECT
FUELUSE	SFUELUSE
PRICES	SPRICES
WELLREG	SWELLREG
CRDPROD	SCRDPROD

13. PMM.MAKE3.HIST.FLATFILE

This program reads in the output data from **12** above and produces a file containing PMM output data for the history and STEO years.

Output: flatfile   to PRJ6007.RFHIST6

---

[1]The last historical year was included to provide a check that the estimates for the forecast years were reasonable.

H.3 Processing Other Historical Data

In addition to developing an input history file (described in Appendix H-1), the PMM team utilizes other historical data to develop some inputs and to support analysis of the model results. This section describes the updating of these data, which is usually done on an annual basis.

Crude Oil Price Data

EIA-14: Crude oil prices are used to calculate historical margins which are used to analyze the margins estimated in the model. The series used is the refiner acquisition cost (RAC) of imported crude oil which comes from Form EIA-14. The domestic and composite series are also maintained but the imported RAC is the series used in the margin calculations (Contact Elizabeth Scott 202-586-1258). Program needs updating to read a four digit year variable.

The file to update the crude prices each year is:
        PRJ6007.EIA14.READ.FROZEN   where yy represents the year

        Input files: PRJ6105.ANNUAL.FROZEN.Dyymm where yymm represents year and month
                          Use command (SL &6105prj.) Because the files are on the old system.
        Output files: (all located in PRJ6007.A.SASDB)

YMCRyy	monthly prices for year yy	
QTCRyy	quarterly prices for year yy	
YRCRyy	annual prices for year yy	
YMCRUDE	monthly prices from 1974 through year yy	
QTCRUDE	quarterly prices from 1978 through year yy	
YRCRUDE	annual prices from 1978 through year yy	

A new file must be created each year, changing the yy=s of the previous year to the current year.

EIA-856: The EIA-856 survey data were used in the past for analyzing results from the PMM. The EIA-856 collects prices by crude stream for imported crude oil. Differentials between these prices and the world oil price (the refiner acquisition cost of imported oil from the EIA-14) can be calculated and compared with model results. The crude streams can also be segregated by PADD regions and the aggregate crude types found in the PMM. The primary file for reading the EIA-856 data and performing various calculations is

        PRJ6007.EIA856.READ95.PORT   (Missing)

Petroleum Product Price Data

Data on petroleum product prices is obtained from the EIA-782 surveys. The EIA-782A survey contains only refiner data, the EIA-782B survey includes petroleum marketers. Prices are produced monthly and updated for an annual publication. One file reads the monthly data, and a second file is set up to read the numbers from the annual data. The file names are as follows:

PRJ6007.A.IMP99.ADF	reads monthly data for 1999 (used for AEO due to timeliness)
PRJ6007.A.IMP98.ADF	reads final monthly data for 1998

Each year the program from the previous years data should be rerun using the final, RLSE3, data. The program should be modified to read the preliminary,RLSE2, data from the most recent year, run again, and resaved with a new name.

Input files: PRJ6015.E782P.R.DATA.ADF.D1998mm.RLSE3 (for final annual update of the monthly data, where mm represent months)
PRJ6015.E782P.R.DATA.ADF.D1999mm.RLSE2 (for monthly data where mm represents months)

Output files: IMP99A   contains refiner data only
IMP99B   contains refiner and marketer data combined
(these files are found in PRJ6007.A.SASDB.STATE.AByyyy, where yyyy represents two consecutive years (i.e., two years of data are placed in one SASDB, then a new SASDB is created for the next two years, and so on.))

Historical Prices and Margins

Historical wholesale and end-use prices from the EIA-782 are aggregated and presented in tabular form by product type and Census division. The end-use transportation prices include State and Federal taxes but for jet fuel and LPGs the State taxes are not included prior to 1995.

Differentials with the world oil price (the refiner acquisition cost of imported oil from the EIA-14) are also calculated by product type and Census division and presented in tabular form for analyzing similar margin calculations from the PMM. The following program has been written to perform these

calculations and develop the tables. The margins include the 2-cents-per-gallon local tax that is currently being added to gasoline price projections.

> PRJ6007.NEMS.HIST.PRICES.MARGINS

Summary

Once the monthly prices from the EIA-782 are finalized for a particular year, set up and run the program A.IMPyy.ADF for that year (yy is the year).   Set up and run the EIA14.READyy.FROZEN for that year. Then set up and run NEMS.HIST.PRICES.MARGINS to get the price and margin tables. Update with the annual data as it becomes available.

APPENDIX I

Ethanol Supply Model

Appendix I. Ethanol Supply Model

I.1 Model Purpose

The objective of the ethanol supply model is to provide the NEMS Petroleum Market Module (PMM) with supply curves for corn and cellulose based ethanol, thus allowing the PMM to forecast transportation ethanol demand throughout the NEMS forecast period. To be consistent with the market clearing mechanism adopted for NEMS, the model provides ethanol prices in the form of annual price-quantity curves. The curves, derived from an ethanol production cost function, represent the prices of ethanol at which associated quantities of transportation ethanol are expected to be available for production of E85 and ETBE, and for blending with gasoline.

The delivered ethanol prices are provided to the PMM linear program in the form of a unique supply curve for each of the nine U.S. Census Divisions. The majority of ethanol currently produced in the United States is made from corn and is produced in the East North Central Census Division (NEMS region 3), and the West North Central Census Division (NEMS region 4). Smaller amounts are available in the East South Atlantic (NEMS region 6), the Mountain (NEMS region 8), and the Pacific (NEMS region 9) Census Divisions. The PMM also models planned cellulose based ethanol production beginning in 2001 in the Middle Atlantic (NEMS region 2) and West South Atlantic (NEMS region 7) Census Divisions. The majority of growth in cellulose ethanol production, however, is forecasted for Census Divisions 3 and 4, where large quantities of corn stover (the most likely biomass feedstock) are available, and in Census Division 9, where ethanol demand is expected to grow in response to the California ban on MTBE in reformulated gasoline.

I.2 Corn-Based Ethanol

Fundamental Assumptions

The corn-based ethanol model uses a process costing approach to model the impacts of net feedstock production costs plus the capital, operating, and process energy costs associated with converting the corn feedstocks to ethanol. In other words, each of the above factors contributes a part of the total price of ethanol.

To determine the delivered ethanol price, the contribution of the net cost of corn feedstock production must be factored in to the total unit price of ethanol. Net cost of corn feedstock is the price of corn less the price of the co-products produced in the conversion of corn to ethanol. Conversion of corn to ethanol is accomplished by either a wet milling or dry milling process. The co-products produced from the wet milling process are corn gluten feed (CGF), corn gluten meal (CGM), and corn oil, while the dry milling process produces distillers dried grains (DDGS). Prices for corn and corn co-products are obtained from the USDA Agricultural Baseline Projections to 2009. Wet milling accounts for about 60 percent of current total ethanol

production, while new ethanol facilities are projected to be dry milling plants.[1] Therefore, the first two steps of the corn ethanol supply curves (representing current production) use a net feedstock price calculated assuming 60 percent of co-products are CGM, CGF, and corn oil, and 40 percent are DDGS. The last two steps, representing new capacity, assume co-products are 100 percent DDGS. The variability of the market price for the feedstock corn and the conversion by-products and the variable influences of competitive uses for corn (e.g., for producing corn syrup) gives rise to broad fluctuations in net corn feedstock prices. All of these factors are considered in the USDA model. In addition, the USDA model was run assuming large increases in ethanol production (3 to 4 billion gallons versus current production of 1.4 billion gallons) to capture feedstock price fluctuations with increased ethanol demand. As ethanol production from corn increases, land becomes scarcer, causing both land and feedstock costs to increase, and feed by-products become less valuable as larger feedstock quantities are produced. These runs were used to develop the last two steps of the corn ethanol supply curves. The USDA price projections end in 2010, therefore prices for 2011-2020 were extrapolated from 2009.

In addition to feedstock prices and quantities, the model requires capital cost, feedstock conversion cost (non-energy operating cost), and energy cost data. The cost data were derived from several sources which are documented in the Inventory of Variables, Data, and Parameters section of this report. Note that with this theoretical approach, only the agricultural, or feedstock production costs are modeled as a function of the total quantity of ethanol produced. The conversion plant process costs, (capital, operating, and process energy) are independent of production quantities. The feedstock production cost components are estimated statistically, whereas the conversion process costs are determined from engineering concepts and data. Actual ethanol conversion process data are, for the most part, proprietary.

Capital and conversion costs were assumed to be constant across all Census Divisions and for all forecast years. Energy costs vary across Census Divisions as a function of fuel price. The model assumes wet milling plants consume 20 percent natural gas and 80 percent coal, while dry milling plants consume 50 percent natural gas and 50 percent coal[2]. Natural gas prices are obtained from the NEMS Natural Gas Transmission and Distribution model, and coal prices are from the NEMS Coal Market Model. It was also assumed that the quantity of energy needed for ethanol conversion decreases through the forecast period as ethanol plants become more efficient over time. The supply/price curves in Census Division 3 and 4 also include a $0.10 per gallon credit on steps one and two. This credit is a weighted average of producer incentives and State tax credits offered by various states within these Census Divisions. The ethanol blender's Federal excise tax credit, which is currently $0.054 per gallon of gasohol (10 percent ethanol, 90 percent gasoline), is modeled separately in the PMM.

Key Computations and Equations

---

[1]Urbanchuk, J.M. 1998. "Review of Alternative Ethanol Supply Curves Used in the Energy Information Administration's National Energy Modeling System".
[2]Wang, M. et al 1997. "Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Fuel Ethanol Produced from U.S. Midwest Corn".

Net feedstock costs are calculated in a separate spreadsheet by subtracting USDA projected co-product prices from the price of corn. These costs are tabulated as a function of ethanol production quantity in the PMM input file WETOHIN. This file also contains the capital cost, conversion cost (non-energy operating cost), and energy cost data. Linear interpolations are performed to calculate intermediate yearly values for the quantity of energy consumed at the ethanol plant, and the net feedstock price for each ethanol quantity step. Once the data is read and the interpolations are performed, the ethanol price is calculated from the following equation:

$$PETOH_{cd,t,e} = FC_{t,e} + CAPCST*CCF + OPCST$$
$$+ QEN_t*PEN_{cd,t} - STSUB_{cd} \qquad \text{(I-1)}$$

where:

$PETOH_{cd,t,e}$ = Delivered price of ethanol produced in Census Division cd in year t for volume step e ($/gal),

$FC_{t,e}$ = Feedstock corn production cost in year t for volume step e ($/gal),

$CAPCST$ = Capital cost for conversion technology ($/gal),

CCF = Capital cost factor (dimensionless),

$OPCST$ = Operating costs, exclusive of energy ($/gal),

QEN_t = Quantity of energy needed to convert corn to ethanol in year t (MMBtu/gal),

$PEN_{cd,t}$ = Price of energy used in the corn-to-ethanol conversion process in Census Division cd in year t ($/MMBtu),

$STSUB_{cd}$ = State incentive for ethanol production in Census Division cd ($/gal).

The price of energy on the first two steps of the supply curve (current production) is calculated assuming 60 percent of the existing plants are wet mills (consuming 20 percent natural gas and 80 percent coal), and 40 percent are dry mills (consuming 50 percent natural gas and 50 percent coal). The price of energy for the last two steps of the supply curve is calculated assuming all new facilities will be dry mill, consuming 50 percent natural gas and 50 percent coal. The price of energy in each case is calculated as follows:

Steps 1 and 2:

$$PEN_{cd,t} = (0.32*PNGIN_{cd,t}) + (0.68*PCLIN_{cd,t}) \qquad \textbf{(I-2)}$$

Steps 3 and 4:

$$PEN_{cd,t} = (0.50*PNGIN_{cd,t}) + (0.50*PCLIN_{cd,t}) \qquad \textbf{(I-3)}$$

where:

$PNGIN_{cd,t}$ =   Industrial price of natural gas for Census Division cd in year t ($/MMBtu),

$PCLIN_{cd,t}$ =   Industrial price of coal for Census Division cd in year t ($/MMBtu).

The capital cost factor (CCF) used in equation I-1, which is based on a 8-year amortization period, is calculated as follows:

$$CFF = MC\_RMPUAANS_t * (1 + MC\_RMPUAANS_t)^8 / ((1 + MC\_RMPUAANS_t)^8 - 1) \qquad \textbf{(I-4)}$$

where:

$MC\_RMPUAANS_t$ =   yield on AA-grade utility bonds in year t (a Macroeconomic Activity Module output variable).

Inventory of Variables, Data, and Parameters

MODEL INPUT: *CAPCST*

DEFINITION: Capital cost for conversion technology for crop *I* in year *t*.

The current value is $1.00 per gallon on steps one and two, and $2.00 per gallon on steps three and four of the supply curves. Costs are the same for all years. Located in the WETOHIN input data file.

SOURCE: Walsh, M. et al 1997. *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price*. Oak Ridge National Laboratory, Oak Ridge, TN.

MODEL INPUT: *OPCST*

DEFINITION: Operating costs, exclusive of energy, for conversion technology of corn.

Value is $0.27/gal. for 2000 thru 2020. Located in the WETOHIN input data file.

SOURCE: USDA/ERS. 1988. *Ethanol: Economic and Policy Tradeoffs*. Agricultural Economic Report No. 585. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

MODEL INPUT: *PCLIN*

DEFINITION: Price of coal for industrial use in Census Division *cd* in year *t*.

Located in the Price common block, (MPBLK).

SOURCE: Generated by the Coal Market Model.

MODEL INPUT: *PNGIN*

DEFINITION: Price of natural gas for industrial use in Census Division *cd* in year *t*.

Located in the Price common block, (MPBLK).

SOURCE: Generated by the Natural Gas Transmission and Distribution Model.

MODEL INPUT: *QEN*

DEFINITION: Quantity of energy needed to convert corn to ethanol in year t.

Values, in million Btu per gallon, are as follows: 0.050 in 1990, 0.041 in 2000, 0.037 in 2005, 0.035 in 2020. This decreasing trend is based on the assumption that energy required decreases linearly over time. Located in the WETOHIN input data file.

SOURCE: Marland, G. and A.F. Turhollow. 1991. "CO_2 Emissions From the Production and Combustion of Fuel Ethanol from Corn." *Energy*, 16(11/12):1307-1316.

I.3 Cellulose-Based Ethanol

Theoretical Approach

The cellulose ethanol model also uses a process costing approach to model the impacts of net feedstock production costs plus the capital, operating, and process energy costs associated with converting the corn feedstocks to ethanol. As with the corn model, each of the above factors contributes a part of the total price of ethanol.

Biomass feedstock supply is not modeled in the Petroleum Market Model ethanol model. Biomass price/quantity data are obtained from the Renewable Fuels Model of NEMS and are used as input to the ethanol model. The "Model Documentation: Renewable Fuels Module of the National Energy Modeling System", DOE/EIA-M069(2000) contains a complete description of the approach and assumptions used in generating the biomass feedstock supply functions.

Briefly, the biomass use in NEMS is modeled as two distinct markets, the captive and non-captive biomass markets. The captive market pertains to users with dedicated biomass supplies that obtain energy by burning biomass byproducts resulting from the manufacturing process. The noncaptive market is defined to include the commercial, transportation, and electric utility sectors, as well as the resources marketed in the industrial sector. There is an additional noncaptive market serving residential uses of biomass.

EIA developed a fairly simple model structure consisting of one supply schedule per region. This schedule defines the quantity and cost relationships of biomass resources accessible by all noncaptive, non-residential consumers. It is based on an aggregation of supply/price information from U.S. Forest Service and forest product experts. The wood portion of the cost-supply schedule is static throughout the model period. Energy crop cost-supply schedules are also developed and superimposed onto the wood total.

Fundamental Assumptions

A basic assumption for the biomass feedstock is that the supply price for noncaptive biomass energy is the same across all sectors. Biomass feedstock costs are input from the NEMS Renewable Fuels Model at the Census Division level. Biomass usage by the PMM ethanol model is fed back to the Renewable Fuels Model.

An important modeling consideration for cellulose ethanol production is the imposition of a constraint on the amount of ethanol production capacity assumed for the early years of the forecast. Ethanol from cellulose is relatively new technology and ethanol production from cellulose is currently at the

demonstration level. A constraint on cellulose ethanol production prevents unrealistically large increases in production capacity from occurring suddenly in response to favorable market prices. Cellulose ethanol production capacity is allowed to grow 5 percent per year from 2001 to 2005, 10 percent per year from 2006 to 2010, and 15 percent per year after 2010.

In addition to feedstock prices and quantities input from the Renewable Fuels Model, the ethanol model requires feedstock conversion and energy cost data, and capital and operating cost data. The conversion and capital cost data were derived from the Oak Ridge National Laboratory Report *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price,* Marie Walsh et.al., June, 1997 for year 2000 as follows:

Capital Cost	0.515 $/gal
Operating Cost	0.348 $/gal
Power Credit	-0.157 $/gal
Total Conversion Cost	0.706 $/gal

The AEO 2000 reference case assumes that cellulose conversion technology will improve over time such that full utilization of hemicellulose sugars, combined with modest reductions in cellulase enzyme costs will yield a savings of 27 cents per gallon over year 2000 cost by 2015[3]. The conversion costs are reduced linearly from 2000 to 2015 to a maximum of 27 cents per gallon. Conversion costs are constant from 2015 to 2020. Ethanol production costs are assumed to be constant across the United States, however, feedstock availability and price varies from Census division to Census division. The largest growth in ethanol production is expected in Census regions 3 and 4 where Midwestern corn stover would be desirable raw material because of its large volume, competitive price and proximity to current ethanol production plants. The feedstock available in Census region 9 are forest residue and rice straw. Feedstock conversion efficiency also improves over the forecast, from 85 gallons per ton in year 2000 to 103 gallons per ton by 2015. Currently, most state producer and tax incentives (limited by production volume) are at their maximum. Therefore, no State subsidies are assumed in the cellulose ethanol supply/price curves. As with corn-based ethanol, the ethanol blender's Federal excise tax credit, which is currently $0.054 per gallon of gasohol (10 percent ethanol, 90 percent gasoline), is modeled in the PMM.

Key Computations and Equations

The main computations performed by the cellulose portion of the ethanol model involve the derivation of an ethanol supply-price curve for each Census division. The computations consist of three major steps:

1. Reading in ethanol component cost data from the PMM input file WETOHIN.

---

[3]National Renewable Energy Laboratory 1999. *Bioethanol Multi-Year Technical Plan*.

2. Obtaining biomass feedstock prices at the census division level from the Renewable Fuels Model.

3. Derivation of delivered ethanol prices, calculated as a function of the biomass feedstock price and the ethanol conversion costs.

Total Conversion Costs are calculated as follows:

$$TOTCONV_t = CAPCST_t + OPCST_t + PWRCDT_t \qquad \text{(I-5)}$$

where:

$TOTCONV_t$ =   Total ethanol conversion cost for year t,

$CAPCST_t$ =   Capital cost for year t,

$OPCST_t$ =   Operating cost for year t,

$PWRCDT_t$ =   Power credit for co-products combusted and sold as power for year t.

The delivered ethanol price equation is as follows:

$$PETOH_{cd,t} = FC_{cd,t} + TOTCONV_t \qquad \text{(I-6)}$$

where:

$PETOH_{cd,y}$ =   Delivered price of cellulose ethanol in census division cd in year t

$FC_{cd,y}$ =   Biomass feedstock cost for census division cd in year t.

Inventory of Variables, Data, and Parameters

MODEL INPUT: *CAPCST*

DEFINITION: Capital cost for conversion technology for cellulose ethanol.

The current value is $0.398 per gallon for year 2000. Located in the WETOHIN input data file.

SOURCE: Marie Walsh et. al., *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price*. Oak Ridge National Laboratory, June 1997.

MODEL INPUT: *OPCST*

DEFINITION: Operating cost for conversion technology for cellulose ethanol.

The current value is $0.269 per gallon for year 2000. Located in the WETOHIN input data file.

SOURCE: Marie Walsh et. al., *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price*. Oak Ridge National Laboratory, June 1997.

MODEL INPUT: *PWRCDT*

DEFINITION: Power credit for co-products combusted and sold as power.

The current value is $-0.09 per gallon for year 2000. Located in the WETOHIN input data file.

SOURCE: Marie Walsh et. al., *Evolution of the Fuel Ethanol Industry: Feedstock Availability and Price*. Oak Ridge National Laboratory, June 1997.

MODEL INPUT: *FC*

DEFINITION: Biomass feedstock cost for census division *cd* in year *y*.

Biomass feedstock costs are input from the Renewable Fuels Model under the variable PBMET.

SOURCE: National Energy Modeling System common block WRENEW.