EIA MODEL DOCUMENTATION:

WORLD OIL REFINING LOGISTICS DEMAND MODEL

"WORLD"
Reference Manual

March 14, 1994

Version 1.1

Demand Forecasting Division

Office of Integrated Analysis and Forecasting

Energy Information Administration

1000 Independence Avenue, S.W., Washington, DC 20585

A review of "WORLD" features, capabilities, and applications for the analyst and management.

A reference for use by technical analysts and support personnel.

Prepared by:

Science Applications International Corporation
8301 Greensboro Drive
McLean, Virginia 22102

EIA Technical Monitor
G. Daniel Butler
Task 93-088, Subtask 1

The initial version of this manual was originally prepared by EnSys Energy & Systems, Inc. of Flemington, N.J. under Contract No. DE-AC01-87FE61299

ACRONYMS AND ABBREVIATIONS

AEO	EIA Annual Energy Outlook
API	American Petroleum Institute
BAU	Business As Usual
BTU	British Thermal Unit
BTX	Benzene, Toluene, and Xylene Aromatics
BPD	Barrels Per Calendar Day
BPSD	Barrels Per Stream Day
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, C5 is Pentane etc.
DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
IEA	International Energy Agency
IEO	EIA International Energy Outlook
LPG	Liquified Petroleum Gas
MBD	Thousand Barrels Per Calendar Day
MMBPD	Million Barrels Per Calendar Day
MTBE	Methyl Tertiary Butyl Ether
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
RFG	Reformulated Gasoline
RYM	Refinery Yield Model (EIA)
SCF	Standard Cubic Feet
OB1	Optimization with Barriers 1
OSL	Optimization Subroutine Library
TAP	Toxic Air Pollutant
VOC	Volatile Organic Compound
WORLD	World Oil Refining Logistics Demand (model)

TABLE OF CONTENTS

1. INTRODUCTION - STRUCTURE AND USE OF THE MANUAL

This manual is intended primarily for use as a reference by analysts applying the **WORLD** model to regional studies. It also provides overview information on **WORLD** features of potential interest to managers and analysts.

Broadly, the manual covers **WORLD** model features in progressively increasing detail.

SECTION 2 provides an overview of the **WORLD** model, how it has evolved, what its design goals are, what it produces, and where it can be taken with further enhancements.

SECTION 3 reviews model management covering data sources, managing over-optimization, calibration and seasonality, check-points for case construction and common errors.

SECTION 4 describes in detail the **WORLD** system, including:

- data and program systems in overview
- details of mainframe and PC program control and files
- model generation, size management, debugging and error analysis
- use with different optimizers
- reporting and results analysis.

SECTION 5 provides a detailed description of every **WORLD** model data table, covering model controls, case and technology data.

SECTION 6 goes into the details of **WORLD** matrix structure. It provides an overview, describes how regional definitions are controlled and defines the naming conventions for all model rows, columns, right-hand sides, and bounds. It also includes a discussion of the formulation of product blending and specifications in **WORLD**.

Several *Appendices* supplement the main sections. *APPENDIX A* lists the current regional and sub-regional organization of the model. *APPENDICES B, C, and D* provide details of **WORLD** process and blending technology and products. *APPENDIX E* lists all **WORLD** tables and associated files. *APPENDICES F and G* list all **WORLD** model codes respectively by category and alphabetically. *APPENDIX H* gives a complete listing of the JCL stream for running the model on the mainframe. *APPENDIX I* provides a description of the changes made to the data tables since September 21, 1992 when the **WORLD** model data was first delivered to EIA. *APPENDIX J* describes the model in conventional mathematical notation. *APPENDIX K* displays the model in a block diagram format.

Separate documentation exists for the specific features of the U.S. *Detailed Refinery Model (DRM)* and for the EPA gasoline emission equations.

2. OVERVIEW OF WORLD FEATURES AND APPLICATIONS

2.1 BACKGROUND TO MODEL EVOLUTION

Assessment of issues surrounding the future of U.S. and global refining can only be taken so far by static or simplified analyses. The world petroleum industry is technically complex, has the economic attributes of a co-product industry, its different aspects and regions are highly inter-related. It contains considerable ability to adjust to changed circumstances. Finally, it is faced today by major challenges presented by environmental and product quality initiatives.

The **WORLD** model was designed to bring all of the key elements of the world petroleum industry together into one simulation tool, with the specific goal that it realistically address "what if?" issues that are departures from present day "Business As Usual".

The components of the **WORLD** model have been developed over many years and applied to studies such as:

Haddar, G. R. and R. M. Davis, *"Navy Fuel Production in the Year 2000"*, O.R.N.L. No. 6684, September, 1991.

EnSys Energy & Systems, *"Year 2000 BAU Outlook for Global and U.S. Refining Sensitivities and Implications for the SPR Crude Mix"*, D.O.E. Office of Strategic Petroleum Reserves, November, 1991.

EnSys Energy & Systems, *" Prospects for U.S. Refining Under Global and Environmental Impacts - Implications for Security"*, D.O.E. Office of Energy Emergencies Plans and Integration, October, 1993.

WORLD Model Features

model

- multi-regional linear programming model using advanced software

crude oils

- representation of over 120 world crude oils

refining technology

- a detailed and tested representation of fifty refinery processes
- advanced technologies for *reformulated fuels* and military fuels

product formulation and demand

- detailed breakout of major, minor and military petroleum products and demands
- up to 30 discrete products can be simulated
- detailed representation of product blending and quality specifications

transportation

- comprehensive inter-regional transportation of crudes, products and intermediates

regional disaggregation

- representation of the world's major regions with flexibility to redefine regions to meet specific needs
- flexibility to create refining sub-regions, e.g. to distinguish different classes of refiner

industry structure

- capability to study changes in world industry structure using regional refinery process investment feature

data and case flexibility

- advanced supporting databases on supply, refining, transportation, product specifications and demand enable many disruption, government initiative, technology and other questions to be assessed

system performance and flexibility

- ability to run quick, low-budget studies or to increase regional detail by utilizing model feature to reduce refining detail under user control

2.2 DESIGN GOALS

The **WORLD** system was developed to meet five design goals:

1. ***integration*** *of industry elements*

2. ***realism*** *under a wide range of "business-as-usual" and non-BAU scenarios*

3. ***scope*** *to address forward issues, horizons, and technical challenges*

4. ***flexibility*** *to address different needs and applications*

5. ***performance and portability*** *across different computers*

To achieve these goals, the **WORLD** system has been built around the following key elements:

- model generation and report writing code written in Haverly Systems' OMNI language and designed to maximize the user's flexibility to make major as well as minor model alternations through changes to data tables only - not to code; also to dynamically contain model size to those elements specified by the user

- input premise tables that allow extensive case and model re-definition without recourse to code changes

- scaling of internal coefficients to minimize solution time

- capability to manipulate regional and refinery definitions (in conjunction with the supporting spreadsheet databases)

- refining technology, product blending and specifications databases that represent fully the technologies and qualities surrounding reformulated as well as conventional fuels

- supporting spreadsheet sub-systems used to manage detailed data for crude and non-crude inputs, refining, transportation and demand and to generate input data tables for direct use by OMNI

- advanced process unit investment capability allowing for cost variations for refinery scale and between regions

- facility to disaggregate regions by user-defined refinery category

- a variety of OMNI reports covering world
  - regional supply/demand balance including refinery gain and losses
  - refining operations and investment
  - crude movements
  - intermediates movements
  - regional product production/import/export/demand balances
  - regional prices and costs

- user-controlled "delta" reporting to compare base and variant cases

- interfaces to and operation with leading optimizers including MPSIII, MPSX, OSL, OB1.

- code that is portable across IBM mainframes, IBM RISC 6000 workstations and 486 PC's.

2.3 WORLD REGIONAL FORMULATION

The regional formulation of **WORLD** is data driven, that is regional make-up can be modified solely by altering data tables without alteration of OMNI code. The one exception to this rule is in cases where the number of regions is increased beyond approximately 12, in which case some report writer layout modifications may be necessary.

"WORLD" REGIONS
(BASE GLOBAL FORMULATION USED 1990-1993)

1. PADD I
2. PADD's II, III, IV, Canada East and Interior
3. PADD V, Canada West
4. Caribbean Extended
5. Northern Europe
6. Southern Europe
7. North Africa, Eastern Mediterranean
8. Persian Gulf
9. Pacific High-Growth Countries, including Japan
10. Rest of South America/Africa/Asia
11. Eastern bloc Countries (net imports/exports only)

Because of the building block approach to regions, and **WORLD** system features, regional formulation can be readily modified.

In the **WORLD** model, crude supply regions, non-crude supply regions, refining regions, and product demand regions are decoupled, i.e. they may be defined as coincident or as separate from each other. In the **WORLD** variant U.S.-only EIA *Detailed Refinery Model*, the model is formulated with crude supply by EIA Supply Region, refining by PADD and product demand by Census District. In the current global formulation, regions have, however, been set up as coincident.

Crude supply region for each produced crude is selected in ***Table CRDDISP***. Crude, non-crude, refining and product regions are all defined in ***Table REF***. See discussion of these tables for further details. ***Table REF*** also associates each refinery region with a non-crude supply region.

The current **WORLD** regions are aggregates of some 18 sub-regions. These in turn are aggregations of individual countries or, in some cases (U.S.A., Canada, France) of sub-country regions. Base **WORLD** data are thus held at three levels: country/sub-country, sub-region, region. Regional reformulation which differently aggregates or disaggregates the existing sub-regions is relatively straightforward, e.g. to break out Japan as a separate region. Reformulation at the country level, e.g. to show Saudi-Arabia as a discrete region, can also be achieved through data table changes.

APPENDIX A details the current **WORLD** make-up of regions and countries.

2.4 MODEL INPUTS AND OUTPUTS

WORLD INPUTS (Case Assumptions)

The **WORLD** model is a linear programming model which simulates the operation of the world-wide petroleum industry based on user-specified assumptions regarding the time horizon and scenario of interest. For a complete **WORLD** case, the following are the main input assumptions to be specified and input by the user:

Feedstocks

- crude supply by nation by crude type including SPR crudes in SPR draw cases
- FOB price of the balancing marker crude whose input is allowed to float (generally Saudi Light)
- fixed quantities of non-crude inputs to the refining supply system, notably NGL's, grain ethanol, synthetic petroleum fuels[1], returns from the petrochemicals sector such as steam cracker gasoline
- base available capacity for production of "merchant" MTBE
- a variable range of quantities with regional prices for methanol[2], natural gas, purchased electricity
- amounts of crude-based streams, notably resid, allowed to refinery fuel[3]
- "CPE" (Centrally Planned Economies) net product supply or demand

Products

---

[1] Synthetic petroleum fuels include gasoline and other products derived from coal and gas, for instance in South Africa and New Zealand.

[2] The price of methanol in ***"WORLD"*** is a function of the region and the regional price for natural gas.

[3] Operating with no constraints on the composition of the refinery fuel pool allows an unrealistically large flexibility for disposition of residual fuel. Consequently, residual fuel and other crude-based inputs are set based on historical data and likely trends with total fuel consumption balancing on process gas plus purchased natural gas.

- demands for some 28 petroleum products by region, essentially all fixed except for elemental sulfur and fuel grade coke which are priced and treated as by-products

- key qualities of all major products[4]

Refining

- base "nameplate" capacities of some 50 process units covering primary processing (distillation), secondary processing, yield and quality upgrading, ancillary units (hydrogen production, sulfur recovery, utilities generation) representing established technologies, and new technologies centered mainly on reformulated fuels production

- for each unit in each region, standard stream day service factor and estimated effective availability factor reflecting, e.g. refinery practice of double training key units such as sulfur recovery or poorer operating practices in third world regions

- for each regional refinery, controls on operations of major units, e.g. severity, feed composition

- for cases with refinery investment open:

    - factors to represent capital cost/location factor, and capital recovery factor (cost of capital)[5] in each region

    - any limits on capacity additions, e.g. no net increase in PADD 1 distillation capacity

---

4 ***"WORLD"*** incorporates both base grades of each product with standard qualities and the capability to input and track quality differences between world regions. Quality variation is tracked firstly by establishing regional splits between different base grades of the major products, e.g. gasoline (4 conventional and 1 reformulated grade), middle distillates (3 grades), residual fuels (4 grades). Gasolines are differentiated principally on octane (lead-free basis), distillates and residual fuels on sulfur and viscosity/pour point. Further regional differences within major grades can then be entered; the impacts of these differences on blend pool qualities are tracked and accounted for in the model.

5 Capital recovery factor may be directly input or calculated from the cost of capital, tax region, economic life, and depreciation schedule.

Transportation

- allowed dispositions (destinations) for each crude and each product; this in part to control the number of transportation options by eliminating extremely unlikely or essentially duplicate routings and in part to prevent movements that are not allowed for political reasons, e.g. no Alaskan North Slope (ANS) crude oil exports, no Libyan imports to U.S., embargo on Arab crudes to U.S.

- transportation cost for each crude, product, and shipped inter-refinery intermediate stream

- capacity limits on pipelines and any other physical (or political) transportation mode/group limits being represented when transportation with capacity limits is activated,

General

- limitations on individual activities to improve realism of results, e.g. requiring certain minimum volumes of Fluid Cat Cracker (FCC) feedstocks to move into the U.S. to reflect the existence of several refineries for whom this is their primary feedstock, a "micro" factor that in the aggregated model can be subsumed.

These case assumptions define the present-day or future scenario to be simulated. Development of future horizon cases in particular requires careful consideration of the uncertainties underlying projections and thus how the parameters that influence the industry could evolve. For instance, the following are among key basic factors influencing any current forward-looking study:

- ex-Soviet Union petroleum supply/demand import/export balance

- balance of future OPEC versus non-OPEC production

- variability in specific country crude production and mix

- evolution of regional capital cost location factors for process unit investments depending on the effects of environmental legislation

- extent of new gas distribution projects and their influence on regional demands for residual fuel oil and heating oil

- evolution of gasoline, distillates and residual fuel oil quality by region, especially drives to clean and reformulated fuels

- likelihood of substitution of petroleum products by alternative fuels

- forecast transportation routes, modes, capacities and costs

- availability of new refining technologies and their costs

While certain of these parameters will often have been set by the world supply/demand forecast used for a particular study, numerous parameters ranging from details of non-OPEC regional growth rates for individual products to specific refining assumptions have to be derived from ancillary sources and/or by analyst judgement.
Given the above inputs, the **WORLD** model simulates the operations, technology, and economics of the world refining industry, using all the available options - crude shipping, processing, investment (when allowed), blending, intermediates and product shipping - to satisfy the specific product demands feasibly and optimally (i.e. at minimum global cost); this while respecting all the constraints on the system, notably shipping limits, capacity and operational limits, product blending specifications, regional product demands.

WORLD OUTPUTS

The outputs from a simulation can be categorized into three groups:

1. Physical Information

- crude, non-crudes, products and intermediates movements, including capacity utilizations when capacitated transportation activated

- refinery generation and purchase of utilities and variable non-crude feedst-ocks (methanol, natural gas)

- process unit capacity additions in every refinery (when allowed)

- process unit operations, regional refining and merchant plant throughputs and utilizations
- blending activities and compositions, including gasoline emissions based on EPA equations
- product demands (sales), generally fixed

2. Refining and Market Economic Information

- marginal costs on every crude where there is an active movement into the region. These equate to FOB prices at port of origin and to CIF prices at port of delivery.
- finished product marginal costs (open market prices) in every region[6]
- values of intermediate streams in every refinery
- economic rents (expansion incentives) on process units at their capacity limit (either where investment is not activated or where allowed active investment is limited and at its maximum)
- costs (relaxation incentives) on limiting product specifications
- costs (relaxation incentives) on other imposed constraints, e.g. process unit operations, specific movements
- costs of investments in new capacity (when allowed)
- economic rents (expansion incentives) on capacitated transportation modes at their capacity limit

---

[6] Note that the only prices input are generally those for (a) the marginal crude, (b) variable non-crudes (gas and methanol), (c) minor refined products (sulfur and fuel grade coke). All other crude, non-crude product prices are derived as outputs. These output prices are affected principally by (a) the level of the input marker crude price and (b) the slackness or tightness in refinery upgrading capacity relative to light versus heavy product demand.

3. Regional and Global Economic Information

The specific cost and activity data available from a **WORLD** solution can be used to build up a picture of the revenues, rents, and costs associated with

- crude producers
- non-crude producers
- refiners
- shippers

by region, building up to the consumers' cost by region and globally. The net import bill can also be reported (currently for U.S. regions only).

Comparing these outputs across cases, it is possible to identify the "macro" economic effects on producers, refiners, consumers, and regions of changes in the world petroleum supply situation - whether changes in BAU assumptions, the effects of a disruption, or the effects of different emergency responses to a disruption.

Overall, the **WORLD** model:

- realistically simulates the refining operations and economics of the world's regions
  (this because it contains detailed refining matrices)

- ensures a feasible solution to meeting world regional oil demands identifying material balance flows across regions and globally
  (this provided input assumptions allow a feasible solution)

- reflects and simulates the effects of the economic cost/profit forces driving industry activities
  (this since the majority of crude and product trading today is related to open market prices, and also because virtually all members of the petroleum industry employ LP models to plan their refinery and logistical operations. The central assumption of the ***WORLD*** *model is that the industry operates*

*to maximize profits. The **WORLD** model simulates this by meeting a fixed set of demands at the minimum cost.)*[7]

- provides an integrated simulation which generates internally consistent physical flows, refining market, regional economics and interactions.

The **WORLD** model simulates regional effects. Insights at the level of individual countries or refinery types can be obtained but only where the model has been appropriately disaggregated.

[7] *For further information on the use of LP in the petroleum refining industry, see Bodington, C.E. and Baker, T. E. 1990, "A History of Mathematical Programming in the Petroleum Industry", Interfaces 20:4 (July-August), pp.117-127.*

2.5 ANALYTICAL SCOPE AND POTENTIAL ENHANCEMENTS

Since its inception in 1988/89, the **WORLD** model has undergone progressive enhancement. The model itself, and its single refinery sub-set, have been applied in studies relating to:

- future SPR crude mix
- future jet fuel production capability
- refiner flexibility under supply disruption
- long-range competitive costs of refining and gasoline production
- reformulated gasoline impacts on prototypical U.S. refineries
- analysis of "real time" and "what if?" scenarios, market developments, SPR drawdown and jet fuel supply during the Middle East crisis.

Recent applications and developments have centered on:

- using the model with full investment and reformulated fuels capabilities operative to evaluate future U.S. energy security against alternative outlooks for Year 2000 BAU
- applying **WORLD** in similar fashion to the Year 2000 to assess alternative SPR crude mixes against different BAU/crude import outlooks
- bringing the reformulated gasoline technology representation up to the latest state-of-the-art, based on extensive literature survey.

Incorporating latest technology data, and effective linearized versions of the EPA gasoline emission models, provides the basis for gauging the impacts of the next round of environmental developments regarding reformulated gasoline, conventional gasoline and diesel.

Because **WORLD** incorporates many cost, technology, demand, and logistics components, it can today be applied to an extremely wide range of analyses and is particularly well-suited to assessment of the effects of environmental and strategic/policy initiatives, for instance:

- impacts of environmental legislation affecting refined product markets (reformulated fuels) and - potentially - direct refinery emissions
- supply and market impacts of short-term developments and present or future disruptions, including effects of alternative IEA/SPR strategies
- changes in crude supply, product demand pattern, product quality, shipping modes and costs on the refining and trade patterns of the world oil industry in the short, medium, and long term
- impacts of policy/strategic initiatives to expand U.S. crude production, implement conservation measures, and/or substitute alternative fuels
- effects of regional differences and changes in unit capital and fixed operating costs, capital recovery rate or gas costs. Such changes could, for instance, stem from new environmental emissions regulations.
- effect of (changes in) import/export constraints and tariffs, e.g. relaxing constraints on export of Alaskan crude or raising tariffs on product imports to the U.S. or other world regions
- effects of structural changes in U.S. or world regional oil product patterns, e.g. through implementation of major gas transmission and distribution projects

WORLD is a modelling system - not a single model. Using it, different model variants can be developed, e.g. of a given world region (for instance, the U.S.A. or Northern Europe) or of given refinery classes (for example, small U.S. refineries).

Potential future directions for model developments include:

- direct simulation of the effects of EPA-type "model" equations for the control of reformulated gasoline quality and emissions. (This feature has been implemented for the EPA Simple Model, based on proprietary EnSys methodology and can be implemented for the EPA Complex Model once this is finalized.)

- implementation of rigorous refinery emissions and loss, simulation, control technologies and costs

- extension to rigorously track the processing, costs, and solid waste disposal aspects of traditional light, low contaminants crude oils versus increasingly available heavy, high contaminants[8] crudes

- extension into the gas sector for:

  - production of methanol as an alternative fuel
  - direct use of compressed natural gas as an alternative fuel
  - production of synthetic gasoline and distillate[9]

  thereby capturing the potential long-term interactions between gas and petroleum in the area of transport fuels and enabling policy impacts to be simulated and quantified.

- extension into the petro-chemicals sector to directly capture interaction between gas/NGL's, petro-chemicals and refining.

- extension to incorporate explicitly all world regions, namely the ex-"Soviet bloc" regions plus China

- extension to analyses of overseas regions of concern.

---

[8] Key properties or contaminants here include metals, nitrogen, sulfur, and potential free carbon (pitch or coke) based on low hydrogen-to-carbon ratio in the crude.

[9] Several catalytic processes now exist and intensive research is being undertaken. Commercial plants exist, but generally in remote locations where opportunity cost of gas is low. Dropping costs could, in the future, make gas-delivered fuels competitive with petroleum products.

3 MODEL DATA AND CASE MANAGEMENT

3.1 DATA SOURCES

A complete **WORLD** model case is drawn from numerous data sources, and the activity of **WORLD** modelling analysis requires an on-going commitment on the part of each user to the gathering of formal statistics and projections, ad hoc data and perspectives on actual and potential developments impacting the petroleum industry in all world regions; also on-going review and update of refinery technology data. Due to the level of detail at which the **WORLD** model operates, most published statistics require amplification (further disaggregation) in order to generate **WORLD** model case data tables. For example, gasoline is often reported as "motor gasoline" which then must be split into several grades according to octane number and other qualities. Set out below is a brief commentary on sources and methods of disaggregation for the main categories of **WORLD** model data.

3.1.1 Process Technology and Cost Data

Relatively static compared to case data, refining technology and cost data nevertheless need periodic review and update. This is especially true today since environmental legislation, lighter product slates and heavier crude slates have spurred new process technology developments affecting existing processes, new processes and costs.

Areas of current emphasis include:

- numerous developments to existing and new processes related to production of cleaner and reformulated gasoline and distillate
- enhancements to residuum upgrading processes, especially for handling heavy crude oils with high sulfur, metals and carbon residue contents
- developments in technologies for refinery emissions control and the processing of refinery waste streams
- technologies for production of gasolines and distillates from natural gas
- developments in additives and chemicals treatment technologies

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.

3.1.2 Refinery Capacity Construction and Utilization Data

Published *Oil & Gas Journal* data are the primary source of operating nameplate refinery capacity data for each refinery worldwide. These data require essentially annual updating. These also require careful cross-checking for error, omissions, refinery ownership/name changes, operating status, etcetera. EnSys' approach has been to use additional published statistics, e.g. from EIA, together with published articles on national, company or individual refinery activities and in-house sources to supplement and cross-check the base *OGJ* data.

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

For U.S. refineries, periodic surveys by the NPRA, API and NPC provide detailed insights into actual utilizations on primary and secondary units, together with ancillary data on operating modes, blendstock properties, etcetera. Such data are less readily available for other regions, distillation aside, although relevant periodic studies are undertaken by such organizations as IEA, NATO, EC, World Bank, United Nations, East-West Center.

Because of their growing importance, it is necessary today to track installed and projected capacity for MTBE and TAME plants, both in-refinery and merchant. Sources are similar to those described for refinery data.

3.1.3 Crude Supply and Product Demand Data

For building up historical or forward horizon **WORLD** studies, the primary sources of supply and demand data tend to be

EIA	(*Petroleum Supply Annual, International Energy Annual, Annual Energy Outlook, International Energy Outlook*)
IEA/OECD	(*Quarterly* and *Annual Statistics* on OECD nations but also numerous other countries)
U.N.	(mainly for third world countries)

In general, the reference statistics or projections provide a framework of overall supply/demand check totals plus some detailed numbers, but leave many gaps which must be filled by the analyst.

A. Crudes

Numerous sources, including EIA, IEA, Petroleum Economist, publish actual and projected crude production data by nation. Issues here primarily relate to (a) breakdown of national production by region and/or crude grade and (b) the extent to which NGL's are included in the crude production data.

For the U.S.A., crude breakdowns by state are published by the EIA. These data have to be supplemented by knowledge of individual crude grades. For crudes outside the U.S., periodic statistics of production - with API or API and sulfur - are published. However, accessing national energy offices or statistical bureaus (as in Canada, for instance) and ad hoc surveys and articles is necessary.

B. NGL's

For NGL's, national production statistics are available (e.g. from EIA). Outside the U.S.A. (*Petroleum Supply Annual*), little official data is available on the breakdown of NGL's between C_2, C_3, C_4, and C_{5+} . Again, reliance is often on ad hoc articles or direct sources to obtain estimates of breakdowns for major producers.

C. Other Hydrocarbons and Alcohols

Minor non-crude supplies such as petrochemical returns, grain ethanol, synthetic fuels from gas and coal (New Zealand and South Africa) are to be found in the main published sources. Merchant MTBE supplies are tracked in the **WORLD** model principally by monitoring **WORLD** regional merchant plant capacity.

D. Products

U.S. (EIA) and OECD area product demand statistics are available in level of detail close to that used in the **WORLD** model. Critically, these sources contain breakdowns of most minor products ("other"). They also contain data on the quantities and make-up of refinery fuel and of bunker fuels, with breakdown between marine diesel and bunker C. A major challenge centers on establishing realistic breakdowns of "other" products in non-OECD regions. Techniques include

(a) utilizing available data on individual countries, e.g. from in-house projects or published studies,

(b) extrapolating to Third World type countries by using the breakdowns of less-developed OECD countries,

(c) using published studies and data to identify individual components of "other", such as petrochemicals naphtha, and

(d) using refinery capacity data on such plants as lubes and waxes, asphalt, coking and aromatics to back-calculate estimated regional productions.

3.1.4 Product Specification/Grade Split Data

For the U.S.A., 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 calibrating case studies. Where actual qualities differ substantially from nominal specifications[10] (i.e. substantial product quality giveaway is commonplace),

[10] As one instance, approximately one-third of U.S. kero-jet has been reported as produced to Jet A-1 specifications rather than the officially required, less stringent Jet A specifications.

the analyst must judge where in an emergency or forward study any reduction in this quality giveaway should be allowed.

For non-U.S. regions, such sources as EC regulations, national statistical sources, published surveys, and oil company data can provide product quality details. In general, though, the picture is complex. The authors' main goal is to capture the major product quality or grade splits, notably:

- gasolines by equivalent clear octane
- distillates by sulfur content and cloud point
- residual fuels by sulfur content and viscosity

Seasonal variations are important most notably on distillate cloud point and residual fuel oil viscosity/pour point. Winter tightening of these specifications substantially raises effective world demand for distillates, as reflected in the typical fourth-quarter peak in kero-jet prices. Increasingly significant - in the U.S.A., at least - is differentiation on RVP and oxygen content between winter and summer gasolines.

3.1.5 Transportation Data

WORLD transportation data center on marine mileage tables used in conjunction with cost models for four tanker categories:

40,000-60,000	dwt	
120,000	dwt	
250,000	dwt	
40,000-60,000	dwt	Jones Act

Cost models developed by ICF allow variation in capital recovery rate to reflect different tanker supply/demand markets. They yield raw crude/dirty product rates. These are multiplied by factors to produce raw clean product rates.

To the raw tanker movement costs are added, as appropriate:

- canal and pipeline dues
- lightering costs
- import tariffs (either flat rate or add valorem).

Sources include marine mileage tables, ICF in-house data, and official sources for dues and tariffs.

U.S. transportation data on activities, capacities and rates have been developed from the ICF databank that supports the OSPR NACOD model.

3.1.6 Product Yield and Quality Blending Data

The WORLD model and its supporting systems have been evolved mainly through assignments with government agencies, notably: ORNL, EIA, EPA, DoE OSPR, DoE Energy Emergencies. These enabled EnSys to obtain inputs from DoE, DoD, DLA, DFSC, U.S. Air Force, U.S. Navy, U.S. Army, NATO, API, NPRA, AIR, ATA and jet engine manufacturers, as well as the Trenton Jet Propulsion Lab.

The vintage of data in the model is almost entirely 1985 through 1993.

The model draws from in-house data sources, review and commentary received from major oil companies, and information drawn from assignments to date. Broadly stated, the data sources include:

- 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.

Data extracted were subject to expert review and revision in light of total ENSYS petroleum industry experience and assignments with numerous private clients. Supporting property vs. cutpoint interpolation programs have been developed by ENSYS for PC use. In the main, the ENSYS approach has not been to use process unit yield correlations to generate the RYM Table data, but rather to extract data from the literature and in-house files to represent particular operating modes, severities and feedstock qualities.

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, p173.

Pour Point blending Indices - ibid., p175.

RVP blending indices have been garnered from several public and in-house sources and have been verified against Gary & Handwerk, p166.

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

Gasoline component emissions data (VOC's, TAP's and NOx) present in the model have been developed using a proprietary EnSys methodology for linearizing the EPA Simple and Complex Model equations.

3.1.7 Units of Measurement

The general rule adopted in the model is that quantities of oil are in millions of barrels per day, prices or costs are in dollars per barrel and quantities of money are therefore in millions of dollars per day . (For modelling of smaller systems than the present model handles, smaller units could be chosen (eg thousands of barrels/dollars per day). The change would be effected simply by the choice of units for crude and non-crude availability, process capacity and demand data.)

Exceptions to the above rule are:

1. Gases lighter than propane are measured in millions of barrels FOE per day. These are based on the following conversion factors:

Gas stream	Code	BFOE/lb	SCF/BFOE
Hydrogen	HH2	.009597	19662
Hydrogen sulfide	H2S	.001168	9538
Methane/natural gas	NGS	.003752	6303
Ethane	CC2	.003505	3600
Process gas	PGS	.003505	3600
Ethylene	C2E	.003399	3972

One barrel FOE is approximately 5.9 million BTU.

2. Yields of, and demands for, coke are measured in short tons per barrel and short tons per day respectively. A figure of 5.0 barrels per short ton is used.

3. Yields of, and demands for, sulfur are also measured in short tons per barrel and short tons per day respectively. A figure of 3.18 barrels per short ton is used.

4. 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/OLX, ETH/ETX, C24, ALK, CPL, DIP, DIM, ARP, C4I, H2P, H2X and SUL.
Note also that unit activity level of H2P, H2X and SUL activities represents the production of 0.1 MMBFOE of hydrogen and 0.1 MMST of sulfur per day, and uses 0.1 units of capacity.

5. Quality and specification units are those specified in the Method of Test or are dimensionless (as in the case of blending indices). The only point which needs to be mentioned is that gasoline sulfur contents and specs, SPM, are in parts per million by weight, while those for distillates, SPC, are in per cent weight.

6. Steam consumption is given in lb/bbl. Thus an activity in MMBPD consumes steam in MMlb/day. Steam generation is in MMlb/hour and the generator program applies a scaling factor of 24 to convert hours to days.

   The consumption of .00493 BFOE per day to raise 1 lb/hr of steam is equivalent to 1225 Btu per lb steam.

   Electricity consumption is in KWH/bbl. Generation is in KWH.

3.2 SHORT VERSUS LONG TERM CASE HORIZONS

A short term - non-investment - **WORLD** model run does assure equilibrium and consistency among demands and prices for an instant in time. In order to obtain either intermediate or long term economic equilibrium, a series of iterative model runs are necessary, in which the price solution of each model run is processed through the pertinent demand elasticities to estimate a new set of demands which in turn are fed back into the model to derive a second set of updated price solutions. The feedback loop between model solutions and demand elasticities is repeated until economic equilibrium is reached.

For instance, in simulating a disruption case only once, without the iterative process described above, output modelled prices represent a very short run snapshot of disruption effects, before demand has had time to adjust. Based on historical analyses, an intermediate equilibrium would be likely to be reached three to six months after the onset of the oil supply disruption, with long term equilibrium requiring three to five years.

The **WORLD** model can be used to calibrate economic equilibrium for all three time periods including very short term, intermediate and long term. The price elasticity varies in each of these three time frames and reflects the nature of the petroleum product demand response, whether to crisis driven oil prices or to changes in demand structure or process technology and economics.

In a short-term "real time" disruption, underlying BAU demand data will not be fully up to date, but crude supply, refining configurations, transport capabilities, product qualities, and external cost will be well known; added to which open market prices will calibrate the state of the market and associated refining tightness or slackness. These market prices equate to short-run marginal costs based on the essentially fixed refining capacity available.

In establishing future long-term BAU scenarios, the approach is necessarily different. Today's installed refining capacity, even with firm additions[11], will generally be inadequate to meet long-term requirements for product quantities or qualities. Consequently, the process of establishing long-term simulations must necessarily allow process unit capacity

[11] EnSys generally considers firm additions to be projects that are beyond the planning stage and are under engineering, construction, or start-up stages.

investment to be generally open, to allow the model to make additions to its capacity base using an appropriate discount rate. The crude and product prices that emerge reflect the technologies, operating and capital costs of marginal incremental facilities needed to convert crude into products, convert one product into another - notably upgrade residual fuel oil to gasoline and distillates - and to enhance the qualities of products, e.g. to produce ultra-low sulfur instead of conventional diesel.

The long-run BAU solution, therefore, necessarily represents a market at long-term equilibrium with refining facilities matched to requirements based on long-run unit utilization factors and costs. Any variations from this long-term equilibrium, e.g. to create a slack or tight refining situation as the basis for a disruption analysis, need to be superimposed by deviating from the total installed capacities and/or the effective availabilities assumed in the base BAU solution.

The level of required nameplate capacity addition, and associated investment cost, will be affected by the availability (PUL) factors assumed by the analyst. These should generally be long run factors extrapolated - with adjustments as appropriate - from known historical utilizations. The analyst is cautioned, though, that whatever the effective process unit availabilities assumed, the **WORLD** case will install in each region only the exact amount of additional capacity required. Arguably, even long-term analyses should simulate projected summer and winter situations, as well as year-round average, in order to arrive at realistic assessments of total future capacities required. This is particularly the case for the U.S.A., where substantial differences between winter and summer gasoline are emerging.

Should the analyst then "lock in" these future capacities for further studies - e.g. disruption or seasonal analyses - adjustments to the availability factors (PUL's) are likely to be necessary. Under locked-in capacities, product prices will again represent short-term rather than long-term equilibrium.

3.3 OVER-OPTIMIZATION, CALIBRATION, AND SEASONALITY

3.3.1 Over-Optimization

There has always been a potential for refinery LP models to over-optimize and to predict performance that could not be achieved in actual operations. This potential is due to the addition of many decision variables to obtain a more detailed representation of operations that allowed the LP model to use refinery streams in a manner that was impossible in practice. EnSys' approach is to apply several methods to prevent this, namely:

1. **forcing blends to tighter than nominally specified properties**, i.e. ensuring that realistic product quality giveaway is built in throughout.

   This becomes especially critical in forward studies of reformulated gasoline and distillate where, for instance, using 0.05% instead of a more realistic ex-refinery target of 0.035-0.04% sulfur for low sulfur diesel could significantly overstate production capability and understate cost and investment effects. Similarly, we would expect to use no more than 22% actual target against a 25% nominal aromatics specification.

2. **selectively limiting blending flexibility** e.g. to prevent excessive dumping of high sulfur or high aromatics distillates into fuel oil as cutter stock

3. **constraining refining process operations to realistic limits**. Limiting such parameters as FCC conversion, FCC residuum feedstock, reformer severity to realistic levels is critical to maintaining realism. Such controls are particularly necessary in **WORLD** in light of the richness of present day and advanced process options it contains.

4. **not representing refinery operations that verge on sub-optimization**. Certain operations may be undertaken in individual refineries to achieve second order optimization gains. Allowing these to apply to a whole region could cause spurious over-optimization. Reformate fractionation is a case in point. Used occasionally by refiners, it would arguably cause over-optimization if included in **WORLD**. Conversely, if seen as widely necessary to meet future gasoline blending requirements, then it should be fully incorporated.

5. **constraining refinery capacities to their effective availability**. Several studies including NPRA surveys have pointed to the existence of plant capacity that is effectively spare or not always available, e.g. because it is needed seasonally is no longer fully utilized due to changed processing patterns, is a tertiary processing unit such as alkylation or gasoline fractionation and tends to have lower utilization, or is restricted to low utilization levels by refinery operating practice, e.g. sulfur or hydrogen plants which are often "double-trained" since the whole refinery is dependent on their not shutting down. In the **WORLD** model, name-plate and effective available capacities are distinguished using an availability factor[12] which is applied in addition to a standard service factor for each process unit.

6. **assessing the commercial status and operations record of newer processes** and, as appropriate, placing limits on their pace of introduction.
Far-reaching environmental legislation in the U.S. has spurred rapid development of new and improved process technologies. One analytical challenge centers on determining how fully to incorporate newer technologies for forward-looking studies. Allowing only today's established technologies for a study looking beyond 2000 is likely to understate the refining industry's future capability and to overstate the costs and difficulty of adapting to new legislation or other developments. Conversely, allowing use of little-tested process units or variants risks over-optimistic results and conclusions.

   EnSys' general approach has been to include new processes and variants (such as catalyst types) only when processes have reached the commercial stage[13] or are very direct developments from existing proven technologies.

[12] *Column PUL* in the capacity tables.

[13] At least one world-scale unit in sustained and successful operation.

3.3.2 Calibration and Validation

EnSys applies several approaches to calibrate and validate the **WORLD** model. The process is essentially an on-going one.

1. EnSys has put considerable effort into **validating the model's volume balances both overall and unit by unit**. We have crossed-checked and weight-balanced yields on the crude and other units. Using historical EIA Petroleum Supply Annual data for PADD III, we have verified the overall refinery weight balance (to within 0.3%).

   EnSys has also implemented an IEA/EIA style world supply/demand balance report which takes into account refining volume gain, catalyst coke production and refinery fuel and natural gas consumption. This can be compared with historical or forecast balances put out by the above or other organizations.

2. EnSys has **used actual data on past horizons to validate model performance** with emphasis on:

   - crude and product marginal costs and differentials
   - crude and product flows
   - refinery unit operations and utilization levels
   - limiting product qualities

For instance, a detailed calibration was made against EIA Petroleum Supply Annual (PSA) for 1989, for the U.S.-only *Detailed Refinery Model* **WORLD** variant. [14] This comparison indicated that the validation was quite good with total crude volumes from the model only + 0.48% above actual PSA values and total production just 0.28% higher. A more complete comparison, including assumptions, can be found in the cited reference.

3. Especially on current periods, for which data are incomplete, **primary emphasis is put on calibrating against known open market prices** since establishing the degree of tightness in the world regional refining system is key to accurate analysis. Calibrating to establish a base for evaluating potential developments in the middle of the Iraq/Kuwait Middle East crisis is a case in point.

[14] *"Detailed Refinery Model Calibration Report", June, 1993 and Letter of October 20,1993 from Martin Tallett of ENSYS to G.H. Harp of EIA.*

It should be pointed out that:

A. often one is dealing with incomplete data or data containing errors and that therefore there are practical limits to the significance that can be attached to any one validation exercise. It is necessary to re-validate the model over time. Validation relies as much on continually searching for data and insights on specific market topics as it does on cross-checking internal model details.

B. validation is less achievable in studies of forward horizons; for instance, long run crude and product price differentials may change for structural reasons. One has to rely more on gauging whether results are reasonable and make sense.

C. EnSys has found that just because a model reproduces an historical actual period does not necessarily mean that it will respond realistically when put to simulate a scenario that departs from business-as-usual.

3.3.3 Seasonality

The **WORLD** model was designed from the outset to operate on seasonal (quarterly or winter/summer) as well as annual average cases. This was originally done because the importance of distinguishing the time of year was recognized in studying disruptions, SPR drawdowns and impacts on product cost and production capability, including that of jet fuel. Gasoline volatility and Clean Air Act initiatives have since still further differentiated summer from winter.

To effectively study immediate short-term horizons, taking account of actual current inventories is essential. For longer term studies, quarterly load on the U.S. and global refining system can be adjusted in **WORLD** to reflect typical product/intermediate stock draw or build for that quarter. Since the unit of time in the model is an "average day", the flow can be based on annual demands (divided by 365 days per year) or on any other period of time such as a week, month, or several months.

In the future, it will be necessary to account for seasonal stock variations in butanes and potentially MTBE and other intermediates, in light of winter/summer differences in gasoline RVP and oxygenation.

The seasonal variation in **WORLD** is not just limited to inventory effects. The model also incorporates separate winter/summer/annual average product specifications which can be selected under user control. In addition, seasonal changes in crude production levels, Soviet/Eastern Europe net exports and major unit turnarounds can also be included.

3.4 CASE CONSTRUCTION CHECKPOINTS

The **WORLD** modelling system contains cross-checks on user errors only to the extent of mis-formulation of OMNI data tables and of the generated matrix. **At present, there are essentially no safeguards against user data errors.** It is, therefore, up to the user to cross-check data entries.

Set out below is a partial list of data entry check-points and error signals.

3.4.1 Data Entry Checkpoints

marker crude price	generally Saudi Light entered in ***Table CRDAV***, but should also be entered in transportation spreadsheet if being used. Here it sets crude and product price levels for computation of import tariffs.
marker crude availability	***Table CRDAV*** entry should allow flexibility versus the calculated amount of marker crude required. *(Set the availability to, say, 1 mmbpd higher than the anticipated amount required.)*
prices of (variable) non-crude inputs	***Tables (Q)NCP***. Ensure prices for natural gas and methanol are mutually consistent and, if required, consistent with crude price.
product demands	ensure ***Tables (Q)PRDMD*** generally have been adjusted as follows: - **PGS** demand adjusted to any <u>net</u> sales from the refining sector - **CKL**demand in short tons per day, fixed demand (should generally be no higher than 35-50% of total market coke demand) - **CKH** demand floats with a price, typically \$10-\$20 per short ton - sulfur demand floats with a price, typically \$100 per short ton - demands for distillate and residual fuels include bunkers but exclude refinery fuel consumption - lubes, coke, asphalt, and aromatics demands consistent with corresponding plant capacities *Note: The **WORLD** model currently allows inter-regional shipping of aromatics and lubes but not asphalt or coke. (There is, however, appreciable inter-national coke trade and the **WORLD** model can be adjusted to incorporate this.)*
product blends	check that no product is input both as a spec and a recipe blend (JP4, JP5)

supply-demand balance

if necessary, using results from a first-pass run and adjusting actual sulfur and coke outputs back to bbls, cross-check that supply and demand data are in balance by constructing an EIA-type balance:

	crude inputs
+	non-crude inputs
+	estimated (reported) volume gain
=	finished product demand sales
+	refinery fuel inputs (excluding natural gas)
+	catalytic coke production

In general, though, **WORLD** results will not precisely match EIA/IEA-type supply-demand balances, this because world oil operations, fuel consumptions, etc. are simulated dynamically and in detail

refinery capacity data

If a non-investment case, make sure nameplate stream day capacities are present in ***Tables (R)CAP and (Q)CAP*** under the **MAX** column. If an investment case, make sure (a) investment flag is set in ***Table CONTROL*** and (b) base capacities appear under **CAP** in ***Tables (R)CAP***, and entries under **MAX** are only present where actual expansion is to be limited.

Ensure utilizations (**PUL** factors) in ***Tables (R)CAP and (Q)CAP*** reflect the short or long term nature of the case scenario.

refinery operations data

Ensure in ***Tables (R)POL***:

- FCC, cat reformer, flexicoker operating limits have been correctly estimated
- **PFH** constraint on H_2S to refinery fuel is set to **MAX** zero unless the run is historical

- the constraints on residual oil to refinery fuel have been set, generally to **FIX** limits

product specifications data

Ensure all required specifications are activated in ***Table EXSPEC***.

Ensure Winter, Summer, or Year Average specifications have been set in ***Table CONTROL***.

Ensure ***Tables W/S/Y(Q)G/DSP*** contain any desired regional specification variances.

crude dispositions and vessel types

Ensure ***Table CRDDISP*** reflects:

- any changes in allowed or disallowed crude movements
- required vessel sized for movements

general bounds

Ensure ***Table VECBNDS*** has been updated for any changes to general bounds, e.g.:

- limits on crudes processed in local refineries
- limits on crudes moved into the U.S.A., notably from Mexico and Venezuela
- limits on non-crudes movements into U.S. regions

3.4.2 Common Error Signals

A. Matrix Generation

- a return code other than 0 signals an error, generally in input data tables, and should not be ignored

B. Matrix Optimizer Input and Reduction

- OMNI messages indicating increases in allocation of workspace areas (WA, DAD, etc.) in combination with otherwise inexplicable OMNI errors - notably "TABLE NOT FOUND" - can mean OMNI has insufficient space available to accommodate all data. Increase the workspace allocations in GENCOMP, GENEXE to the levels indicated.

- the optimizer will generate messages during **INPUT** and **REDUCE** (or **TRACE**) regarding any inconsistencies in matrix structure including structural infeasibilities. These must not be ignored. Either there should be no messages or those present should be well understood.

C. Matrix Optimizer Infeasible Solution

- a massively infeasible solution tends to indicate missing or grossly erroneous data tables or a severe imbalance in input supply/demand data.

  Check level of marginal marker crude utilization. If at minimum or maximum, then there is a likely imbalance. Also check natural gas intake.

- a solution with a small number of infeasibilities tends to indicate minor data problems, e.g.:

  - incompatibility between crude availabilities and bounds (***Table VECBNDS***)
  - incompatibility between lubes, asphalt or aromatics demand and plant capacity available to supply

- incompatibility between demands for low sulfur coke (**CKL**) and either coking capacity or, more likely, low sulfur crude availability *This problem can occur if **CKL** demands have been mistakenly entered in mmbbls not mm short tons per day.*
- missing demand outlets for market coke or sulfur

D. Report Writer
Major Imbalances

- check consumption of marginal crude. If low, check for excessive movements on particular products (e.g. **DFA**). If high, there may be a data table error allowing a product to be exported from a region without being manufactured.

- check consumption of natural gas. In the past, a reasonably correctly formulated matrix nonetheless allowed spurious volume gains through vectors "looping". (This would not occur with a weight balanced model.)

4 WORLD SYSTEM

4.1 OVERVIEW OF SOFTWARE AND HARDWARE

The **WORLD** model comprises a series of linked sub-systems which together permit cohesive data management, matrix generation, optimization and report writing. At the core of the system is extensive program code written in Haverly Systems' OMNI language. This handles two main functions:

1. the manipulation of case and "permanent" input data into a generated industry-standard LP matrix[15]

2. the generation of multiple reports from matrix data and run solution files.

A key factor of OMNI is that it enables the model to be highly data-driven, i.e. the code has been written so that very many model changes such as adding new regions, process units, crudes, products, specifications as well as changing virtually any data items can be handled without modification to the code; data table modifications are all that is needed.

The MPS LP matrix data file is input to, analyzed and optimized by one of the leading optimizer software packages. Ketron's MPSIII simplex-based optimizer will run the **WORLD** model, but with difficulty when **WORLD** is used in investment mode. New generation "interior point/barrier method" optimization software, such as OSL from IBM and OB1 from Ketron, optimize **WORLD** with superior performance and consistency as compared to simplex optimizers. A model such as **WORLD** appears to find the weaknesses in optimizers in terms of both their diagnostic and optimizing capabilities and therefore optimizer selection is critical to smooth model development and use.

[15] The long-established industry norm for LP matrix card image data sets is the so-called "MPS" format. Regrettably, there is no universal standard for format of LP solution output files.

The **WORLD** model contains, manipulates, and computes many thousands of input data items. These include:

- detailed crude and non-crude availabilities
- detailed product demands (historical and projected) and specifications
- process capacity data by unit by refinery worldwide
- transportation routing, mileage and cost data
- process yield and product blending data
- process cost data

To manage these data, EnSys has developed sophisticated spreadsheets which output OMNI format case data tables. The spreadsheets, originally written in "VP Planner 3D", are being converted to "Quattro Pro". OMNI code and optimization capability (although not so readily the supporting spreadsheets) are today portable across IBM mainframes, 386/486 PC's, IBM RISC 6000, and potentially other workstations.

WORLD investment mode runs that will take 3 to 15 CPU hours under MPSIII on the EIA 3084QX IBM mainframe take only 30 minutes to optimize under OB1. The same run on a 486/33mHz PC takes around 53 minutes under OB1, and $2^1/_2$ to $3^1/_2$ hours under OSL. RISC workstation run times are appreciably quicker. These run times will likely be rivalled by PC's based on Intel's 486/66mHz CPU chip and especially by the next generation "P5" processor due out in 1993.

Overall, current and forthcoming high-end PC's in combination with the new generation optimizers, such as OB1 and OSL, and the PC version of Haverly's OMNI, represent a breakthrough in that the complete **WORLD** system can now be most effectively brought together on a PC, or a PC networked to a RISC workstation for fastest turnaround.

For PC installation of the **WORLD** model, the minimum hardware and software requirements are:

- main memory of 32 megabytes[16]
- PC OMNI Assembler package
- OSL or OB1 optimizer

[16] EISA bus and a minimum 300 megabyte high performance hard drive are also recommended. A current 33mHz 486 Intel CPU chip can be directly replaced by the double internal clock speed 66mHz 486 chip.

4.2 DATA SUB-SYSTEMS

The **WORLD** model can be viewed as a combination of data and program core components or sub-systems. The data sub-systems are focussed on data management and the preparation of input data tables. There are 7 such sub-systems, encompassing

1. process technology: crude oils, refining, NGL's, petrochemicals, and merchant oxygenates
2. product blending and specifications
3. refinery and merchant oxygenates capacity and operations
4. crude production and non-crudes inputs
5. crude, product, and intermediates transportation
6. general limits
7. finished product demand

Each sub-system constitutes a set of OMNI data tables with, in the case of all except 1 and 6, an associated spreadsheet system for manipulating raw data into OMNI table form.

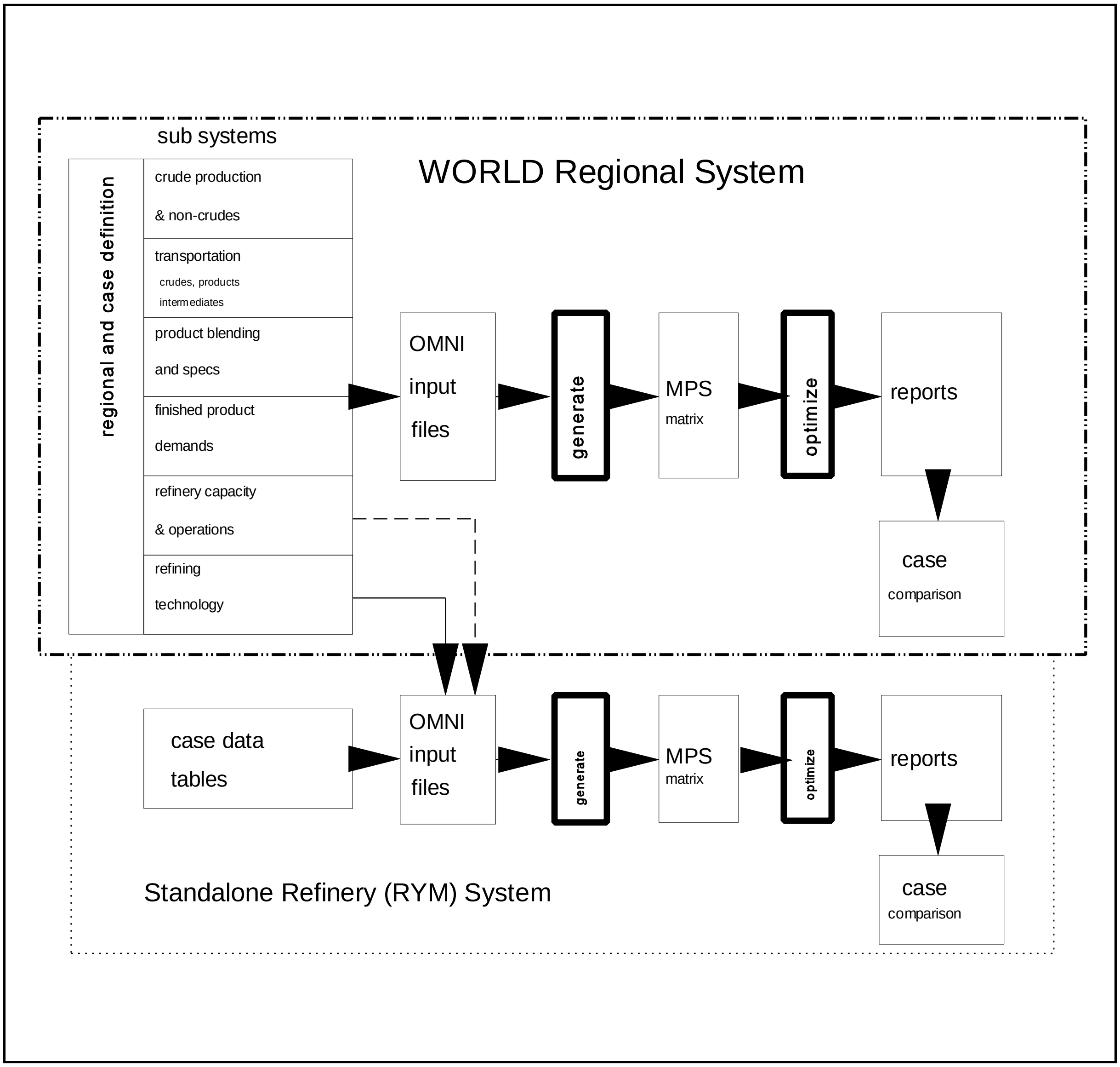
A fuller description of each **WORLD** data sub-system follows.

4.2.1 Process Technology: Crude Oils, Refining, NGL's, Petrochemicals and Oxygenates Sub-System

A. Crude Oils and Refining Technology

- **representation of over 120 world crude oils** encompassing main grades from every producing country; also synthetic and specialty naphthenic crude oils

- a detailed and tested representation of **over fifty refinery processes including advanced technologies and operating modes for reformulated** and military fuels.
  (See *APPENDIX B* for list of processes and key operating modes.)


sub systems
WORLD Regional System
regional and case definition
crude production
& non-crudes
transportation
crudes, products
intermediates
product blending
and specs
finished product
demands
refinery capacity
& operations
refining
technology
OMNI
input
files
generate
MPS
matrix
optimize
reports
case
comparison
case data
tables
OMNI
input
files
generate
MPS
matrix
optimize
reports
case
comparison
Standalone Refinery (RYM) System

- specific capability for **reformulated gasoline**, ultra low sulfur/**low sulfur plus aromatics diesel**, multiple jet fuel grades and several residual fuel oil grades

- user activated investment feature builds up **full annualized investment costs for capacity addition which are tailored by region** for location factor and capital recovery (cost of capital), can be used to reflect refinery scale (e.g. to capture the economy-of-scale disadvantage of small refineries)

B. NGL's, Petrochemicals, Merchant Oxygenates Plants

- optional user generation of a "petrochemicals" facility in any or all refining regions. This can be used to incorporate ethylene cracking or potentially other processes within the model and is currently being used to simulate merchant MTBE plant operations, investment and shipping for forward horizons. It is also used to simulate NGL availability and potentially plant operations, distinguishing NGL inputs to oil refineries from NGL inputs to product demand for LPG etc.

4.2.2 Product Blending and Specifications Sub-System

- detailed representation of blending options, component qualities and specifications for major, minor and military products

- **some 30 discrete products** can currently be represented including essentially all products represented in the EIA Petroleum Supply Annual, plus reformulated and military grades
  (See *APPENDIX C* for list of products.)

- **world country-by-country gasoline octane database** reduces leaded octanes to a lead-free basis and allocates gasoline demand into four representative conventional gasoline grades (two of which are U.S. premium and regular unleaded); can then be used to project changes in world region clear pool octanes, depending on assumed trends in lead levels and grade mixes.

- **reformulated gasoline blends** are available for use in addition to the conventional grades. (Currently, one reformulated gasoline blend is in use to contain model size but the number can be expanded simply by data changes.) Qualities cover all anticipated specifications plus atmospheric reactivity; also **linearized versions of EPA equations for control of gasoline emissions are being implemented**

- discrete representation of conventional versus low sulfur/aromatics diesel
- separate blending capabilities for Jet A/A-1, JP-8, JP-5, JP-4 and potential high density JP-8X/JP-11 fuels with rich representation of blend properties
- user option to select recipe blend representation of minor products such as JP-4, JP-5
- **multiple residual fuel sulfur grades** represented
- **user control of product specifications generated** case-by-case[17]
- **winter/summer/regional variation of product specifications.**
(See *APPENDIX D* for listing of model blend properties.)

4.2.3 Refinery Capacity and Operations Sub-System

- **every refinery worldwide** (outside "eastern bloc" areas) **with capacity by process unit type** is represented in a spreadsheet-type database; basis is reviewed Oil & Gas Journal data plus other in-house sources
- currently represents base capacities as of January 1991
- 3-dimensional feature incorporates **known capacity addition projects by refinery** through 1994; enables base individual and regional capacities to be generated for different horizons within this time-frame. (**WORLD** investment feature - if activated - enables further capacity additions.)

[17] The WORLD model contains a very rich set of product specifications. For most studies, only a sub-set of these is needed. The "exspec" feature enables the user to control the specifications actually generated for each product, hence model emphasis and size.

- **refinery status indicator** enables user to "switch" on or off individual refineries and projects in the database, e.g. if closed or if a tentative project moves to the construction stage

- standard process unit stream day factors are incorporated for each type of unit. An additional **capacity utilization factor** enables the user to adjust nameplate capacity to effective available capacity to accommodate such factors as: estimated seasonal shutdowns - or shutdown deferrals, typical long term industry utilization rates, lack of inter-connection of all process units in a region[18]

- sub-system provides for **user control of operations on key units** including: FCC, catalytic reforming, distillate hydrotreating, refinery fuel pool. (See *APPENDIX B* for details.)

- facility to generate and/or purchase steam and power

- additives purchasing and blending including diesel pour depressant, ignition improver, specialty jet additives and gasoline manganese additive

4.2.4 Crude Production and Non-Crudes Supply Sub-System

- national crude oil production levels (actual or projected) with grade breakdowns

- U.S. crude production broken down by major grade within state

- U.S. and foreign SPR's represented with crude grades and proportions

- syncrudes from tar sands (Canadian and Venezuelan)

- NGLs production by country/region with facility to break out C_2's/C_3's/C_4's/C_5+ or to aggregate C_3's/C_4's

- other non-crude inputs including full blended ethanol, splash blended ethanol, petrochemical sector returns, synthetic petroleum products, methanol

[18] Recognizing the model's implicit assumption that all units in a region are inter-connected and capturing the reality that they are not through adjusting utilization rates is significant in preventing model over-optimization.

- natural gas purchase for fuel/feedstock uses
- "eastern bloc" net crude and product trades

4.2.5 Crudes, Products and Intermediates Transportation Sub-System

- develops fully built-up movement/import costs under a wide variety of scenarios
- **inter-regional movements database** incorporates mileages, fuel consumption plus long term capital and other cost components for main marine vessel classes and provision to vary to reflect case scenario
- user selects vessel size for each marine movement
- user controls which movements are generated
- movements reflect pipeline and canal routings and tariffs
- crude, product and intermediate import tariffs (flat rate and ad valorem) for U.S., Europe and other world regions
- transportation capacity limits, where activated

4.2.6 Finished Product Demand Sub-System

- **directly utilizes major available historical data sources** including: Petroleum Supply Annual for the U.S.A., OECD/IEA statistics, EIA International Energy Annual, UN data
- demands are fixed quantities by PADD for U.S., by East and West for Canada and elsewhere by country with major products demands for essentially all countries outside "eastern bloc". Demand functions that allow demand to vary with price are not included.
- PADD and country data are first aggregated into "sub-regions" for easy final aggregation and for projection of demands

- facilities incorporated to aggregate and desegregate product data within categories, including military fuels

- **historically developed major seasonal inventory/demand variations enable user to select typical quarterly demands** from annual base data, including for LPG's and asphalt

- BAU data can be overridden and adjusted to reflect non-BAU scenarios

- **incorporates growth rates** to project demands by five major product groups by "sub-region" to any future horizon.

4.2.7 General Limits

- simple vector bounding feature allows user to control activity of any individual vector in the model; most often used to control movement vectors e.g. to reflect crude exporting policies and to ensure a proportion of a country's crude production is run in local refineries.

4.3 PROGRAM SUB-SYSTEMS

4.3.1 Overview

A. WORLD Generation Sub-System

The OMNI matrix generation code is almost entirely data driven by control tables and tables output by the refinery technology and case data sub-systems. Matrix configuration and size is dynamically controlled based on number of regions defined, refineries per region, active units and process operating modes in each refinery, whether investment activated, active regional and global product demands, allowed transportation movements.

Table-driven matrix generation code improves generation efficiency and model run time by identifying and eliminating inactive process units, operating modes (vectors) and intermediate streams dynamically, based on case data.

Refinery matrix downsizing - a table driven feature, developed and tested but not fully implemented to date, enables users to optionally select a less detailed matrix formulation for some or all regions. This is potentially valuable where the user wishes to limit turnaround time, computer costs and/or to explicitly represent more or smaller refining regions. Given the increasing complexity of refining worldwide augmented by the trend to reformulated fuels, this feature may be most useful for shorter term studies and/or where it is desirable to represent a large number of refining regions, e.g. in a study with primary emphasis on transportation.

B. Optimization Sub-System

WORLD works with all optimizers that accept the MPS format matrix output by OMNI and which generate OMNI-compatible solution files. **WORLD** has been optimized mainly using MPSIII, OSL and OB1. With built-in proprietary EnSys scaling methods, the model runs stably without degeneration or other problems. Matrix statistics are problem dependent but, with EnSys' 11 region model running in present day <u>non-investment</u> mode, model size is approximately 4300 rows, 16800 columns, 125000 non-zero elements. Run time on an IBM 3084QX under MPSIII is typically 10 to 40 CPU minutes. Investment mode model comprises nearer 4,800 rows by 25,000 columns. Running under OSL or OB1 is straightforward; under MPSIII problematical. Under OB1, optimization of the full year 2000 model with investment active takes 27-33 CPU minutes on the EIA mainframe, 53 minutes on a 486/33mHz PC.

C. Reporting and Analysis Sub-System

WORLD OMNI report code generates data driven reports covering:

- world oil supply/demand balances including refinery gain and catalytic coke production,
- refinery operations, utilizations and investment,
- refinery feedstock/production balances,
- crude movements, in detail and in aggregate
- intermediates and products movements,
- transportation mode capacity utilizations, when capacitated transportation activated
- assignment of non-crude inputs,
- regional product production/import/export/demand balances, patterned after EIA/IEA reporting conventions
- product blending and gasoline emissions per EPA equations
- crude and product marginal costs/prices
- regional cost to the consumer,
- regional economics including producers', refiners, and shippers' rents.

Generation of the reports is dependent on user selection.

In addition to the above, EnSys has developed a "delta" report which - under user control of criteria - reports key differences between two solutions, e.g. a base case and a variant.

D. Stand-Alone Refinery Model Sub-System

A single refinery "RYM" option uses its own case input data tables, matrix generation and report writing code together with the **WORLD** refinery technology database including the full reformulated fuels features to generate a single refinery matrix and reports.

Alternatively, the **WORLD** model can be run directly in single-refinery mode, e.g. to simulate one region. Note, however, that at least one associated crude supply and product demand region must be activated, with (realistic or nominal) transportation links.

4.3.2 Program Flow and Control

A. General/PC OMNI Program Flow

OMNI programs are at the core of the **WORLD** model. Therefore, to use the **WORLD** control files it is necessary to understand something of the way in which OMNI programs work and of OMNI syntax for compilation and execution.

An OMNI program is broken up into "logically complete units" or LCU's. Each LCU represents a separately compilable and executable piece of program. The OMNI system will arrange this automatically if the programmer does not, but the result is a large number of very small pieces of program. The programs associated with the **WORLD** system are consciously divided into LCU's. The advantage of doing so is that the numbering of the LCU's can be retained unchanged through many program modifications, and the execution of the programs can be controlled.

OMNI EXECUTION ON A PC

When OMNI is executed, a filename appearing as a command line parameter may be specified. OMNI then uses that file as a set of input instructions. The operation of the **WORLD** system on PC's currently uses four such command files: **GENCOMP, GENEXE, RPTCOMP** and **RPTEXE**. These control respectively the compilation and the execution of the generator and report programs. The reason for running the compilation and execution steps separately is that the former runs quickly and may detect data or program errors, while the latter is more time-consuming but generally runs without error. Samples of the files follow:

GENCOMP - reads all data tables in the named files and creates a new data-dictionary called DEMO.DD. Reads and compiles the generator program and saves the compiled program to a file called DEMO.LCU.[19] Executes certain preliminary LCU's (see below).

Note that OMNI instructions must begin in specific column positions in the line. These starting positions are not correctly reproduced in this document.

SAMPLE FILE

```
OMNI,NUDD=DEMO.DD,NULCU=DEMO.LCU
        ALLOCATE,DAD=9288,P1=148068,EX=65535
        COMPILE,MAGENIV,SL
        LIST,OFF
* MODEL INPUT DATA
        SWITCH TO D:\EIASYS\OXRYMW21.392
        SWITCH TO D:\EIASYS\AVSPEC.692
        SWITCH TO D:\SPR\CRMIX\CRDISP2S.N30
        SWITCH TO D:\EIASYS\89CRDNCP.PRN
        SWITCH TO D:\EIASYS\89CRTRAN.PRN
        SWITCH TO D:\EIASYS\89DEMAND.PRN
        SWITCH TO D:\EIASYS\89PRTRAN.PRN
        SWITCH TO D:\EIASYS\89REFCAP.PRN
        SWITCH TO D:\EIASYS\VECBNDS.392
        LIST,ON
```

[19] The name DEMO can be altered but the suffixes .DD and .LCU are required by OMNI.

```
* OMNI GENERATOR PROGRAM
        SWITCH TO D:\EIASYS\OXYMAGN3.692
        EXECUTE,(75,104)
        ENDJOB
```

GENEXE - executes the bulk of the generator program, producing an MPS-format matrix file called RECOUT1.

<u>SAMPLE FILE</u>

```
OMNI,UPDD=DEMO.DD,RDLCU=DEMO.LCU
        ALLOCATE,DAD=9288,P1=148068,EX=65535
        EXECUTE,(110,125)
        ENDJOB
```

The generated model is then ready for input to whatever optimizer is being used. Every optimizer will produce a "solution" file (SOLFILE), containing the solution data in one of two or three standard formats, which subsequent OMNI programs can read. This solution file is to be distinguished from the solution listing, which may also be filed.

In order to run reports, OMNI must first produce a "packed solution" file (PACKSOLN) by using the OMNI command SOLUTION. A PACKSOLN file may contain more than one solution, and if the delta report is to be run, it must do so.

Note that, if the report writer program contains references to the matrix as well as to the solution, the commands which create the SOLFILE and PACKSOLN files must be so informed. In that case, the files will also contain the matrix data required.

RPTCOMP - reads data files associated with the report and adds them to the existing DD file; reads the report program and adds the compiled LCU's to the existing LCU file.

SAMPLE FILE

```
OMNI,UPDD=DEMO.DD,UPLCU=DEMO.LCU
        ALLOCATE,DAD=10368
        COMPILE,MAGENIV,SL
* REPORT DATA
        SWITCH TO D:\EIASYS\MTFIXREP.392
        SWITCH TO D:\EIASYS\RPTCTRL.392
* OMNI CODE
        SWITCH TO D:\EIASYS\OXRWJL.392
        SWITCH TO D:\EIASYS\DELTARPT.392
        ENDJOB
```

RPTEXE - this file serves two purposes: it controls which parts of the main report program are executed according to the entries in ***Table REPLCU***. If that table calls for the delta report, this file also controls which parts of the delta report program are executed according to the entries in ***Table DEL10LCU***. The report output file is named RECOUT4 by OMNI.

SAMPLE FILE

```
OMNI,UPDD=DEMO.DD,RDLCU=DEMO.LCU,RDPKS
        ALLOCATE,DAD=12288,NV=186624,SD=8192,WA=222528
* NOTE- IF PACKSOLN FILE EXISTS USE 'RDPKS' ON FIRST LINE
*       - IF NO PACKSOLN FILE EXISTS 'RDPKS' IS DELETED AND A
*               'SOLUTION' STATEMENT IS INCLUDED AS FOLLOWS.
*               FOR MAIN REPORT PLACE DATANAME USED IN OPTIMIZER 'FILESOL'
*               COMMAND IN COLS 1-8 OF LINE AFTER SOLUTION STATEMENT.
*               ENTRIES ARE SHOWN BELOW COMMENTED OUT
*               NOTE DESCRIPTION OF FILESOL SOLUTION NAME MUST
*               MATCH BOTH NAME AND CASE (UPPER/LOWER)
*               FOR DELTA REPORT, PLACE DATANAMES FOR TWO SOLUTIONS IN
*               COLS 1-8 AND 9-16 OF LINE AFTER SOLUTION STATEMENT.
*       SOLUTION,STANDARD,NOMTX
* NEW2SOL7
        LIST,ON
        EXECUTE,4800
* EXECUTE REPORT SEQUENCE AS DESIGNATED IN TABLE REPLCU
* INITIALIZATION
        EXECUTE,200
```

```
        BYPASS,EXCEPT TABLE REPLCU(R,L205),GO TO 500
* CRUDE SHIPPING BY DESTINATION
        EXECUTE,205
        BYPASS,500
        BYPASS,EXCEPT TABLE REPLCU(R,L212),GO TO 505
* CRUDE SHIPPING BY ORIGIN
        EXECUTE,212
        BYPASS,505
        BYPASS,EXCEPT TABLE REPLCU(R,L213),GO TO 510
* CRUDE SHIPPING BY ORIGIN US-ONLY
        EXECUTE,213
        BYPASS,510
        BYPASS,EXCEPT TABLE REPLCU(R,L214),GO TO 515
* REGIONAL PRODUCT BALANCE
        EXECUTE,214
        BYPASS,515
        BYPASS,EXCEPT TABLE REPLCU(R,L215),GO TO 520
* REGIONAL PRODUCT SALES, MARGINAL COST AND CONSUMERS' COST
        EXECUTE,215
        BYPASS,520
        BYPASS,EXCEPT TABLE REPLCU(R,L219),GO TO 525
* PRODUCT SHIPPING
        EXECUTE,219
        BYPASS,525
        BYPASS,EXCEPT TABLE REPLCU(R,L220),GO TO 530
* PRODUCT SHIPPING US-ONLY
        EXECUTE,220
        BYPASS,530
* INTERMEDIATE SHIPPING WITH US-ONLY OPTION
* IF EITHER 222 OR 223 IS REQUIRED, 221 MUST BE EXECUTED FIRST
        BYPASS,WHEN TABLE REPLCU(R,L222),GO TO 531
        BYPASS,WHEN TABLE REPLCU(R,L223),GO TO 532
        BYPASS,GO TO 540
        BYPASS,531
        BYPASS,WHEN TABLE REPLCU(R,L223),GO TO 533
        EXECUTE,221,222
        BYPASS,GO TO 540
        BYPASS,532
        EXECUTE,221,223
        BYPASS,GO TO 540
        BYPASS,533
```

```
          EXECUTE,221,222,223
          BYPASS,540
          BYPASS,EXCEPT TABLE REPLCU(R,L224),GO TO 544
* NON-CRUDE TRANSFER REPORT
          EXECUTE,224
          BYPASS,544
          BYPASS,EXCEPT TABLE REPLCU(R,L225),GO TO 545
* CRUDE/PRODUCT SUMMARY REPORT BALANCE
          EXECUTE,225
          BYPASS,545
          BYPASS,EXCEPT TABLE REPLCU(R,L226),GO TO 550
* CAPACITY UTILIZATION REPORT
          EXECUTE,226
          BYPASS,550
          BYPASS,EXCEPT TABLE REPLCU(R,L239),GO TO 555
* ECONOMIC SUMMARY REPORTS
          EXECUTE,239
          BYPASS,555
          BYPASS,EXCEPT TABLE REPLCU(R,L240),GO TO 560
* ACCOUNTING SUMMARY REPORTS
          EXECUTE,240
          BYPASS,560
          BYPASS,EXCEPT TABLE REPLCU(R,L245),GO TO 565
* BLEND REPORTS, INCL GASOLINE
          EXECUTE,245
          BYPASS,565
          BYPASS,EXCEPT TABLE REPLCU(R,L246),GO TO 570
* BLEND REPORT EXTENSION, TABLE REX
          EXECUTE,246
          BYPASS,570
          BYPASS,EXCEPT TABLE REPLCU(R,L280),GO TO 575
* INVESTMENT REPORTS
          EXECUTE,280
          BYPASS,575
          BYPASS,EXCEPT TABLE REPLCU(R,L300),GO TO 580
* GLOBAL ECONOMIC SUMMARY
          EXECUTE,300
          BYPASS,580
          BYPASS,EXCEPT TABLE REPLCU(R,L500),GO TO 745
* DELTA REPORT CONTROL
```

```
* ROWS SECTION
        EXECUTE,500
* EXECUTE DELTA REPORT SEQUENCE AS DESIGNATED IN TABLE DEL10LCU
        BYPASS,EXCEPT TABLE DEL10LCU(A,L501),GO TO 585
* REFINERY POLICY ROWS
        EXECUTE,501
        BYPASS,585
        BYPASS,EXCEPT TABLE DEL10LCU(A,L502),GO TO 590
* OXYGENATE POLICY ROWS
        EXECUTE,502
        BYPASS,590
        BYPASS,EXCEPT TABLE DEL10LCU(A,L503),GO TO 595
* CRUDE BALANCES FOB
        EXECUTE,503
        BYPASS,595
        BYPASS,EXCEPT TABLE DEL10LCU(A,L504),GO TO 600
* CRUDE BALANCES CIF
        EXECUTE,504
        BYPASS,600
        BYPASS,EXCEPT TABLE DEL10LCU(A,L505),GO TO 605
* NON-CRUDE BALANCES
        EXECUTE,505
        BYPASS,605
        BYPASS,EXCEPT TABLE DEL10LCU(A,L506),GO TO 610
* REFINERY UTILITY BALANCES
        EXECUTE,506
        BYPASS,610
        BYPASS,EXCEPT TABLE DEL10LCU(A,L507),GO TO 615
* OXYGENATE UTILITY BALANCES
        EXECUTE,507
        BYPASS,615
        BYPASS,EXCEPT TABLE DEL10LCU(A,L508),GO TO 620
* REFINERY STREAM BALANCES
        EXECUTE,508
        BYPASS,620
        BYPASS,EXCEPT TABLE DEL10LCU(A,L509),GO TO 625
* OXYGENATE STREAM BALANCES
        EXECUTE,509
        BYPASS,625
        BYPASS,EXCEPT TABLE DEL10LCU(A,L510),GO TO 630
```

```
* REFINERY UNIT CAPACITIES
        EXECUTE,510
        BYPASS,630
        BYPASS,EXCEPT TABLE DEL10LCU(A,L511),GO TO 635
* OXYGENATE UNIT CAPACITIES
        EXECUTE,511
        BYPASS,635
        BYPASS,EXCEPT TABLE DEL10LCU(A,L512),GO TO 640
* GASOLINE QUALITIES
        EXECUTE,512
        BYPASS,640
        BYPASS,EXCEPT TABLE DEL10LCU(A,L513),GO TO 645
* DISTILLATE QUALITIES
        EXECUTE,513
        BYPASS,645
        BYPASS,EXCEPT TABLE DEL10LCU(A,L514),GO TO 650
* RECIPE BLENDS
        EXECUTE,514
        BYPASS,650
        BYPASS,EXCEPT TABLE DEL10LCU(A,L515),GO TO 655
* REGIONAL DEMANDS
        EXECUTE,515
* COLUMNS SECTION
        BYPASS,655
        EXECUTE,516
        BYPASS,EXCEPT TABLE DEL10LCU(A,L517),GO TO 660
* CRUDE PRODUCTION
        EXECUTE,517
        BYPASS,660
        BYPASS,EXCEPT TABLE DEL10LCU(A,L518),GO TO 665
* RAW MATERIAL PURCHASES
        EXECUTE,518
        BYPASS,665
        BYPASS,EXCEPT TABLE DEL10LCU(A,L519),GO TO 670
* RAW MATERIAL TRANSFERS
        EXECUTE,519
        BYPASS,670
        BYPASS,EXCEPT TABLE DEL10LCU(A,L520),GO TO 675
```

```
* REFINERY UTILITY PURCHASES
        EXECUTE,520
        BYPASS,675
        BYPASS,EXCEPT TABLE DEL10LCU(A,L521),GO TO 680
* OXYGENATE UTILITY PURCHASES
        EXECUTE,521
        BYPASS,680
        BYPASS,EXCEPT TABLE DEL10LCU(A,L522),GO TO 685
* CRUDE SHIPPING/DISTILLATION
        EXECUTE,522
        BYPASS,685
        BYPASS,EXCEPT TABLE DEL10LCU(A,L523),GO TO 690
* CRUDE DISTILLATION
        EXECUTE,523
        BYPASS,690
        BYPASS,EXCEPT TABLE DEL10LCU(A,L524),GO TO 695
* REFINERY OPERATIONS AND INVESTMENTS
        EXECUTE,524
        BYPASS,695
        BYPASS,EXCEPT TABLE DEL10LCU(A,L525),GO TO 700
* OXYGENATE OPERATIONS AND INVESTMENTS
        EXECUTE,525
        BYPASS,700
        BYPASS,EXCEPT TABLE DEL10LCU(A,L526),GO TO 705
* INTERMEDIATE TRANSFERS
        EXECUTE,526
        BYPASS,705
        BYPASS,EXCEPT TABLE DEL10LCU(A,L527),GO TO 710
* INTER-REFINERY SHIPPING
        EXECUTE,527
        BYPASS,710
        BYPASS,EXCEPT TABLE DEL10LCU(A,L528),GO TO 715
* OXYGENATE SHIPPING
        EXECUTE,528
        BYPASS,715
        BYPASS,EXCEPT TABLE DEL10LCU(A,L529),GO TO 720
* GASOLINE BLENDING
        EXECUTE,529
        BYPASS,720
        BYPASS,EXCEPT TABLE DEL10LCU(A,L530),GO TO 725
```

```
* DISTILLATE BLENDING
        EXECUTE,530
        BYPASS,725
        BYPASS,EXCEPT TABLE DEL10LCU(A,L531),GO TO 730
* RECIPE BLENDS
        EXECUTE,531
        BYPASS,730
        BYPASS,EXCEPT TABLE DEL10LCU(A,L532),GO TO 735
* PRODUCT SHIPPING
        EXECUTE,532
        BYPASS,735
        BYPASS,EXCEPT TABLE DEL10LCU(A,L533),GO TO 740
* REFINERY-TO-REGION MAKE VECTORS
        EXECUTE,533
        BYPASS,740
        BYPASS,EXCEPT TABLE DEL10LCU(A,L534),GO TO 745
* REGIONAL PRODUCT SALES
        EXECUTE,534
        BYPASS,745
        ENDJOB
```

The functions of generator and report LCU's are discussed in more detail in the following section.

The following table lists input and output files from various kinds of OMNI run.

Command File	Input Files	Output Files
GENCOMP	Data and program files listed in GENCOMP	LISTING (LISTERR) DD and LCU files named in first line of GENCOMP
GENEXE	DD and LCU files	LISTING RECOUT1 (matrix file)
(optimizer)	RECOUT1	Solution listing SOLFILE
RPTCOMP	Data and program files listed in RPTCOMP DD and LCU files	Modified DD and LCU files LISTING (LISTERR)
RPTEXE	DD and LCU files PACKSOLN file or SOLFILE	LISTING RECOUT4 (report file)
TABGEN	OXYRYM file TABCHECK program file	TAB.DD and TAB.LCU RECOUT4 (report file)

The TABCHECK program is referred to in section C below.

Note that OMNI uses a number of standard file names (e.g. RECOUT1), and does not check whether, in writing a new file, an existing file of the same name will be overwritten. It is therefore up to the user to control whether over-writing occurs, by renaming any existing files which are desired to be kept before executing a further run.

B. Mainframe Job Control

Set out in *APPENDIX H* is a total job control stream from an illustrative **WORLD** model run on the EIA mainframe. Note that EIA run time rules generally exclude weekday daytime **WORLD** optimization runs; also that MPSIII does not adequately handle **WORLD** investment cases. Barrier optimizers such as OB1 and OSL are necessary to run **WORLD** effectively in investment mode.

The JCL stream is more complex compared to that for a PC run. It does however contain additional features. Most notable are the controls on job steps. The MPSSOLV optimize step is not run unless the W10GEN OMNI matrix generation step return code is 0. The W10REP OMNI report step is not run unless both the W10GEN and MPSSOLV steps return codes of zero.
[IBM JCL statement COND=(0,NE,W10GEN) translates into "if W10GEN return code is not 0 do not run this step".]

In other words these safeguards stop the run if there is any matrix generation error and stop the report step if there is any optimize result other than an optimal solution. Infeasible and unbounded solutions and major input or pre-solve errors return non-zero codes from MPSIII. One benefit is that it is immediately obvious whether the run has been successful. Wasted run time is avoided as is the risk of misinterpreting reports from an infeasible solution as being optimal.

C. File Organization

Data and program file organization on the PC and the mainframe follow the same general pattern. The main difference seen by the user relates to the much larger number of visible work files and file parameter definitions required for mainframe runs.

The preceding *Section 4.3.2* provides further details on typical OMNI file structure. *APPENDIX E* indicates the principal data files and their ***Table*** contents. In general, the sequencing of references to data files by OMNI SWITCH TO statements is not important.

4.3.3 Matrix Generation and Model Management Programs In Detail

A. Matrix Generation

LCU 75 provides for scaling of quality blending coefficients by forming and modifying a ***Table BSCAL***. It also performs calculations necessary for the evaluation of costs for investment cases by modifying ***Tables INVUNT*** and ***INVGEN*** (this portion is bypassed in non-investment cases). It further ensures that, in investment cases, ***Table REF*** has a non-blank entry in column MAX for each process unit; otherwise capacity increases would be prevented.

LCU 99 reads the gasoline and distillate master spec ***Tables MMGSP*** and ***MMDSP***, and the change spec tables according to the setting in ***Table CONTROL***, and creates individual regional spec ***Tables (Q)GSP*** and ***(Q)DSP***. The ***Tables (R)GBLND*** and ***(R)DBLND*** are created, which control the specification blending in refinery R so as to meet the specs in all demand regions supplied from refinery R.

LCU 100 creates ***Table ACU*** containing the atmospheric distillation yields for all model crudes using ***Table AVC*** (which contains all the data from assay crudes) and ***Table CRC*** (which shows how non-assay crudes are made up from assay crudes). It then ensures that any very small coefficients which have arisen are either "murdered" or rounded up.

LCU 101 applies scale correction factors to various numbers in the data tables. For instance, steam consumption is entered as lbs per barrel. When multiplied by the activity level in barrels per day, the units become lbs per day. For convenience in the sizes of the numbers, steam generation is expressed in lbs per hour, so a factor of 24 has to be applied. This type of scaling of numbers in the data tables is to be distinguished from matrix scaling discussed elsewhere. LCU 101 also applies inflation factors derived from ***Table INVGEN*** to the refining variable costs (OVC) to convert them to current year dollars.
LCU 102 is concerned with the calculations associated with lead blending in gasolines. This is not used in the **WORLD** model since all gasoline octane data are reduced outside the matrix to their equivalent lead-free values.

The most important function of LCU 103 is to modify the capacities in the (R)CAP tables to actual available capacities, taking account of stream day factors and utilization rates.

LCU 104 converts all API gravity qualities and specifications into specific gravities, so that gravity and sulfur specs may be correctly modelled (See *Section B* below on blending). The above LCU's are executed as part of the GENCOMP run, to ensure that the data tables are modified in readiness for the GENEXE run to generate the matrix.

The generation of the model starts with LCU 110, which outputs the NAME card and the ROWS section of the matrix. During this process, it creates tables (R)EXSTR and (R)EXUNT which list streams and units excluded by the data tables (See *Section B* below).

LCU 115 outputs the columns of the matrix representing capacity expansions (only in an investment case), crude and non-crude purchases, shipping vectors for crudes, intermediates and non-spec-blended finished products, and the processing activities. During this latter step, it creates ***Tables (R)XCOL*** which list process activities which cannot be used because their feed streams have been excluded by ***Tables (R)EXSTR***. Such activities are not generated.

LCU 116 creates the columns representing both specification and recipe blending, taking components from intermediate stream balance rows and placing the blended product in refinery balance rows. The shipping vectors for spec-blended products are generated here.

LCU 117 generates sales (demand) vectors. The sales vectors take product out of the regional demand balance row.[20] The vectors are generally bounded, to represent the regional product demand, and also carry the sales revenues for those products whose sales are not fixed in quantity.

LCU 120 creates the RHS and LCU 125 creates the bounds section. This completes the generation of the model.

[20] Other entries into the regional product demand rows are product import and export vectors.

B. Model Size Management

MATRIX REDUCTION BY THE OPTIMIZER

Most optimizers contain procedures for matrix reduction, i.e. the conversion of the model as input by the user to a smaller but mathematically equivalent model. This is done by

(a) eliminating vectors which can be shown to be fixed at zero by the conditions of the problem,

(b) eliminating rows which can be shown to be non-constraining by the conditions of the problem, and

(c) eliminating rows and columns which contain no elements as a result of previous deletions.

In carrying out this analysis, it may be found that certain rows cannot possibly be satisfied, i.e. the problem as set is infeasible. This constitutes valuable evidence of some error in model data or structure. Of course, the failure of the reduction process to detect infeasibilities does not mean that no infeasibilities exist; the final test is whether the optimizer can find a feasible solution.

A further reduction step is available with most optimizers, in which a row is found which effectively defines one vector as the (possibly weighted) sum of a number of others. This enables that vector and that row to be eliminated.

The result of matrix reduction is that, for example, if a given process unit has zero capacity in a given case, its processing vectors and the streams which that unit alone produces are eliminated from the model. If a given crude is not available, its shipping and processing activities are removed. The process unit and the crude are retained in the input data tables, however, since they may be required for other cases.

In the **WORLD** model, crude oils are supplied to regional balance rows from which they are distributed to the refineries of the region. The vector supplying the regional row must equal the sum of the vectors taking crude to the refineries in the region. Thus, that vector and the regional balance row may be removed wherever there is only one refinery in a region. The marginal value on that row represents the CIF value of the crude, and if that row were permanently removed, the CIF value would have to be calculated. However, once the solution is obtained, the removed rows and columns are restored and the CIF value becomes available for inspection.

MATRIX REDUCTION BY **WORLD OMNI CODE**

The availability of a REDUCE procedure in all first rank optimizers means that the user need not be overly concerned that his model contains a number of redundant rows and columns. However, there is some advantage in not generating such redundant parts of the model in the first place. The PC RECOUT1 file for the WORLD model is commonly several megabytes in size, and can only be saved on a floppy disk using data compression. The reading, writing and inspection of such large files is slow. EnSys' experience has been that incorporating extra code to reduce matrix size can shorten total generation time since the extra time to run the additional code is outweighed by the saving in writing a smaller MPS matrix file.

The **WORLD** system currently manages model size by means of three input data tables, EXSPEC, EXCAP and EXPOL.

Table EXSPEC is brought into play only if the entry in ***Table CONTROL***, row SPC is non-blank. If this is so, then only those specifications with non-blank entries in ***Table EXSPEC*** are generated anywhere in the model. Further control is exercised through ***Tables W, S and Y)Q)GSP***, by means of which gasoline specifications may be controlled for individual regions. ***Tables W, S and Y(Q)DSP*** serve a similar function for distillate specs.

The columns of ***Table EXCAP*** are process units and those of ***Table EXPOL*** are ***Tables (R)POL*** constraints. The rows of both tables are intermediate streams. Non-blank entries under the respective columns show which streams would be excluded if the corresponding process unit were absent (***Tables (R)CAP***) or if the corresponding mode of operation were excluded (***Tables (R)POL***).

From these input data tables, the generator program develops three more sets of refinery-specific tables, ***(R)EXSTR, (R)EXUNT*** and ***(R)EXCOL***.[21] The ***(R)EXSTR*** tables list, for each refinery, those streams actually excluded by tables ***(R)CAP*** and ***(R)POL*** for the case generated. Similarly, tables ***(R)EXUNT*** list those units actually excluded by ***Tables (R)CAP*** by reference to a master list of process units in ***Table INVUNT***. The ***(R)EXCOL*** tables list those operating modes of the process units which depend upon feed streams which have been excluded. Generation of row names and column vectors is dependent upon what appears in these tables.

The result of this processing of input data via "EX" tables is that all product specifications, process units, processing vectors, blending vectors, and intermediate streams not

[21] These are internal OMNI tables which the user generally does not see.

needed for the case are not generated. The effect on matrix and file sizes and read/write and optimize times can be substantial, especially when **WORLD** is being run against a near term horizon when forward-looking units, products, qualities, etcetera, are not relevant. The impact for a model run examining a long-term scenario with reformulated fuels and investment open will, conversely, be more limited.

The EXSPEC facility for controlling product specifications is particularly valuable in enabling **WORLD** to adjust from quick (low definition) screening studies to detailed studies of new or military fuels.

C. Model De-Bugging

It is clearly important that the model correctly depict material balance. This is not a simple matter in a volume-based model, particularly when some streams (e.g. the light gases hydrogen, hydrogen sulphide, methane, ethane) are measured in barrels FOE, and some other streams (e.g. coke and sulfur) are in short tons. Each processing vector in the model has an entry in a LOS row, which is simply the number which has to be added to the other yield figures to make the total zero; a positive figure represents a volume loss, a negative one a gain.[22] Given the disparity of units, this is not entirely satisfactory.

An OMNI program, TABCHECK, has been written which checks each column of the processing data tables to ensure that the LOS figure is correct. The program is also designed to carry out a mass balance over each column of the process tables, using gravity data from model blending tables with additions for minor streams. The goal is to ensure that the model is in mass balance. The program has recently been extended to provide a sulfur balance over each process activity.

The program TABCHECK produces a RECOUT4 file (the standard OMNI name for a report program output) which lists those streams for which gravity data are not available, and then the volume, weight and sulfur balances for each column of each processing data table. It also produces back-calculated API gravity and sulfur content for each crude atmospheric distillation vector.

The extended functions of program TABCHECK have recently been extended. It can now be made to output

- a list of differences in component qualities between tables GCB and DCB,

[22] The LOS row entry in effect represents the combination of volume gain and weight loss across the unit.

- a table CAPEX which is a generated version of EXCAP designating streams which originate on only one process unit,

- a table POLEX, a generated version of EXPOL designating streams which only originate in activities subject to Tables (R)POL constraints,

- a list of missing qualities required for specification blending calculations. (If a required component quality is missing, OMNI does not report the fact; it merely fails to generate the matrix element).

- volume, weight and sulfur balances on user-selected units

4.3.4 Matrix Diagnostics, Optimization and Analysis Programs In Detail

A. Overview of Optimizer Functions

There are now available two fundamentally different types of LP optimizer, those using the Simplex method and those using the more recently invented barrier method. Geometrically speaking, the feasible region (the region, in the multi-dimensional space defined by the activities of the matrix, within which lie the points representing solutions satisfying the constraints) is a hyper-polygon bounded by the hyper-planes representing the constraints.

It was realized very early in the history of linear programming that any unique optimal solution must lie at a vertex of this hyper-polygon. The algebraic equivalent of the geometrical vertex is a "basic" solution. The Simplex algorithm moved from one basic solution to another, continually improving the solution until no further improvement was possible. The barrier method starts from some point within the hyper-polygon and thence travels in the direction which improves the solution fastest, until it is close to the optimal value. Depending on the algorithm, the program may then revert to Simplex for the final stages of the optimization and/or to verify optimality.

Each type of optimizer has its advantages and disadvantages. Simplex optimizers vary considerably in speed and stability, but they share certain characteristics:

- the time taken to solve problems of similar complexity but differing size varies roughly with the number of rows raised to a power between 2 and 3,

- the complexity of the model is a significant parameter in determining solution time, or indeed, solubility. (Complexity is measured by the density of non-zero coefficients or by the average number of such coefficients per column. In this connection, it may be noted that the REDUCE process may decrease the size of a model at the expense of increased complexity).

- it is possible to "save a basis" (which is a shorthand way of characterizing a "basic" solution) and restart the same or a similar problem from an advanced stage of the computation,

Barrier optimizers are as yet less well tried, but ENSYS' experience tends to show that:

- the time taken to solve problems of similar complexity but differing size is more nearly directly proportional to the number of rows,

- the complexity of the model has little impact on solution time (indeed the method was originally developed in an attempt to solve a highly complex model which was almost insoluble by the existing Simplex methods),

- the concept of a "basis" is foreign to the barrier methods. An optimal basis may be saved (since the optimal solution is, by definition, basic) but it cannot be used to restart a barrier-type computation or reduce the time to find the optimal solution for a slightly modified problem.

- an optimization which is started in barrier mode may decide to switch to Simplex at some stage. There is no way to return to barrier optimization once this has happened. This appears to be a sign that the optimal solution is not far away, or that the problem is infeasible.

B. Matrix Error Analysis

There are three points before the optimization starts where errors may be indicated:

1. on running the OMNI programs to read the data and generate the model. This may indicate missing or garbled data Tables, or incorrect path names to the data or program files. **Ensure that RETURN CODE 0 is obtained on each run.**

   *(If the RETURN CODE is not zero, it takes the form 10n, where the digit n indicates the severity of the most severe error detected. In order to locate errors, it is recommended that the file LISTING is searched for the error messages beginning *E*. Use LIST,ON and LIST,OFF in GENCOMP and GENEXE to control which portions of the input data appear in the LISTING file.)*

2. on INPUT of the model to the optimizer. Ensure that the reason for each message produced by INPUT is understood (some may be important, others not). The messages may indicate, for example, that a row mentioned in the COLUMNS section is not in the ROWS section, or a BOUND has been applied to a non-existent column.

3. on REDUCE. Optimizers differ widely on the usefulness of the messages output at this stage. OSL is particularly poor; if it finds the model infeasible, it may list only the first infeasible row found; there may be many others.[23] If REDUCE does not find infeasibilities, there are no useful messages at all, beyond the size of the reduced matrix. (Since OSL produces a non-readable file called REDUCE.OSL which enables the full solution to be restored, this situation would appear to be rectifiable). MPS III 'TRACE', on the other hand, provides a detailed list of all structural errors, of all rows and columns eliminated via a three-pass REDUCE, and of structural infeasibilities found in the matrix. Clearly, this serves as a very useful diagnostic tool.

C. Sample Optimizer Control Programs

1. MPS III (Simplex)

Set out below is a sample MPSIII control file as used on the EIA mainframe for **WORLD model runs. MPSIII has numerous features for which detailed reference should be made to the MPSIII manual or to Ketron support. The following are brief comments only and are not intended to be exhaustive.**

[23] If OSL produces an error message of the form "the intersection of row rrrr and column cccc means the solution will be infeasible by xxx.xx", this indicates OSL has found a structural infeasibility. OSL identifies row rrrr and column cccc by number only. To identify the row and column by name, it is necessary to restart OSL using INPUT or GETPROB to reactivate the matrix, then to run SOLUTION straight away, exit OSL and inspect the SOLUTION printout which identifies rows and columns by name as well as number.

general

- the control program is set up to automatically take appropriate actions depending on the run outcome, namely:

- to output optimal basis (MAPOUT), solution print (SOLUTION "ACTIVE") and solution file ("SOLUTION "STANDARD") when the result is an optimal solution

- to output final infeasible basis, solution print and return code 1 (XCCODE=1) when the result is an infeasible (or unbounded) solution (XDONFS)

- to stop and issue a return code of 1 if major errors are encountered, usually on CONVERT, SETUP or TRACE. (Internal MPSIII macro XDOMAJERR performs these actions by default unless redirected otherwise.)

specific

- TITLE causes a run title to be printed at the top of every solution page and to be included in the solution file; useful for identifying each run

- CRASH, MAPIN and WHIZMAPN represent alternative optimization starting methods. CRASH is appropriate if no good starting basis is available. MAPIN brings in a card image basis file, e.g. an optimal file from a previous slightly different run. WHIZMAPN brings in an internal format basis from the file WHIZFILE. This method must only be used **where the previous problem is absolutely identical in structure to that now being started**.

- WHIZARD is the main MPSIII optimization strategy control macro and contains many options:

- TRACE is a powerful debugging tool. It takes the matrix through a three stage successive matrix reduction, printing each finding or action taken on matrix redundancy. It also reports structural infeasibilities. **Output from CONVERT (matrix input), SETUP and TRACE should always be carefully checked, especially when developing or applying a new model version.**

- 'FREQ' SAVIT effects a save of the internal format basis to the WHIZFILE with an iteration frequency determined by the value in DC cell SAVIT

- MAPOUT saves a card image external basis file. This is usually invoked after completion of optimization, for saving a final - hopefully optimal - basis, or for periodic saves of intermediate bases according to an XDOFREQn iteration frequency[24]

- SOLUTION plain or "ACTIVE" outputs a solution print file. "ACTIVE" causes only those columns/vectors which are active to be included in the print file. This is valuable in substantially reducing solution print file size, search times etc. Note though that vectors which in the basis but at zero activity are included.

- SOLUTION "NAMES" lists infeasibilities at the top of an infeasible solution.

- SOLUTION "STANDARD" outputs a solution file in format readable by OMNI.

[24] Note, MPSIII appears to have difficulty with *WORLD* runs in restarting from the same solution point if either an internal basis save to WHIZFILE of an external MAPOUT basis save is invoked. This leaves the user in the unenviable position of having to avoid intermediate saves in order to keep the run stable.

SAMPLE WORLD EIA MAINFRAME MPSIII CONTROL STREAM

```
                    PROGRAM('ND')
                    TITLE('"NPC" CASE LO DMD NO SUBSTIT SEV SPEC - LOW CKL DMD')
                    INITIALZ
                    ASSIGN('CEMMPS','CEMMPS','CARD')
                    MOVE(XDATA,'CEM')
                    MOVE(XPBNAME,'CEMREGD')
                    CONVERT('FILE','CEMMPS')
                    WRITE('*** CONVERT COMPLETE ***')
                    MOVE(XOBJ,'OBJ')
                    MOVE(XRHS,'RHS')
*  XSETLB =0 SETS NON BASIC VECTORS AT UB, =-1 AT LB
*  USED TO SET INV VECTORS NOT IN BASIS AT ZERO NOT UB
                    XSETLB=-1
                    XFREQINV=50
                    SETUP('BOUND','BND','MAX')
                    WRITE('*** SETUP COMPLETE  ***')
                    XFREQLGO=200
                    XFREQLGA=200
*                   XFREQ1=20000
*                   XFREQ1=5
*                   XEPS=.00001
                    MVADR(XDONFS,LOOK)
*                   MVADR(XDOFREQ1,SAVBAS)
*                   MAPIN ('FILE','INBASIS')
*                   CRASH
                    WHIZMAPN
                    WHIZARD('NOFE','MERIT','STABLE',STBIT,'FREQ',SAVIT)
*                   WHIZARD('NOFE','TRACE','STABLE',STBIT,'FREQ',SAVIT)
*                   WHIZARD('NOFE','MERIT','STABLE',STBIT,'FREQ',SAVIT)
*                   WHIZARD('NOFE','MERIT','FREQ',SAVIT)
*                   WHIZARD('NOFE','MERIT','DUAL','FREQ',SAVIT)
*                   WHIZARD('NOFE','TRACE','FREQ',SAVIT)
*                   WHIZARD('DUAL','NOFE','TRACE','FREQ',SAVIT)
*                   WHIZARD('DUAL','NOFE','TRACE')
*                   WHIZARD('NOFE','TRACE')
*                   PRIMAL
                    MAPOUT('FILE','BASIS')
                    WRITE('*** WHIZARD COMPLETE ***')
```

```
           CLOSEF('BASIS')
           WRITE(' *** BASIS SAVED ***')
           SOLUTION('ACTIVE')
*          SOLUTION
           EXEC(PERUZIT)
           EXIT
LOOK       WRITE('NO FEASIBLE.. SOLUTION')
*          SOLUTION('ACTIVE')
           SOLUTION('NAMES')
*          EXEC(PERUZIT)
           MAPOUT('FILE','BASIS')
           XCCODE=1
           EXIT
PERUZIT    WRITE('BEGIN PERUSAL')
           SOLUTION('STANDARD','FT03F001')
           STEP
SAVBAS     WRITE('SAVE BASIS    ')
*          SOLUTION('ACTIVE','NAMES')
*          XCCODE=1
*          EXIT
*          MAPOUT('FILE','BASIS')
           CONTINUE
SAVIT      DC(5000)
STBIT      DC(5)
           PEND
```

2. OB1 (Barrier)

Set out below is an illustrative EIA mainframe run taken from an EnSys **WORLD** test case run late in 1991. Note that OB1 requires 32 megabytes of (virtual) memory *[REGION=(32M)]*. Under EIA mainframe rules, this eliminates daytime running regardless of required run time.

Several other points are worth noting:

- OB1 uses a large number of FORTRAN work files.

  FT24001 is the input MPS format matrix ("RECOUT1") file.

  FT36 through 41 include card image basis output and matrix reduce files.

- the OB1 control program is comparatively short. One key command is REORDER. Use of REORDER 5 suggested by LPI was found to cut TRIP or **WORLD** optimize time by half.

Future OB1 runs should be set up on the advice of its suppliers.

```
//OB1STEP    EXEC PGM=OB1,TIME=(99,59),REGION=(32M),
//*          COND=(16,NE,W10GEN)
//           COND=(0,NE,W10GEN)
//STEPLIB    DD DSN=SYS3.OB1.V0.LOADMODS,DISP=SHR
//FT05F001   DD DUMMY
//FT06F001   DD SYSOUT=A
//FT24F001   DD DSN=CN6134.PRJ.ENSYS.CEM.W10BCD2,DISP=SHR
//* WORLD 2000 BAU CRUDE MIX CASE
//FT25F001   DD SYSOUT=*,DCB=(LRECL=140,BLKSIZE=140,RECFM=FBA)
//FT26F001   DD DUMMY
//FT28F001   DD SPACE=(TRK,(50,50)),UNIT=SYSDA
//FT30F001   DD SYSOUT=*,DCB=(BLKSIZE=133,RECFM=VBS)
//FT34F001   DD SPACE=(TRK,(50,50)),UNIT=SYSDA
```

```
//FT35F001      DD DUMMY
//FT35F001      DD DSN=CN6134.PRJ.ENSYS.CEM.OB1SOLN,
//*                UNIT=DASD,DISP=(NEW,CATLG),
//                 UNIT=DASD,DISP=SHR,
//                 SPACE=(CYL,(4,1),RLSE,CONTIG),
//*                DCB=(RECFM=VBS,LRECL=251,BLKSIZE=2510)
//                 DCB=(RECFM=VBS,LRECL=204,BLKSIZE=2044)
//FT36F001      DD DSN=CN6134.PRJ.ENSYS.CEM.W20BSOB1,
//                 DISP=SHR
//FT37F001      DD SPACE=(TRK,(50,50)),UNIT=SYSDA,
//                 DCB=(RECFM=U,DSORG=PS)
//FT39F001      DD DSN=CN6134.PRJ.ENSYS.CEM.W20BSOB2,
//                 DISP=SHR
//FT40F001      DD DSN=CN6134.PRJ.ENSYS.CEM.W20BSOB3,
//                 DISP=SHR
//FT41F001      DD DUMMY
//*FT41F001     DD DSN=CN6134.PRJ.ENSYS.CEM.W20BSOB4,
//*                DISP=SHR
//FT42F001      DD DUMMY
//FT29F001      DD *
BEGIN
* WORLD ENSYS MODEL
NAME            CEM
METHOD 2
INITIAL BOUNDED
REORDER 5
MAXIMIZE
OBJECTIVE       OBJ
RHS             RHS
BOUNDS          BND
PRINT   SOLUTION  1
PRINT   OMNI 1
PRINT   BYVALUE 2
END
/*
//
```

3. OSL (Either Simplex or Barrier)

ENSYS' experience is mainly with the Haverly Systems version of the IBM Optimization Subroutine Library. This provides a number of commands which interface with the IBM subroutines. A run may be conducted interactively or using a command file. The former mode displays to the monitor screen but requires the user's intervention from time to time. The latter mode runs without supervision but records the run only to a disk-file which cannot be inspected (i.e. there is no output to screen) while the run is in progress.

A typical command stream would be (note - this is NOT how comments should be included):

```
input,file=<matrixfilename>
set,rmaxmin=-1                 ; maximization, +1 to minimize
reduce                         ; with optional type parameter
loadbas,file=<basisfilename>   ; if Simplex and if basis available
solve,init=0                   ; if Simplex and if basis available
solvebar,alg=3                 ; if barrier - optional algorithm
solution,file=<filename>       ; printable solution file
savebas,file=<basisfilename>   ; if required
filesol,dataname=<dataname>    ; output SOLFILE if reports required
end
```

4.3.5 Reporting and Results Analysis

A. Main Reports

The output of the report program may be controlled by the user. ***Table REPLCU*** specifies which LCU's are to be executed.

LCU 4800 is optional but LCU 200 must always be executed. LCU 4800 outputs a title page. LCU 200 performs various initialization tasks.

LCU 205 reports CRUDE SHIPPING BY DESTINATION. For each crude in the model, ordered by destination, it lists the destination, the grade (as defined in ***Table CRDAV***), the quantity shipped and the CIF value. For those regions to which Saudi Light is also shipped, the CIF differentials versus Saudi Light are reported.

This LCU also produces a second report, TOTAL CRUDE RUN BY TYPE AND SOURCE FOR EACH REGION. For each region a table is output, the rows of which categorize crudes into groups by API and sulfur, the columns being the regions of origin of the crudes.[25]

LCU 212 reports CRUDE SHIPPING BY ORIGIN, listing individual crudes ordered by region of origin and giving the destination, quantity and CIF value.

LCU 214 outputs a REGIONAL PRODUCT BALANCE report for each region, showing how regional demand for each finished product is met by a combination of refinery production, imports and exports. This report is only meaningful where crude supply, non-crude supply, refining and demand regions have been defined as co-incident.

LCU 215 produces three reports, each listing all the products and all the regions. The first shows quantities of product, the second the value and the third the cost to the consumer, obtained by multiplying the quantity and the value. The "values" of the products are the marginal values on the regional product demand rows, and represent the equilibrium spot prices for the products in international trade.

LCU 216 and 217 perform the same function as L215 but for U.S. and non-U.S. regions respectively.

[25] The original intent of this report was to allow the user to identify the main changes occurring in regional crude slates - in terms of crude types and origins - without being "snowed" by masses of detail on single crudes.

LCU 219 is the PRODUCT SHIPMENT REPORT, detailing all movements of finished product between regions. It shows the regions of origin and of destination, the quantities and the shipping cost (which is a model input).

LCU 221, the INTERMEDIATE STREAM SHIPMENT REPORT, does the same for movements of unfinished product.

LCU 224, the NON-CRUDE TRANSFER REPORT, shows how non-crude inputs are distributed among the refineries.

LCU 225 outputs a number of report tables; first, the CRUDE/PRODUCT SUMMARY REPORT BALANCE. This totals, for each regional refinery:

- the crude production, imports and exports, and hence the quantity refined in the region,
- the inputs of non-crudes,
- the imports and exports of unfinished products,
- hence the total regional input,
- the total regional product make, and finally,
- the gain or loss over the region as a whole.

Note that this balance excludes any input of natural gas, and it does not count the production of refinery fuel or catalyst coke.

Then follows a report on MERCHANT PLANT OXYGENATES and their disposal.

Next the REGIONAL REFINERIES EIA CATEGORIES BALANCE REPORT, which shows, for each refining area, the total inputs of crude, non-crude and unfinished products, and the output of each finished product, FCC catalyst coke, refinery fuel, and hence an overall gain/loss. The intent of this report is to show regional balances on the same basis as that used by EIA and IEA.

There is next a report on the utilization of natural gas by region, the amount used as fuel and as input to the hydrogen generation plant. These are given both in barrels

FOE and in MMscf. Associated adjustments to the REGIONAL REFINERIES EIA CATEGORIES BALANCE REPORT due to the inclusion of natural gas are also shown.

Finally for LCU 225, there is a report on the severity of operation of cat reformers and cat crackers by region, and the fraction of residue in feed to the FCC.

LCU 226 provides the CAPACITY UTILIZATION REPORTS, one table for each region showing available capacity and throughput for each unit. When a unit is fully utilized, a marginal value is also given, which indicates the incentive to expand capacity.

LCU's 239, 240, 245, and 246 are little used since they generate highly detailed refining operations reports. EnSys has not attempted to fully maintain these reports, namely:

LCU 239	Refinery ECONOMIC SUMMARY
LCU 240	Refinery ACCOUNTING SUMMARY
LCU 245/246	Refinery PRODUCT BLENDING REPORTS

LCU 246 reports only on those blended products (normally low volume, specialized distillate blends) which are listed in ***Table REX*** in file MTFIXREP. For those blends which are reported, the composition in terms of blend components, the qualities and, when the specification is limiting, the quality marginal value are listed.

LCU 250 reports on gasolines identified in ***Table EPA*** as under emissions control, i.e. which have active VOC, TAPs and prospectively NOx emission reduction specifications simulating the EPA Simple or Complex Model equations. The report set out relevant gasoline blend volumes and qualities by production region/ refinery and also reports by demand region. Summer versus Winter situations are differential (based on ***Table CONTROL*** flag **SSN**). Summer Class B versus Class C volatility region blends are reported separately. (These are defined by where the third character of the gasoline blend name and the emissions reductions specification names is a B or a C.)

LCU 280, which is available for investment cases, gives the INVESTMENT REPORTS. These detail, for each region, the amount of unit expansion for each process, and the capital and fixed operating costs attendant upon such expansion, together with regional cost totals.

LCU 300 provides a GLOBAL ECONOMIC SUMMARY. For each region the total cost of finished products is given as the Consumer Cost. This is apportioned between payments to the region's crude and non-crude suppliers, and refining rent and variable costs. Shipping costs are arbitrarily divided 50/50 between source and destination regions. The total consumer cost minus the total of payments to the regional industry may be positive (for regions which are net importers of oil and exporters of cash) or negative (for net exporters of oil and importers of cash). The figure is indicative of the balance of payments for each region, and, when summed over all the regions, should of course be zero.

LCU 320 reports on capacity utilization of transportation modes.

B. Delta Reports

The purpose of the DELTA REPORT is to highlight differences between two solutions. To run the delta report, a PACKSOLN file must be created containing at least two solutions.

In principle, it lists differences in

- slack activities on rows,
- marginal values on rows,
- activity levels on columns, and
- d_j values on columns

The differences that are reported are controlled by the user in two ways:

1. percentage deltas below a user-determined level are not reported

2. absolute deltas below a user-determined level are not reported whatever the percentage change

For process capacity rows, the row activity is of more interest than the slack activity. The critical percentage change may be set at a different level for capacity rows than for other rows.

The critical differences are set in ***Table DELSIZE***. ***Table DEL10LCU*** also permits the user to select on which categories of rows and columns the program will report.

5 WORLD MODEL DATA TABLES

This section describes in detail the function and content of the **WORLD** model data tables. *APPENDIX E* summarizes the data tables and the typical associated file structure. *APPENDIX F* lists by category the model row and column codes used in data tables. *APPENDIX G* lists row and column codes in alphabetical order.

CASE DATA

CASE DATA - CRUDE AND NON-CRUDE AVAILABILITIES (FILE CRDNCP)

Table CRDAV	Crude oil availabilities
Tables (Q)NCP	Availabilities of non-crude inputs region Q
Table YPRDMD	Availabilities of products from Eastern Bloc (treated as negative demands)
Table YINTDMD	Availabilities of intermediate products from Eastern Bloc (treated as negative demands)

The latter two tables could be multiplied for other non-refining regions. Further-more, positive demands may be inserted to represent "sinks" for products.

CASE DATA - PRODUCT DEMANDS (FILE DEMAND except ***Table YPRDMD*** which is in file CRDNCP)

Tables (Q)PRDMD	Product demand in region Q

CASE DATA - REFINING (FILE REFCAP)

Table CONTROL	Investment and specification control flags
Table REF	Refineries and regions
Tables (R)CAP	Refining capacities - refinery R
Tables (R)POL	Refinery controls - refinery R
Tables (R)UAP	Utility purchases - refinery R
Tables (Q)CAP	Refining capacities - oxy-refinery Q
Tables (Q)POL	Refinery controls - oxy-refinery Q
Tables (Q)UAP	Utility purchases - oxy-refinery Q

CASE DATA - QUALITIES (FILE AVSPEC)

Table EXSPEC	Gasoline and distillate specs reduction
Table MMDSP	Master distillate/fuel oil specifications
Tables W(Q)DSP	Changed specs - region Q - winter
Tables S(Q)DSP	Changed specs - region Q - summer
Tables Y(Q)DSP	Changed specs - region Q - year average
Table OCTWT	Global octane weightings
Table MMGSP	Master gasoline specifications
Tables W(Q)GSP	Changed specs - region Q - winter
Tables S(Q)GSP	Changed specs - region Q - summer
Tables Y(Q)GSP	Changed specs - region Q - year average

SHIPPING DATA - CRUDES (FILE CRDDISP)

Table CRDDISP	Permitted crude movements

SHIPPING DATA - CRUDES (FILE CRDTRAN)

Table CRDTRAN	Crude shipping costs

SHIPPING DATA - PRODUCTS (FILE PRDTRAN)

Tables (R)PRDTRAN	Finished product shipping costs ex refinery R
Tables (Q)PRDTRAN	Finished product shipping costs ex non-refining region
Tables (R)INTRAN	Intermediate product shipping costs ex refinery R
Tables (Q)INTRAN	Intermediate product shipping costs ex oxy-refinery or non-refining region

SHIPPING DATA - MODES/CAPACITIES (FILE TRMODES)

Table TRMODES	Transportation modes and associated losses
Table TRCAPS	Transportation mode capacities

CASE DATA - BOUNDS ON SPECIFIC ACTIVITIES (FILE VECBNDS)

Table VECBNDS	Bounds on specific activities

In considering the data tables it should be remembered that, in the OMNI language, a blank table entry is not the same as a zero entry. Also that in OMNI it is possible to test for the existence of a non-blank entry irrespective of its value. Thus, when reference is made to a non-blank entry, any entry is equally effective.

5.1 MODEL STRUCTURE AND CONTROL TABLES

MODEL GENERATION CONTROL

TABLE REF	***REFINERIES AND REGIONS***
Column names	Four columns, IN, US, REC and LOC, plus one column for each region.
Row names	Eight rows, IN, CR, OX, DM, SD, US, REC and LOC, plus one row for each refinery.

Entries

Row **IN**, column IN must be left blank.

A non-blank entry in row **IN** indicates that the corresponding region is to be included in the model.

A non-blank entry in row **CR** indicates that the region is a crude origin region. The origin region for each crude is designated as a fourth character added to the crude type designator in ***Table CRDDISP***.

A non-blank entry in row **OX** indicates a "non-crude supply/ merchant oxygenate" region. This is a pivotal region type in the model and combines several functions:

1. "point of entry" into the model via ***(Q)NCP tables*** of regional non-crude inputs including NGLs, methanol, other non-crudes and natural gas
2. production of "merchant" oxygenates
3. "gathering point" for crudes shipped from regions of origin that are then processed in any refinery associated with the "oxy" region.

In general, an "oxy" region will have at least one refinery associated with it.

A non-blank entry in row **DM** indicates that the region is a demand region with a ***(Q)PRDMD table*** and represents a product "sink".

A non-blank entry in row **SD** indicates a "foreign" supply/demand region with ***(Q)PRDMD*** and ***(Q)INTDMD tables*** representing either a "source" or a "sink" of products and intermediates.

A non-blank entry in row **US** indicates that the region is to be considered part of the U.S. for import/export reporting purposes. Similarly, a non-blank entry in column **US** shows the corresponding refinery to be a U.S. refinery.

A non-blank entry in row **MU** indicates that there is more than one oil refinery in the region. (This feature is no longer used under the new designation of different region types.)

A non-blank entry in a row corresponding to a refinery indicates that the refinery belongs to the corresponding **OX** region. An **OX** region may have more than one refinery, but not vice versa. Note that the key associated is now refinery to **OX** region. A refinery is no longer associated with a "local" demand region.

A non-blank entry in column **IN** indicates that the corresponding oil refinery is to be included in the model.

Row **REC** contains assumed capital recovery factors (per cent per annum) for each region (used for investments in oxy-refineries).

Row **LOC** contains assumed location factors for investment in regional oxy-refineries (ratios relative to US Gulf).

Columns **REC** and **LOC** contain capital recovery factors and location factors respectively, for investment in conventional refineries.

Note that the former restriction that a column name denoting a region could not be also the initial letter of the columns IN, LOC, REC, etc has now been removed.

TABLE CONTROL *INVESTMENT AND SPECIFICATION CONTROL FLAGS*

Column names One column, SET.

Row names Three rows, INV, SPC, SSN.

Entries A non-blank entry in row INV causes investment activities to be generated. A non-blank entry in row SPC activates ***Table EXSPEC*** (see below) and only those specifications indicated there will be generated.

An entry in row **SSN** must be present and must be either 1, 2, or 3 where:

1. causes generation of Year-round average specifications
2. causes generation of Winter specifications (Northern Hemisphere regions)
3. causes generation of Summer specifications (Northern Hemisphere regions)

TABLE EXCAP *STREAMS EXCLUDED BASED ON ABSENCE OF UNIT IN TABLE CAP*

Column names Process unit codes.

Row names Intermediate stream codes

Entries A non-blank entry indicates that, if the unit is absent from ***Table CAP***, the corresponding intermediate stream cannot exist and that part of the matrix structure which applies to that stream is not to be generated.

TABLE EXPOL *STREAMS EXCLUDED BASED ON PRESENCE OF FIX 0 OR MAX 0 IN A TABLES (R)POL ROW*

Column names Constraint codes named in ***Tables (R)POL***.

Row names Intermediate stream codes.

Entries A non-blank entry indicates that, if the constraint is fixed at zero in ***Tables (R)POL***, the corresponding stream cannot exist and that part of the matrix structure which applies to it is not to be generated.

TABLE EXSPEC ***GASOLINE AND DISTILLATE SPECS REDUCTION***

Column names: Quality codes

Row names: 3-character product code followed by a single character N or X signifying a miNimum or a maXimum constraint.

Entries: A non-blank entry signifies that the corresponding quality constraint is to be generated. Conversely, a blank prevents the constraint from being generated. ***Table EXSPEC*** only takes effect if the correct flag is set in ***Table CONTROL***. These three EX tables constitute a system which optionally limits the size of the generated model.

MODEL REPORTING CONTROL

TABLE REG ***ESTABLISHES HOLLERITH FOR REGIONS***

Column name: Arbitrary

Row names: Region codes, crude origin, non-crude supply, "oxy" and demand regions

Entries: Immaterial: report program does not refer. The entire purpose of the table is to allow 6-character Hollerith to be attached to the region codes for use by the report writer.
Note, region sequence must be the same as in ***Table REF***.

TABLE EPA ***IDENTIFIES GASOLINE BLENDS FOR EMISSIONS REPORTING***

Column name: One column, A

Row names: First two characters of three-character reformulated or conventional gasoline blend names (the third character of the blend name being either B for Class B volatility region or C for Class C).

Entries — A non-blank entry causes the emissions report to search for gasoline blend names with the row entry as the first two characters plus B or C, e.g. RGB, RGC.

TABLE REPLCU — SPECIFIES WHICH REPORT LCU'S ARE TO BE EXECUTED (MAIN REPORT)

Column names — One column, R

Row names — L followed by main report LCU numbers

Entries — A non-blank entry causes the corresponding main report LCU to be executed when the report program is run. The row Hollerith describes which reports will be obtained.

TABLE DEL10LCU — SPECIFIES WHICH REPORT LCU'S ARE TO BE EXECUTED (DELTA REPORT)

Column names — One column, A

Row names — L followed by delta report LCU numbers

Entries — A non-blank entry causes the corresponding delta report LCU to be executed when the report program is run. The row Hollerith describes which classes of matrix rows and columns will be included in the comparison.

TABLE DELSIZE — SPECIFIES PARAMETERS FOR DELTA REPORT

Column names — Five columns A to E

Row names — Variable number of rows named 1 and upwards

Entries — The delta report program compares two solutions. It reports on differences in row slack or pi value, or column activity or dj value.

For unit capacity rows, however, it reports on row activity, not slack.
Columns A to D define tranches of percentage change for the delta report.
Column A defines the upper, and column B the lower, limit for each tranche. As many tranches may be defined as desired.
Changes smaller than the percentage in the last row of column B are not reported.
Columns C and D apply to the section of the report dealing with unit capacity rows, where slack is replaced by row activity.
Column E has values in rows '1' and '2' only. Row '1' defines the smallest absolute change in row slack or column activity which is reported and row '2' the smallest absolute change in row pi value or column dj.
The row Hollerith refers only to columns A to D.

TABLE OBJFN ***SPECIFIES NAME OF OBJECTIVE FUNCTION FOR DELTA REPORT***

Column names One column, A

Row names One row named as the objective function row is named.

Entries A non-blank entry causes the report to include the change in the objective function value.

5.2 RAW MATERIALS AVAILABILITY TABLES

TABLE CRDAV ***CRUDE OIL AVAILABILITIES***

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

Row names — Crude codes

Entries — Column QTY contains the (fixed) availability in MMbpd of each crude with, generally, the exception of one, usually Saudi Arabian Light. This crude is the only one to have an entry in column P, its price in $/bbl.

For reporting purposes, the table also includes data on the gravity, sulfur content and 'grade' of each crude. The grade consists of two letters, the first indicative of the API gravity:

C	> 50
L	36 - 50
M	31 - 36
H	26 - 31
V	18 - 26
X	< 18

and the second indicative of the sulfur content:

L	< 0.5
M	0.5 - 0.8
H	0.8 - 2.0
V	> 2.0

The two-letter grading is used by the report writer to produce a report on crude movements by category of crude so that major consistencies or shifts across cases can be identified.

Column S contains a code letter indicating the source of the crude:

A	Alaska
D	Domestic (ie other US)
F	Foreign
S	US strategic reserve
T	Foreign strategic reserve

but the report program no longer uses this classification.

TABLES (Q)NCP AVAILABILITIES OF NON-CRUDE INPUTS REGION Q

Column names: Five columns, GAS, CST, MIN, MAX and FIX

Row names: Non-crude input codes

Entries: Generally only one of the last four columns will have an entry for a given input. Either the cost (in $/bbl) or a minimum, maximum or fixed quantity (MMbbl per day) will be specified.[26]
A non-blank entry under GAS indicates a stream of natural gas origin. This is only used for reporting purposes.

TABLES (R)UAP UTILITY PURCHASES - REFINERY R
TABLES (Q)UAP UTILITY PURCHASES - OXY-REFINERY Q

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

Row names: Codes for purchased utilities.

Entries: Column CST contains the purchase price of the utility in $ per unit. Columns MIN, MAX and FIX permit the application of limits to the amount purchased.
Column FCT, which applies only to purchases of fuel (FUL) and electric power, contains a factor which converts the units which are used in the process tables for consumption of fuel and power to the units in which the purchase cost is expressed.
In the current model, fuel (FUL) is not purchased and is excluded from the table[27]. Electricity is purchased in KWH and the process tables express power consumption in KWH per barrel; hence the factor is 1.

[26] In general, inputs of all NCP non-crudes are fixed except for methanol and natural gas.

[27] Purchased fuel generally takes the form of purchased natural gas input via *Tables (Q)NCP*.

Purchase of steam (STM) may also be activated in this table, although general practice is to omit it or fix it at zero on the basis that refineries normally generate steam internally.

Other potential entries generally comprise additives such as diesel pour point depressant and ignition improver or lead or manganese gasoline octane additives[28] if used.

[28] TEL is, however, excluded from the ***WORLD*** model, which is run on an equivalent lead-free basis.

5.3 CRUDE, INTERMEDIATE AND PRODUCT TRANSPORTATION TABLES

TABLE CRDDISP PERMITTED CRUDE MOVEMENTS

Column names — Destination region codes.

Row names — First 3 characters crude codes,
fourth character code for crude region of origin.

Entries — Number other than zero indicates class of ship

1	60,000 dwt
2	120,000 dwt
3	250,000 dwt
4	60,000 dwt (Jones Act).

A zero indicates a no cost movement (e.g. a movement of crude within its region of origin)
A blank indicates a disallowed movement.

TABLE CRDTRAN CRUDE SHIPPING COSTS

Column names — Destination region codes (1 character) and transportation modes (2 characters) for a total of 3 characters.

Row names — Crude codes (3 characters only).

Entries — Shipping cost in $/bbl to destination region.

TABLES (R)PRDTRAN FINISHED PRODUCT SHIPPING COSTS EX REFINERY R
TABLES (Q)PRDTRAN FINISHED PRODUCT SHIPPING COSTS EX OXY-REFINERY REGION Q OR SUPPLY DEMAND REGION Q

Column names — Destination region codes (1 character) and transportation modes (2 characters) for a total of 3 characters.

Row names — Finished product codes.

Entries Shipping cost in $/bbl.

Note that there is no ***Table PRDDISP*** indicating permitted product movements. If a non-blank cost (even 0.00) is given in ***Tables (Q) or (R)PRDTRAN***, the indicated movement will be permitted.

Tables (Q)PRDTRAN are used to generate shipments of LPG and natural gasoline from natural gas sources directly to regional demand.

Now that the "make" vectors taking product from refinery balance rows to regional demand rows have been replaced by shipping vectors, it is essential that all products represented in the ***(Q)PRDMD*** tables should also appear in the ***(R)PRDTRAN*** tables. Otherwise some products (eg coke, sulfur) would have no outlet from the refinery.

TABLES (R)INTRAN INTERMEDIATE PRODUCT SHIPPING COSTS EX REFINERY R
TABLES (Q)INTRAN INTERMEDIATE PRODUCT SHIPPING COSTS EX OXY-REFINERY REGION Q OR SUPPLY/DEMAND REGION Q

Column names Destination refinery codes (1 character) plus transport mode (2 characters)

Row names Intermediate product codes.

Entries Shipping cost in $/bbl from source refinery (or "oxy" refinery) to destination refinery.

Tables (Q)INTRAN are used to generate shipments of non-crude inputs to oil refineries.

5.4 GENERAL BOUNDS TABLE

TABLE VECBNDS BOUNDS ON SPECIFIC ACTIVITIES

Column names — Three columns, MIN, MAX and FIX

Row names — Matrix column names

Entries — Any entry will appear in the generated model as a bound of appropriate type on the matrix column.

Table VECBNDS can be used to impose any desired limit on any vector in the model. It is most often used for limiting movements - e.g. on intermediate streams (unfinished oils) into the U.S.A. - or for forcing minimum volumes of regional crudes to be refined in local refineries.

5.5 PRODUCT DEMANDS, BLENDING AND SPECIFICATIONS TABLES

TABLES (Q)PRDMD *PRODUCT DEMAND IN REGION Q*

Column names: Four columns, REV, MIN, MAX and FIX

Row names: First 3 characters finished product codes. A fourth character is provided in case there are different classes of demand for a given product (e.g. for showing demand as a function of price).
Column REV shows sales revenue in $/bbl. The other columns are used to place quantity limits, in MMbpd. Usually, only one column has an entry for any given row.
Table YPRDMD, relating to the former USSR, Eastern Europe and China is used to represent potential product exports from that region as negative demands. Should there be projected imports, these would be shown as positive demands.

TABLE RCP *RECIPE BLEND CONTROL*

Column names: Two columns, A and CST plus intermediate stream codes

Row names: Finished product codes followed by a number. The intention is to provide for different recipes for a given product. The row ending in a zero must be present.

Entries: A non-blank entry in column A activates the corresponding blend.
Column CST contains any cost met in making the blend, e.g. TEL cost for production of aviation gasoline.
The remaining columns contain the volume fractions of the components making up the blend.

TABLES GCC, DCC GASOLINE AND 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.

TABLES GCB, DCB GASOLINE AND DISTILLATE QUALITIES (EXCLUDING GASOLINE OCTANE DATA)

Column names Quality codes

Row names Intermediate product codes

Entries Blending values

TABLE MCO GASOLINE COMPONENT OCTANE RATINGS

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

Row names Intermediate stream gasoline component codes

Entries Research and motor octane blending numbers for each component at four levels of lead.

TABLE OCTWT OCTANE WEIGHTINGS

Simply defines combined or road octane (CON) as a combination of research and motor methods. A fifty-fifty weighting yields the familiar (R+M)/2 octane rating.

TABLE REGBV LEADED REGULAR GASOLINE COMPONENT BONUSES
TABLE LOGBV LEADED LOW OCTANE/LOCAL GASOLINE COMPONENT BONUSES
TABLE PRM/PRB/PRCBVUNLEADED PREMIUM GASOLINE COMPONENT BONUSES
TABLE UNL/UNB/UNCBVUNLEADED GASOLINE COMPONENT BONUSES
TABLE RFM/RGB/RGC REFORMULATED GASOLINE COMPONENT BONUSES

Since the **WORLD** model reduces all gasoline grades to an equivalent lead-free basis, the only entries relevant in these "BV" tables are those under unleaded ROO and MOO octane columns. Non-zero entries are added to the base octanes from ***Table MCO*** and used in the relevant gasoline blend.

Gasoline conventional and reformulated blend names must end in a B or a C (for EPA volatility regions B and C) for gasoline blend and emissions reports to be correctly generated.

TABLES MMGSP MASTER GASOLINE SPECIFICATIONS

Column names Columns A, KWH plus quality codes

Row names Finished gasoline codes, followed in the second part of the table by X (maximum) or N (minimum)

Entries A non-blank entry in column A controls the generation of the corresponding specification control row.
Column KWH contains power requirements for blending.
Remaining columns contain specification levels for the corresponding qualities. (Note that ***Table EXSPEC*** provides a way of generating only SOME of the quality controls).
Note that, to obtain correct weight blending of sulfur content, the quality code SPM (for gasolines) or SPC (for distillates) must be used, since this code is explicitly used by the generator program. The reason for two different codes is to permit different scaling to be applied to each.
Entries under column API comprise estimated product gravities and are used solely to compute delta sulfur coefficients where regional

sulfur specifications differ. For gasoline, a sulfur specification only applies to reformulated gasoline.

TABLE MMDSP MASTER DISTILLATE/FUEL OIL SPECIFICATIONS

Column names A, CST, KWH, STM, plus quality codes.

Row names In the first part of the table, 3-character product codes; in the second part, 3-character product code followed by a single character N or X signifying a miNimum or a maXimum constraint.

Entries Column A needs a non-blank entry in a row with a 3-character row name if the quality constraints on the corresponding product are to be generated. Conversely, a blank prevents generation of any quality controls on that product. (Note that ***Table EXSPEC*** provides a way of generating only SOME of the quality controls).
Columns CST, KWH and STM contain any costs (e.g. additive costs), power or steam consumptions encountered in blending the corresponding products. The second part of the table contains specification values for the quality control equations.
Entries under column API comprise estimated product gravities and are used solely to compute delta sulfur coefficients where regional sulfur specifications differ.

TABLES W(Q)DSP/GSP CHANGED SPECS - REGION Q - WINTER
TABLES S(Q)DSP/GSP CHANGED SPECS - REGION Q - SUMMER
TABLES Y(Q)DSP/GSP CHANGED SPECS - REGION Q - YEAR AVERAGE

Column names Any subset of the column names of ***Table MMDSP/MMGSP***.

Row names Any subset of the row names of ***Table MMDSP/MMGSP***

Entries These tables are demand region specific and are used to enter in differences from the standard specification values in the master MMDSP and MMGSP tables. The generator program first creates a set of region-specific ***Tables (Q)DSP***, which are initially identical

copies of ***Table MMDSP***. Then, according to the entry in ***Table CONTROL***, row SSN, any values given in ***Tables W(Q)DSP or S(Q)DSP or Y(Q)DSP*** will overwrite the corresponding values in the corresponding (Q)DSP tables; similarly for the GSP tables.
In general, blank values in the change spec tables have no effect. However a blank in column A in a row with a 3-character row name will overwrite a non-blank value in the master table, thereby causing the quality control structure for that blend to not be generated.

Note that spec change tables are included for non-refining regions in order that they may import spec-blended products.

Specifications may be entered in change specification tables that have not appeared in ***Table MMGSP*** or ***MMDSP***. This is particularly useful for specifications, including emission reductions that should only exist for a given season (e.g. the specifications for Summer Class B and C reformulated gasoline VOC reductions).

Note that for any specification to be active in the generated matrix, its activation must be anticipated by an appropriate entry in ***Table EXSPEC***.

Change ***GSP table*** modifications to ***MMGSP*** research and motor octanes can be implemented but the specifications must be referred to in the change spec tables as R00 and M00, not RON and MON.

5.6 REFINERY CAPACITIES AND OPERATIONS TABLES

TABLES (R)CAP REFINING CAPACITIES - REFINERY R
TABLES (Q)CAP REFINING CAPACITIES - OXY-REFINERY Q

Column names — CAP, MIN, MAX, STF and PUL.

Row names — Process unit codes.

Entries — Column CAP contains existing unit capacities in MMbpsd. These values only have an effect in investment cases, setting the starting point for capacity increases.
Column MIN, rarely used, forces a minimum throughput to the corresponding unit.
Column MAX contains limits on capacity expansion (over and above the base entered in column CAP) for investment cases, and, for non-investment cases, contains the maximum capacity.
Note, the entries under columns CAP, MIN and MAX correspond to nameplate, stream day capacity.
Column STF contains stream day factors which convert (nameplate) bpsd to (nameplate) bpcd.
Column PUL contains percentage utilizations, which convert nameplate calendar day capacity to actual available capacity.
The STF factors are typical, standard stream day factors for each process unit type. They are not varied and are the same for each world oil refinery region. In contrast, the PUL factors represent actual utilizations and will vary from unit to unit from region to region and from case to case.

Any non-blank entry in column MIN will cause generation of a minimum capacity row with that RHS. In a non-investment case, the entry under CAP is redundant and the maximum capacity is taken from the entry in the MAX column, which generally must be present. In an investment case, the RHS value is taken from the CAP column, and the investment vector is bounded at MAX - CAP. If, in an investment case, column MAX contains any blank entries, then the matrix generator code generates an entry of 10.0 mmbpd[29]. Note

[29] EnSys has found that bounding the investment vectors reduces run time - for instance, by approximately 10% for OSL.

that the user can still place explicit MAX bounds on investment if desired, e.g. to prevent further distillation capacity increase. Also note that for utility or pseudo units whose capacity is not measured in mmbpd, the user should make an entry under MAX, unless it is desired to limit the allowed throughput to the value entered under CAP+10.0.

TABLES (R)POL REFINERY OPERATING CONTROLS - REFINERY R
TABLES (Q)POL REFINERY OPERATING CONTROLS - OXY-REFINERY Q

Column names OBJ, MIN, MAX, FIX and PCT.

Row names There are two classes of row names, those which are necessary to the generation of essential parts of the matrix and those which generate additional processing constraints. The former class is relatively fixed; the latter may change with changing circumstances. The fixed rows are: OBJ, LOS, COK, OVC, APF and FRL.
The remaining rows correspond to processing constraints and are discussed below.

Entries A non-blank entry in column OBJ in any of the first class of rows causes generation of a non-constraining row used for accounting and reporting purposes. This is used in table rows OBJ, LOS and COK. (Actually, the matrix generator program will generate an objective function row named OBJ irrespective of the entry in table row OBJ). The other accounting rows form totals of refinery loss and FCC catalyst coke respectively.
In the same class of rows, a non-blank entry in one of the other columns causes generation of a row of corresponding type. Thus, the row OVC sums other refining variable costs, APF sums losses of light ends to fuel and FRL sums evaporation losses.
It is recommended that this portion of the (R)POL tables not be altered.

The process constraint rows in the current formulation are as follows:
SVR, SVH, SVL, SVC limit severity on FCC, RFH, RFL and RFC respectively.

ITB, HTB limit 1% and 2% fuel oil to high sulfur fuel oil respectively,[30]
PFH, PFL, PFU, PFF limit H_2S[31], very low (0.3%), low (1%), and high (3%) sulfur fuel oil[32] to refinery fuel respectively,
FLX limits the use of flexicoking activities (which are actually depicted as modes of operation of the fluid coker) to the level of known flexicoker capacities,

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

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

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

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

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

---

30 ITB and HTB force activities in *Table RST*, which converts low and medium sulfur fuels to high sulfur. This feature is not regularly used, but was introduced to reflect the fact that certain regions which produce and process low sulfur crudes produce low sulfur resid which is used locally and which does not enter the low sulfur resid market. Forcing of non-zero amounts in regions such as Africa could, therefore, avoid over-stating the amount of low sulfur residual fuel that is actually available to the international market.

31 When running historical ***WORLD*** cases (such as for 1989), certain LDC regions do not have sufficient sulfur plant capacity to recover all the H_2S generated, therefore this can be optionally allowed into refinery fuel. For all advanced world regions, and for every world region in a forward-looking study, the PFH entry should generally be set to a maximum of zero.

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

NME limits non-MTBE operations on the in-refinery oxygenate production unit, ETH.

The process table entries in the process constraint rows are of two types:

for severity constraints (SVR, SVH, SVL, SVC) they represent the severity of the given activity (as percentages) and the (R)POL entries represent maximum average severities. The generator program treats any entry in these rows with as percentages.

for the other constraints the process table entries are 0/1. The ***(R)POL*** entries may be in terms of throughput, each appropriate vector having a +1 in the row and the (R)POL entry is taken as a RHS chosen to limit the sum of those vectors, or they may be percentages (understood as percentage of total throughput).
The generator program will construct percentage controls, provided a non-blank entry appears in column PCT of ***table (R)POL***.

The former approach means that fractional targets are often only met approximately in any one run since - especially when investment is open - the total unit throughput is not known for certain in advance. Manual recursion may be necessary to adjust ***Tables (R)POL*** entries. The latter approach means that users may enter severities and fractional targets directly.

Note that the entries in tables (R)POL which represent throughput will appear as entries in the RHS column. In the case of percentage controls, no RHS element is generated.

5.7 REFINERY INVESTMENT DATA

TABLE INVGEN INVESTMENT MODEL PARAMETERS

This table provides the investment parameters required to calculate the total annualized cost of investment and fixed cost coefficients which are placed on the model investment purchase vectors.

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. The capital recovery factor computed in this way may be overridden by region-specific RECovery factors entered in ***Table REF***. (A typical U.S. industry capital recovery factor is around 0.24.)

Study year Nelson indices NIN, NLC, NOP and NLP are entered in ***Table INVGEN*** to inflate capital and fixed operating costs contained in ***Table INVUNT*** to the desired study year cost basis.

The base year Nelson inflation indices correspond to January 1, 1981 and must not be changed unless the base year "OVC" variable operating costs are changed in the refinery process unit data tables are also changed. (See the Oil & Gas Journal issues of April 1,1985 (p 116) and May 6, 1980 for historical values of the Nelson inflation indices). Specifically, if the reference date and cost data are changed, the ***Table INVGEN*** values for NIB, NLB, NOB and NPB must be changed accordingly and all OVC entries in process unit tables must be updated from their current 1/1/81 basis.

Table INVGEN also contains parameters on offsites, land and environmental investments as a function of onsite capital cost, and on labor overhead, maintenance and insurance costs as functions of onsite capital cost and operating labor cost (both in ***Table INVUNT***).

In the current **WORLD** formulation, these factors, as well as those for build-up of capital recovery factor, apply to all regions. Overall, regional capital cost location factors and capital recovery factors may be entered in ***Table REF***. Future versions of **WORLD** could be modified to make the parameters in ***INVGEN*** directly region-specific.

TABLE INVUNT INVESTMENT AND FIXED UNIT COSTS

This table contains the battery limits refinery process unit capital investment costs and basic daily direct fixed labor costs, both in January 1, 1981 dollars; also stream-day factors which in conjunction with ***Table INVGEN*** parameters calculate the total annualized stream of investment-related, labor-related and other fixed costs which are placed on the investment purchase vectors.

Column INV contains the unit investment costs, including royalties, but stripped of all off-site and maintenance costs. These are added on using the input parameters in ***Table INVGEN***. The primary sources for process unit investment costs 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.

Column SIZ contains the corresponding BPCD throughput capacity. Economies of scale are not applied to the RYM investment purchases. Since this is a regional model, it is assumed that all capacity investments are made in typical refining industry increments.[33] The oxygenate plant costs are distinguished between in-refinery oxygenate additions and merchant plants, where the economies of scale significantly lower the investment cost per unit of capacity.

The labor costs under column LAB contain the direct labor for a total of three 8-hour shifts per day. They do not include any administrative, supervisory, overhead or payroll burden components since these are added on by input the parameters contained in ***Table INVGEN***.

33 The ***WORLD*** model can readily be enhanced to introduce a facility which allows the user to set different base unit capacities, with costs adjusted by cost-capacity equipment. This feature would be valuable in studies, e.g. of different refinery size categories.

The stream-day factors under column STF convert BPCD to BPSD and reflect the typical unit on-stream time as a fraction of the total year taking into account planned and unplanned down-time.[34] These stream-day factors are applied to new investment capacity only. The stream-day factors do not account for fall off in unit capacity due to seasonally slack demand periods, tankage limitations and other similar factors.

This effect - i.e. the difference between installed nameplate capacity and effective available capacity - is taken account of by using the fractions PUL from ***Tables (R)CAP*** as the amount of actual capacity added into row (R)uuuCAPL per unit of nameplate bpcd capacity invested in.

[34] The stream day factors entered here should generally be consistent with STF entries in ***Tables (R)CAP***.

5.8 REFINING TECHNOLOGY TABLES

TABLE MATBAL MATERIAL BALANCE STREAMS

Column names	One column, A
Row names	Codes for purchased and intermediate streams
Entries	A non-blank entry in column A ensures that the generated model will contain a material balance row for that stream. Material balance rows for crude oils and for finished recipe and blended products are controlled elsewhere.

TABLE CRC CRUDES REPRESENTED BY ASSAYED CRUDES

This table estimates the properties of minor crude oils by specifying a composite using proportions of the relevant assayed crude oils contained in ***Table AVC***. The crude oils represented in ***Table CRC*** extend coverage to include all appreciable production in foreign countries. Countries with multiple grades are represented either by the individual grade or by a single composite grade. All of the current crude mixtures stored in the SPR caverns are also represented.

Since there are 66 assayed crude oils, condensates and synthetic crudes in ***Table AVC*** to select from, good accuracy may be obtained if the proper proportions are used for estimating the ***Table CRC*** crudes.

TABLE AVC   CRUDE ATMOSPHERIC DISTILLATION UNIT

Atmospheric distillation refinery process unit. This unit characterizes the 66 assayed crude oils by differentiating the yields of the following fractions:

GAS (C2 - SATURATED)		PGS
C3		CC3
IC4		IC4
NC4		NC4
LSR (C5-175)	LON	SRL
LSR (C5-175)	ION	SRI
LSR (C5-175)	HON	SRH
LT NAPH (175-250)	P	LNP
LT NAPH (175-250)	I	LNI
LT NAPH (175-250)	N	LNN
NAPH (250-325)	P	NPP
NAPH (250-325)	I	NPI
NAPH (250-325)	N	NPN
H N/L J(325-375)	P/LF	JPL
H N/L J(325-375)	I/LF	JIL
H N/L J(325-375)	N/LF	JNL
H N/L J(325-375)	P/HF	JPH
H N/L J(325-375)	I/HF	JIH
H N/L J(325-375)	N/HF	JNH
KERO(375-500)	LF/LL/LS	KLL
KERO(375-500)	LF/LL/HS	KLH
KERO(375-500)	LF/HL/LS	KHL
KERO(375-500)	LF/HL/HS	KHH
KERO(375-500)	HF/LL/LS	1LL
KERO(375-500)	HF/LL/HS	1LH
KERO(375-500)	HF/HL/LS	1HL
KERO(375-500)	HF/HL/HS	1HH
HKERO(500-550)	LF/LL/LS	3LL
HKERO(500-550)	LF/LL/HS	3LH
HKERO(500-550)	LF/HL/LS	3HL
HKERO(500-550)	LF/HL/HS	3HH
HKERO(500-550)	HF/LL/LS	4LL

HKERO(500-550)	HF/LL/HS	4LH
HKERO(500-550)	HF/HL/LS	4HL
HKERO(500-550)	HF/HL/HS	4HH
DSL B(550-650)	LP/LC/LS	DLL
DSL B(550-650)	LP/LC/HS	DLH
DSL B(550-650)	LP/LC/MS	DLM
DSL B(550-650)	LP/HC/MS	DHM
DSL B(550-650)	LP/HC/LS	DHL
DSL B(550-650)	LP/HC/HS	DHH
DSL B(550-650)	HP/LC/LS	2LL
DSL B(550-650)	HP/LC/MS	2LM
DSL B(550-650)	HP/LC/HS	2LH
DSL B(550-650)	HP/HC/LS	2HL
DSL B(550-650)	HP/HC/MS	2HM
DSL B(550-650)	HP/HC/HS	2HH
ATMOS RED CRUDE (A-M)		ARA-M

Table AVC also specifies the vacuum residua cut points which are used in ***Table VCU***, the most common being 1050 degrees F.

Data sources are the parent Turner Mason model data (vintage 1978) provided to ORNL by EIA (vintage 1983) 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 was obtained from U. S. Department of Energy, *"Strategic Petroleum Reserve Crude Oil Stream Quality Characteristics"*, August 1, 1990.

Table AVC 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 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 F), according to sulfur content, pour point and cetane index

- Light gas oil (690-800 degrees F), according to sulfur content

- Heavy gas oil (800-1050 degrees F), according to sulfur content

- Vacuum residuum (1050 + degrees F), according to sulfur content, with the high metal/asphaltene content residua being undercut below 1050 degrees F

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:

STREAM CODE	ATMOSPHERIC RESIDUAL SULFUR	ATMOSPHERIC RESIDUAL 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 to 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 some 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, 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 F. Various degrees of desulfurization intensity are also represented, ranging from normal (90% 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, 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, p78.

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 hydro-cracking 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 was 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 % and 85 % 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 F 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 SCF/bbl of feed, depending on the feedstock and severity of the operation. The primary feeds are light and heavy gas oils:

LGP, LGL, LGM, and LGH:	paraffinic, low, medium, and high sulfur light gas oils, 690 to 800 degrees F.
HGP, HGL, HGM, and HGH:	paraffinic, low, medium, and high sulfur heavy gas oils, 800 to 1050 degrees F.
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, p102.

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, p41.

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 SCF/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***:

VACRES	V HI SUL(3.8)	RSV
VACRES	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, p59.

TABLE HCN NAPHTHA HYDROCRACKER

This unit consumes of the order of 1500 SCF/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 **WORLD** "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 F atmospheric tower kerosene cut to a 470 degree endpoint cut in order to make the freezing point specification for JP-8 and Jet A/A-1 jet fuels in the optimal manner conforming to industry practice. This can be regarded as a "pseudo unit" corresponding to an atmospheric tower cut point adjustment when making a jet fuel run, or as a real side-stream fractionator. Data sources are based on in-house ENSYS data, calculations and estimates.

TABLE JFP LIGHT CYCLE OIL/COKER DISTILLATE PRE-FRACTIONATION

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

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

TABLE DHT DISTILLATE DEEP HYDROTREATER

This process hydrogenates middle distillate aromatics and achieves deep desulfurization (to levels beyond those available with conventional distillate desulfurization, see *Table DDS*). Potential feeds include kerosene, diesel and light cycle oils, covering the boiling range from 375 to 650 degrees F. 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% sulfur and less than 10% 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 SCF/bbl feed for virgin distillates and from 1100 to 2100 SCF/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 F. 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% 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 SCF/bbl feed for virgin distillates and from 1100 to 2100 SCF/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, p183.

Benham, A. L. et al, *"REDEX Process Extracts Aromatics"*, Hydrocarbon Processing, September, 1967, p135.

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% overhead cuts
- the corresponding light cycle oil furfural extracts
- coker distillate 80% overhead cuts
- the corresponding coker distillate furfural extracts
- the aromatic furfural unit extracts produced from virgin distillate streams, ranging from 375 to 500 degree F boiling range

This unit employs severe processing conditions and the fuel, power and steam costs are high. Hydrogen consumption can reach 2400 SCF/bbl for the virgin distillate stream aromatic extracts and 3500 SCF/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 F, where the high boiling paraffin waxes are concentrated. Approximately 200 SCF/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, p71.

TABLE RFH REFORMER-SEMI REGENERATIVE-450 PSI REACTOR
TABLE RFL REFORMER-SEMI REGEN/CYCLIC-200 PSI REACTOR
TABLE RFC CONTINUOUS REFORMING LOW PRESSURE/HIGH DENSITY BIMETALLIC 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 F very light virgin naphtha
175-250 degrees F light virgin naphtha
250-325 degrees F intermediate virgin naphtha
325-375 degrees F heavy virgin naphtha
250-400 degrees F heavy FCC gasoline
175-375 degrees F coker naphtha
250-325 degrees F heavy hydrocrackate
215-250 degrees F light virgin naphtha, pre-fractionated 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% 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 215ºF. to produce feedstock to the RFC unit for very low benzene reformate production. (See ***Table GCB*** for comparison of reformate benzene contents.)

Altogether, the **WORLD** 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% 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 F straight run gasoline is fractionated to produce C5-158 light gasoline for gasoline blending and 158-175 degrees F light naphtha for reformer feed. This represents the light end range of currently feasible reformer feed. The splitter now also enables splitting 175-250°F. light naphtha at 215° F. to produce a 175-215° F. light naphtha and a 215-250°F. low benzene reformer feedstock.

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

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

> *"UOP Process Solutions for Reformulated Gasoline"*, copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.
>
> van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March, 1990.

TABLE RES REFORMATE SPLITTER

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

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

> van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March, 1990.
>
> *"UOP Process Solutions for Reformulated Gasoline"*, copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE ARP AROMATICS EXTRACTION

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

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

TABLE ALM ALKYMAX

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

Data sources include the following:

> B. M. Wood et al, *"Alkylate Aromatics in the Gasoline via the UOP ALKYMAX Process"*, copyright 1990, provided by UOP to ORNL.
>
> *"UOP Process Solutions for Reformulated Gasoline"*, copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE CYC CYCLAR

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

HGP:	paraffinic low sulfur gas oil (800-1050 deg F)
HGL:	low sulfur gas oil (800-1050 deg F)
HGM:	medium sulfur gas oil (800-1050 deg F)
HGH:	high sulfur gas oil (800-1050 deg F)
GOH:	hydrofined gas oil (800-1050 deg F)
GOU:	hydrofined gas oil (800-1050 deg F) ultra low sulfur
DFF:	distillate feed (550-690 deg F)
DHK:	desulfurized atmospheric residuum (1050 deg F +). Produced by unit RDS.
HGX:	gas oil raffinate produced by propane solvent deasphalting
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 FED(690-800)	HI S N	HGO FD(800-1050)	HI S N	LGHHGH

LGO FED(690-800)	MD S N	HGO FD(800-1050)	MD S N	LGMHGM
LGO FED(690-800)	LO S N	HGO FD(800-1050)	LO S N	LGLHGL
LGO FED(690-800)	PFFN	HGO FD(800-1050)	PFFN	LGPHGP
HGO FD(800-1050)	LO S N	HYD GAS OIL/LO S 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 and
med.sulfur feed/product	FC6, FC7, FC8	FCR
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	

All Modes	SVR
Ultra-Low Sulfur Modes	FCU

* *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%. 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 % range.

The FCC conversion range represented in the model is from 65 to 85% conversion to 430^{o}F.- 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%. 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%, 0.30%, 1.00%, 2.50%. 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, p58.

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, p63.

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 degree F fractions; heavy catalytic gasoline (250 - 400 degrees F) for reformer feed and gasoline blending; and the front end of light cycle oil for distillate blending.

Coker naphtha (175 - 375 degrees F) 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, p58.

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 BFOE 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 SCF/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 are 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% normal butylene (C4E) and 30% 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 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:

		OXYGENATE PRODUCTS		
METHANOL FEED		MTBE	TAME	THME
ISOBUTYLENE	I4E	X		
REACTIVE AMYLENES	R5E		X	
REACTIVE HEXYLENES	R6E			X
ETHANOL FEED		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, Calif, 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, p16.

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, p126.

"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

Modelling after a recently announced Mobil process, this unit 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 SCF/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%.

Data sources include the following:

Novalany, S. and McClung, R. G., *"Better Alky from Treated Olefins"*, Hydrocarbon Processing, September, 1989, p66.

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, p48.

"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, lighter and higher octane compared to 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 SCF/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 are 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 BFOE throughout the model. Correspondence is 19,646 SCF/BFOE, equivalent to 50.9 BFOE/MMSCF of hydrogen. The hydrogen is produced at 97% purity, containing 3% 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% 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 BFOE 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 BFOE 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 pounds/hour) from refinery fuel (in BFOE) and electricity (in kilowatt hours) from steam (pounds/hour). An efficiency of 31% is assumed for power generation and 70% 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%) 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 AVC*** 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%) of total crude run. The transfer vector is equated with crude run via row APF which is generated in ***Tables (R)POL***. Each crude processing vector in ***Table AVC*** has a 1 entry against APF.

Estimates of the fuel adjustment factors are based on in-house ENSYS data and estimates based on calibration runs and knowledge of refinery losses.

TABLE TRS *PIPING NETWORK AND MISCELLANEOUS TRANSFERS PSEUDO-UNIT*

This unit is self documenting - 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 TRS***, 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 TRS 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.

Table TRS also transfers the aggregated process unit "other" variable process unit costs "OVC" (including catalyst, chemicals and cooling water) to the objective function row "OBJ" and this vector should not be removed.

Table TRS derived from the parent Turner Mason model provided to ORNL and thereafter to ENSYS, and has been amended and extended by ENSYS.

TABLE SCL SCALE FACTORS FOR SOME ROWS OF UNIT TABLES

This table multiplies the row entry for the named unit by the specified scale factor. This table is used to permit small coefficients to be easily entered in the data tables without loss of accuracy.

6. MATRIX STRUCTURE, NAMING, AND BLENDING CONVENTIONS

6.1 OVERVIEW OF MATRIX STRUCTURE

The model divides the world into demand regions; the "traditional" global version has 10 regions with refining capacity and one representing the Eastern Bloc simply as a source of possible imports of crude and intermediate and finished products.

Each refining region has a single refinery comprising the total capacity of all the actual refineries. (The system is capable of generating more than one refinery per region, enabling a region's capacity to be segregated, for example, geographically or by refining complexity). A region will generally also possess an "oxygenate refinery" (only one) which represents the manufacture of petrochemicals, particularly oxygenate gasoline components, outside the conventional refining industry. The "oxy-refinery" is also now the exclusive point of origin for NGL's and other non-crude inputs. These pass through to regional demands, e.g. for LPG and pentanes plus, and/or may be transferred as feed or blendstock into the regional petroleum refineries.

Input to the model are crude oils and non-crude supplies (e.g., NGL, methanol natural gas). For reporting purposes, crude supply regions are usually identified with demand regions, but this is by no means an essential feature. Crude oils are injected into balance rows representing the export terminals, from which they are shipped to the refining regions' balance rows. Marginal values on the export terminal rows are FOB values and those on the regional rows are CIF values.

Each transportation movement must now have a transportation mode associated with it - although, if the user desires, a whole model can be formulated with only one "null" mode. Similarly, each mode - and therefore movement - has an associated capacity, although this may be made effectively free (>0). A transportation loss feature has also been incorporated.

Marine shipping cost varies according to the kind of vessel chosen. There is no explicit modelling of limitations of port capacity or of bunker fuel consumption. (For this reason, distillate and residual fuel oil demands inserted in the model should be inclusive of anticipated bunker consumption). Pipeline and other/minor modes will have an associated cost which is usually the same for all movement using the mode.

Crudes flow from refinery balance rows through the atmospheric crude distillation vectors, where they are split into a number of straight-run fractions. These fractions constitute feedstocks for downstream process units, each of which has its own set of product streams.

There is a balance row for each of these intermediate streams. Some intermediates may be shipped from refinery to refinery.

All processing vectors are subject to capacity constraints, which may be rigid in a non-investment case, or may be raised, at a cost, in a case where investment is allowed. Variable refining costs appear as consumptions of power and steam and, with catalyst and chemicals, as a cash cost.

Finished products are made either by specification or by recipe blending. The latter method is used only for low-volume specialized products.

Products, both finished and intermediate, may be shipped. Intermediates are shipped to conventional refineries from either oxy-refineries, other conventional refineries or supply/demand regions. The transfers are into or out of refinery balance rows. Finished products, on the other hand, are transferred from a conventional or oxy-refinery balance row to a regional demand row. If the product is specification blended, the transferred product meets the spec of the destination region.

Non-crude inputs are available on a regional basis to oxygenate refineries and are transferred to the refinery balance rows or to regional demand. The outputs from oxygenate refineries' processing options are generally shipped as intermediates to conventional refineries for inclusion as blending components.

The objective function, to be maximized, is the sum of sales revenues less the cost of crudes, non-crudes and utilities and the variable costs of refining and shipping. In an investment case, not only is the capital cost of new equipment included, but also the fixed costs associated with its operation. Fixed costs on existing equipment are not included.

6.2 SUPPLY, REFINING AND DEMAND REGIONS CONTROL

In the "traditional" global form of the **WORLD** model, the crude supply, non-crude supply, refining and demand regions are all defined so as to be coincident. This need not be the case, however. The **WORLD** coding scheme allows for de-coupling of region types (for instance, as in the *Detailed Refinery Model*). The structure of regions in **WORLD** is as set out below. ***Table REG*** describes each region.

REGION TYPE	DEFINED BY
crude supply regions	columns of ***Table REF***, row CR, and 4th character of crude name rows in ***Table CRDDISP***
non-crudes supply regions/ oxy-refinery (NGL's, merchant oxy-gen-ates, and potentially petro-chemicals)	columns of ***Table REF*** row OX
oil refineries	rows of ***Table REF***, link to an OX region
product demand regions	columns of ***Table REF*** rows DM, SD

Note that the regions are also described (for Hollerith (text) purposes) in ***Table REG***. The (regional) rows of ***Table REG*** must be in the same sequence as the (regional) columns of ***Table REF***.

6.3 ROWS, COLUMNS, RHS AND BOUNDS STRUCTURE AND NAMING CONVENTIONS

This description uses a nomenclature similar to that of OMNI. OMNI uses the concept of classes, sets of members for each of which a statement is performed. The **WORLD** matrix generator relies heavily on temporary classes, generally defined as the row or column headings of OMNI data tables.

When in this section a character or group of characters occurs in parentheses, this implies indexing over a class. For example, the entry under "Policy rows" reads (R)(ABC) where the class (R) is the class of (one-character) row names of ***Table REF***, and (ABC) is the class of (three-character) row names of the ***Tables (R)POL***. This implies that a row name is generated for each combination of refinery R and policy constraint ABC. When R is 1 (refinery 1), the row names are taken from ***Table 1POL***, and so on.

The oil refineries are designated by the rows of Table REF. The regions are designated by the columns of that table. Oxygenate refineries, at most one per region, are designated by the (letter of the) region in which they are situated. The presence of an oxygenate refinery in region Q is indicated by a non-blank entry in ***Table REF***, column Q, row OX.

6.3.1 Column and Row Type Designators

Certain classes of matrix rows and columns have constant components in their codes, which are listed below.

ROWS

AV	Crude balance at exporting terminal
CB	Crude balance at importing region
CAP	Process capacity constraint
PD	Product demand in demand region or supply/demand in supply/demand region
PI	Intermediate supply/demand in supply/demand region

COLUMNS

INV	Capacity expansion
CP	Crude production
CS	Crude shipping
NP	Non-crude purchase
NT	Non-crude transfer to refinery
IT	Intermediate product shipping
PS	Finished product shipping
SA	Finished product sales in demand region or supply/demand in supply/demand region
SI	Intermediate supply/demand in supply/demand regions

A detailed description of row and column types follows.

6.3.2 Rows Structure and Naming

The ROWS section of the RECOUT1 file, the MPS-format matrix file for input to the optimizer, is generated by LCU 110 of the OMNI generator program. This assigns names and types (L for <, G for >, E for = and N for non-constraint) to each of the model's equations.

Objective function

OBJ

Policy rows

These represent either rows which do not constitute constraints but are used for accounting purposes (e.g. LOS, which simply sums the refining losses) or constraints on unit operating modes, for example on the FCC unit, prevent unrealistic or over-optimal solutions.

(R)(ABC)	for R = rows of Table REF	(oil refineries)
	ABC = rows of Tables (R)POL	(operating constraints)
(Q)(ABC)	for Q = cols of Table REF	(oxy refineries)
	when Table REF((Q),OX)	
	ABC = rows of Tables (Q)POL	(oxy operating constraints)

Crude balance at terminal

For each crude:
quantity produced - sum of quantities shipped out from terminal = 0

AV(CRU)	for CRU = rows of Table CRDAV	(produced crudes)

Crude balance at region

For each crude, in each region to which it may be shipped:
quantity shipped in - quantity used in crude distillation activities = 0

CB(Q)(CRU)	for Q = cols of Table REF	(regions)
	CRU = rows of Table CRDDISP	(crudes)

Utility rows

For each utility in each refinery, oil and oxygenate:
quantity purchased - sum of quantities consumed = 0

(R)(RAW)	for R = rows of Table REF	(oil refineries)
	RAW = rows of Tables (R)UAP	(purchasedutilities/additives)
(Q)(RAW)	for Q = cols of Table REF (oxy refineries)	
	when Table REF((Q),OX)	
	RAW = rows of Tables (Q)UAP	(purchased utilities additives)

Material balance rows

For each refinery stream, for each refinery, oil or oxygenate:
sum of quantities produced - sum of quantities consumed = 0

(R)(ABC)	for R = rows of Table REF	(oil refineries)
	ABC = rows of Table MATBAL	(streams)

(Q)(ABC)	for Q = cols of Table REF	(oxy refineries)
	when Table REF((Q),OX)	
	ABC = rows of Table OXMATBAL	(streams)

Capacity rows

For each refinery and for each process unit:
sum of capacities employed by process activities - capacity added through investment <= existing available capacity

(R)(UNS)CAP(T)	for R = rows of Table REF	(oil refineries)
	UNS = rows of Tables (R)CAP	(process units)
	T = G, L, E	

(Q)(UNS)CAP(T)	for Q = cols of Table REF	(oxy refineries)
	when Table REF((Q),OX)	
	UNS = rows of Tables (Q)CAP	(process units)
	T = G, L, E	

Although it is possible to assign upper (T = L), lower (T = G) or fixed limits (T = E) to the use of process capacity, the **WORLD** model generally is used with only upper limits.

For each transportation mode:

(TM)CAP(T)	for TM = row of Table TRCAPS
	T = G,L,E

Quality rows

For each refinery, for each blended product, for each quality of that product, for each specification limit:

sum of (quantities of components x blending value/index) - sum of/quantity of blend shipped to each demand region x specification blending value/index in the demand region) < or > 0

See discussion of blending below. The direction of the inequality depends on whether the specification is a maximum or a minimum (<0 for maximum spec, >0 for minimum spec). The quantities of blended product are multiplied by the specification quality appropriate to the receiving region for each demand region to which the product is shipped.

(R)(ABC)(COL)(E)

where:	R	=	rows of Table REF	(refineries)
	ABC	=	rows of Tables (R)DSP,(R)GSP	(products)
	COL	=	cols of Tables (R)DSP,(R)GSP	(qualities)
	E	=	N for min, X for max	(spec. type)

One equation calculates the total quantity of the blend from the sum of component quantities and balance with the sum of quantities shipped to demand region.

For each refinery, for each product made by blending to a specification:

sum of quantities of components - sum of finished blend quantities shipped to each demand region = 0

(R)(ABC) where R and ABC are as before.

Recipe blend rows

For each refinery, for each product made by recipe blending:

The sum of quantities of components - quantity of blend to demand - quantity exported = 0

(R)(ABC)	for R = rows of Table REF	(oil refineries)
	ABC = rows of Table RCP	(recipe blended products)

Regional demand rows

For each demand region, for each finished product:

The sum of quantities sent to demand from refineries + quantities imported from non-refining supply/demand (SD) regions - quantity(ies) demanded = 0

For a non-refining region, e.g. Eastern bloc, the availabilities of products and intermediates for export are shown as negative demands.

PD(Q)(PPP)	for Q = cols of Table REF	(regions)
	PPP = rows of Tables (Q)PRDMD	(products "sold")

The code ID(Q)(INT) is used for intermediates.

6.3.3 Columns Structure and Naming

The columns or activities of the model are generated by LCU's 115, 116 and 117 of the OMNI generator program.

Capacity investments (when allowed)

For each refinery, for each process unit:
the amount of added process capacity in MMbpcd

(R)(XYZ)INV	for R = rows of Table REF	(oil refineries)
	XYZ = rows of Tables (R)CAP	(process units
(Q)(XYZ)INV	for Q = cols of Table REF	(oxy refineries)
	when Table REF((Q),OX)	
	XYZ = rows of Tables (Q)CAP	(process units)

Crude production

For each crude oil:
the amount produced in MMbpd

CP(CRU)	for CRU = rows of Table CRDAV	(produced crudes)

Crude shipping

For each crude, for each permitted destination:
the amount shipped in MMbpd

C(P)(Q)(TM)(CRU)	for P = 4th character of rows of Table CRDISP	
		(source region)
	Q = cols of Table CRDISP	(destination region)
	TM = rows of Table TRMODES	
	CRU = first 3 characters of rows of Table CRDISP	
		(crude)

Non-crude purchase

For each region, for each non-crude input:
the amount purchased in MMbpd

NP(Q)(NNN)	for Q = cols of Table REF	(regions)
	NNN = rows of Tables (Q)NCP	(non-crudes)

Non-crude transfer to refinery

For each region, for each oil refinery in that region, for each non-crude input:
the amount transferred to that refinery from the regional oxy-refinery

N(Q)(R)(TM)(NNN)	for Q = cols of Table REF	(oxygenate refinery origin)
	when Table REF((Q),OX)	
	for R = rows of Table REF	(oil refinery destination)
	TM = rows of Table TRMODES	
	NNN = rows of Tables (Q)NCP	

Processing vectors

For each oil or oxygenate refinery, for each process unit, for each mode of operation:
the amount so processed

(R)(XYZ)(ABC)	for R = rows of Table REF	(oil refineries)
	XYZ = rows of Tables (R)CAP except ACU	(process units)
	ABC = cols of Tables (XYZ)	(feeds/modes)
(Q)(XYZ)(ABC)	for Q = cols of Table REF	(oxy refineries)
	when Table REF((Q),OX)	
	XYZ = rows of Tables (Q)CAP	(process units)
	ABC = cols of Tables (XYZ)	(feeds/modes)

(The rows of the Tables (R)CAP and (Q)CAP represent the various process units in oil refinery R or oxygenate refinery Q. For each process unit (e.g. RFC), there is a table with that name containing the data on that process.)

Crude distillation

For each crude, for each refining region to which it is permitted to be shipped:
the amount of crude processed in the distillation unit

(R)ACU(ABC) for R = rows of Table REF (oil refineries)
ABC = rows of Table CRDISP (crudes)

Utility purchase

For each oil or oxygenate refinery, for each utility:
the amount purchased

(R)(ABC) for R = rows of Table REF (oil refineries)
ABC = rows of Tables (R)UAP (purchasedutilities/additives)

(Q)(ABC) for Q = cols of Table REF (oxy refineries)
when Table REF((Q),OX)
ABC = rows of Tables (Q)UAP (purchased utilities/additives)

Internal transfers of intermediate streams

Used to represent the equivalence, condensation, or possible downgrading of, refinery streams

For each permitted source stream, for each permitted destination stream:
the amount transferred

(R)(CBA)(FED) for R = rows of Table REF (oil refineries)
CBA = first 3 characters of rows of Table TRS (source stream)
FED = 4th to 6th characters of rows of Table TRS (destination stream)

Inter-refinery transfers of intermediate streams

For each source refinery (oil (R) or oxygenate (Q)), for each permitted destination refinery (oil (S) only), for each permitted intermediate product (III):
the amount shipped

I(R)(S)(TM)(III) for R = rows of Table REF
S = rows of Table REF
TM = rows of Table TRMODES
III = rows of Tables (R)INTRAN

I(Q)(S)(TM)(III) for Q = cols of Table REF
when Table REF((Q),OX)
S = rows of Table REF
TM = rows of Table TRMODES
III = rows of Tables (Q)INTRAN

The latter coding is also used for shipping of intermediates from non-refining regions (i.e. regions whose refining capacity is not explicitly modelled).

Inter-regional product shipping

For each source refinery, for each permitted destination region, for each permitted finished product:
the amount shipped

P(R)(Q)(TM)(PPP) for R = rows of Table REF (oil refineries)
Q = cols of Tables (R)PRDTRAN (demand regions)
TM = rows of Table TRMODES
PPP = rows of Tables (R)PRDTRAN (finished products)

Shipping vectors on specification blended finished products are also integral to the blending formulation as discussed elsewhere.

P(Q)(S)(TM)(PPP) for Q = cols of Table REF (source regions/ for oxy refineries)
S = cols of Tables (S)PRDTRAN (demand regions)
TM = rows of Table TRMODES
PPP = rows of Tables (Q)PRDTRAN (finished products)

The latter coding (from a region to another region) is used for shipments from non-refining regions.

Blending vectors

For each oil refinery, for each specification blended product, for each component of the blend:
the amount included in the blend

(R)(DEF)(GHI) for R = rows of Table REF (oil refineries)
DEF = rows of Table DSP,GSP (blended products)
GHI = cols of Table DSP,GSP (blend components)

As discussed above, the volumes of the components are balanced by the volumes of the shipping vectors shipping finished blends to demand regions.

Recipe blends

For each oil refinery, for each recipe-blended product:
the amount produced

(R)(ABC)	for R = rows of Table REF	(oil refineries)
	ABC = rows of Table RCP	(recipe products)

Refinery-to-region transfers

Now replaced by product shipping vectors (see above).

Regional sales

For each demand region, for each finished product:
the amount supplied to meet demand

SA(Q)(ABC)(D)	for Q = cols of Table REF	(demand regions)
	ABC = first 3 characters of rows of Table (Q)PRDMD (products)	
	D = 4th character of rows of Tables (Q)PRDMD	

(The fourth character in Tables (Q)PRDMD row names was designed to allow separate demand levels to be set for the same finished product according to, say, demand sector or price tranche. The **WORLD** model does not currently use this facility - the fourth character is always 0.)

In supply/demand regions, the SA vectors may be bounded negative to represent an availability of product for export. The code SI is used similarly for intermediates in supply/demand regions.

6.3.4 Right-Hand Side Structure and Naming

The RHS, generated by LCU 120, represents limits on combinations of activities applied to specific rows (constraints) described above

Policy rows

(R)(ABC) for R = rows of Table REF (refineries)
ABC = rows of Tables (R)POL (operating constraints)

Note: RHS entries are generated only for "throughput" type constraints - see discussion of tables (R)POL above.

Capacity limits

(R)(ABC)CAP(T) for R = rows of Table REF (refineries)
ABC = rows of Tables (R)CAP (process units)
T = G, L, E

(TM)CAP(T) for TM = rows of Table TRCAPS (transportation modes)
T = G,L,E

6.3.5 Bounds Structure and Naming

The BOUNDS set, generated by LCU 125, represents limits on individual activities described above.

Crude availabilities

CP(CRU) for CRU = rows of Table CRDAV (crudes)
Bounds are entries in Table CRDAV

Non-crude availabilities

NP(Q)(NNN) for Q = cols of Table REF (regions)
NNN = rows of Tables (Q)NCP
Bounds are entries in Tables (Q)NCP

Bounds on vectors listed in VECBNDS

Any vector in the model may be limited by an entry in Table VECBNDS, for instance:

limits on crude to regions

C(P)(Q)(TM)(CRU) for P = 4th character of rows of Table CRDISP (source region)
Q = cols of Table CRDISP (destination region)
TM = rows of Table TRMODES
CRU = first 3 characters of rows of Table CRDISP (crudes)
Bounds are entries in Table VECBNDS

Demand (sales) limits

SA(Q)(ABCD) for Q = cols of Table REF (demand regions)
ABCD = rows of Tables (Q)PRDMD (products)
Bounds are entries in Tables (Q)PRDMD

The SA vectors in supply/demand regions may be bounded positive or negative to represent a demand for imports or a supply of exports in the region. For intermediates the code SI is used and the relevant tables are (Q)INTDMD.

Additives and utilities

(R)(ABC) for R = rows of Table REF (refineries)
ABC = rows of Tables (R)UAP (utilities/additives)

Internal transfers

(R)(ABC)(DEF) for R = rows of Table REF (refineries)
ABC = first 3 characters of rows of Table TRS (from stream)
DEF = 4th to 6th characters of rows of Table TRS (to stream)

Capacity purchase limits (if investment permitted)

(R)(ABC)INV for R = rows of Table REF (refineries)
ABC = rows of Tables (R)CAP (process units)

6.4 PRODUCT BLENDING FORMULATION

The basic blending equation is:

(1) $\sum q_i.x_i \geq s.\sum x_i$

where q_i = quality of i^{th} component
x_i = quantity of i^{th} component
s = specification level

The **WORLD** model is volume-based, that is, the units of the activities are barrels (or rather million barrels) per day. If a quality blends linearly by volume, then the above equation is valid where x represents an activity level. (Note that any volume change on mixing is neglected. Also the equation is written as a minimum constraint, but maximum constraints are treated exactly the same way.)

Since the activity levels occur on both sides of the equation, it must be re-arranged:

(2) $\sum (q_i - s).x_i \geq 0$

In this formulation, the coefficient on any vector taking a component into the blend is the difference between the component quality and the specification value.

However, the model almost always contains a further equation of the form:

(3) $\sum x_i - X = 0$

ie there is a vector X whose level is equal to the total quantity. Then equation (1) may be written:

(4) $\sum q_i.x_i - s.X \geq 0$

In this formulation, each vector taking a component into the blend bears the component quality, and the vector taking blended product out of the blend carries the specification value.

For the more complicated situation in which blended product is also exported, and the specification in the receiving region differs from that in the local region, we have:

(5) $$\sum q_i.x_i - s_1.X_1 - s_2.X_2 \geq 0$$

where suffix 1 refers to local demand and suffix 2 to exports.

For qualities which blend linearly by volume, formulations (2) and (4) are equally valid in a volume-based model. Similarly, either is equally valid in a weight-based model for qualities which blend linearly by weight.

Note that the RHS of a quality constraint is zero. The specification value is "buried" within the matrix. This means that changing a spec level is not a simple matter, though in this respect formulation (4) has obvious advantages over formulation (2).

For qualities which do not blend linearly, blending indices have been developed for most qualities which enable the advantages of a linear representation to be retained. Non-linear equations in an otherwise linear model increase solution time excessively, usually involving recursion. The **WORLD** model uses blending indices which are designed to blend linearly by volume, and equation (4) is the type of equation used throughout for specification blending.

Blending indices are of two types. With one type, viscosity for example, the qualities are converted to indices, the indices are blended and the resulting index is converted back to give the blend quality. With the other type, for example octane number, the blending of the indices gives the blend quality directly, without re-conversion. There is some advantage in the latter type. The units of a quality constraint row are, for example, octane-barrels, and the marginal value is in dollars per octane-barrel.[35] This is a difficult enough concept, but dollars per viscosity-index-barrel is exceedingly awkward to convert into a value that is readily meaningful.

[35] Technically, the marginal value on a limiting specification is the slope, i.e. rate of change, of the cost of the specification (y) versus the specification value (x). On residual or distillate fuels, for example, the sulfur specification marginal value represents the dollars per barrel per 1% change in sulfur quality. However, since 1% is a substantial change in sulfur, the reported sulfur/cost marginal value can be expected to alter over changes in specification of less than 1%.

In a volume-based model, qualities which blend linearly by weight (e.g. sulfur content) require a slight modification. Equation (1) then becomes:

(6) $$\sum q_i.g_i.x_i \geq s.\sum g_i.x_i$$

where g_i = density of i^{th} component

There is usually no equation corresponding to equation (3) which calculates the total weight of the blend, so there can be no analogue of equation (4). Instead, equation (6) must be re-arranged similarly to equation (2), i.e.

(7) $$\sum (q_i - s).g_i.x_i \geq 0$$

Hence the coefficient on a vector taking a component into a blend is the difference between the component quality and the specification level, multiplied by the component gravity. This formulation is used in **WORLD** for blending sulfur. (Formulation (7) would also be valid in a weight-based model for qualities blending volumetrically, but g_i would then be specific volume, the reciprocal of specific gravity.)

When a product subject to a sulfur specification is to be exported to a region with a different spec, it becomes necessary to assume a gravity for the product (the same gravity for local demand and for exports). Equation (7) then becomes:

(8) $$\sum q_i.g_i.x_i - s_1.X_1.G - s_2.X_2.G \geq 0$$

where, as before, suffixes 1 and 2 refer to local demand and exports respectively, and G is the assumed gravity.

6.5 MATRIX SCALING

The solution of an LP model is made more difficult if it is badly scaled, i.e. if there is a large range of sizes among the matrix coefficients. An ideally scaled matrix has the absolute values of the non-zero elements clustered about unity with as small a range as possible. Most optimizers have internal scaling procedures which try to achieve this; they are not equally good, sometimes compromising efficiency for speed.

Most of the coefficients in the **WORLD** model are taken directly from OMNI data tables without any further calculation. This is not true of quality and specification data, however. Also, it is possible for the generator program to produce matrix coefficients which are unexpectedly large or small. Some care has therefore been taken to control the sizes of the quality coefficients.

Using internal code and scaling tables, most quality and specification data are divided by 100; exceptions are flash point index (divided by 1000), heat of combustion (divided by 100,000), oxygen content, sulfur ppm, viscosity and luminometer index (unscaled), benzene RVP and content (divided by 10).

It should be noted that OMNI outputs matrix coefficients to a maximum of 6 decimal places. If the first 4 or 5 are zero, there may be some significant loss of solution accuracy. Many of the very small coefficients occur in ***Table ACU***. Matrix generation code rounds up or "terminates with extreme prejudice" the smallest coefficients in ***Table ACU***.

APPENDIX A WORLD REGIONS AND SUB-REGIONS

Assignment of subregions to demand regions of global WORLD model

Note: this assignment is easily changeable by the user.

Region	Sub-regions	Sub-region Descriptions
A	USP1	US PADD1
B	CANE	Canada East
	USP2	US PADD2
	USP3	US PADD3
	USP4	US PADD4
C	CARX	Greater Caribbean
G	MEPG	Middle East - Persian Gulf
M	NAEM	North Africa - Eastern Mediterranean
N	EURN	Europe North
P	JAPN	Pacific High Growth - Japan
	PAHI-OECD	Pacific High Growth - Other OECD
	PAHI-NOECD	Pacific High Growth - Non OECD
S	EURS	Europe South
W	CANW	Canada West
	USP5	US PADD5
X	ASIA	Continental Asia
	ROAF	Rest of Africa
	ROSA	Rest of South America

Assignment of countries to subregions of WORLD model

Note: this assignment is more difficult to change.

Sub-region	**Countries**
CANE	Canada, E
CANW	Canada, W
EURN	Austria
	Belgium
	Denmark
	Finland
	France, N
	Germany, W
	Iceland
	Ireland
	Luxembourg
	Netherlands
	Norway
	Sweden
	Switzerland
	UK
EURS	France, S
	Greece
	Italy
	Portugal
	Spain
	Turkey
JAPN	Japan
PAHI-OECD	Australia
	New Zealand

Sub-region	Countries	
PAHI-NONECD	Brunei	
	Hong Kong	
	Indonesia	
	Malaysia	
	Philippines	
	Singapore	
	Korea	
	Taiwan	
	Thailand	
ASIA	Bangladesh	
	Burma	
	India	
	Nepal	
	Pakistan	
	Sri Lanka	
	Viet Nam	
	Other Asia comprising:	
	Afghanistan	Mongolia
	Bhutan	Nauru
	Christmas Is.	New Caledonia
	Cook Is.	Pacific Is. (US)
	Fiji	Papua New Guinea
	French Polynesia	Samoa (US and other)
	Guam	Solomon Is.
	Kampuchea	Timor
	Laos	Tonga
	Macao	Wake Is.
	Maldives	
CARX	Colombia	
	Ecuador	
	Guatemala	
	Jamaica	
	Mexico	
	Neth. Antilles	

Panama
Trinidad & Tobago
Venezuela
Other America comprising:

Antigua & Barbuda	Dominican Rep.	Martinique
Bahamas	El Salvador	Montserrat
Barbados	Falkland Is.	Nicaragua
Belize	French Guyana	
St. Kitts & Anguilla	Bermuda	Grenada
St. Lucia	Brit. Virgin Is.	Guadeloupe
St. Pierre et Miquelon		Cayman Is.
Guyana	St. Vincent Grenadines	
Costa Rica	Haiti	Surinam
Dominica	Honduras	Turks & Caicos Is.

MEPG
Bahrain
Iran
Iraq
Jordan
Kuwait
North Yemen
Oman
Qatar
Saudi Arabia
South Yemen
UAE

NAEM Algeria
Cyprus
Egypt
Gibraltar
Israel
Lebanon
Libya
Malta
Morocco
Syria

	Tunisia				
	Yugoslavia				
ROAF	Angola				
	Benin				
	Cameroon				
	Congo				
	Ethiopia				
	Gabon				
	Ghana				
	Ivory Coast				
	Kenya				
	Mozambique				
	Nigeria				
	Senegal				
	South Africa				
	Sudan				
	Tanzania				
	Zambia				
	Zimbabwe				
	Other Africa comprising:				
		Botswana	Gambia	Mauritius	Somalia
		Burkina-Faso	Guinea	Namibia	Swaziland
		Burundi	Guinea-Bissau	Niger	Togo
		Cape Verde	Lesotho	Reunion	Uganda
		Central Afr. Rep.	Liberia	Rwanda	W. Sahara
		Chad	Madagascar	St. Helena	Zaire
		Comoros	Malawi	Sao Tome	
		Djibouti	Mali	Seychelles	
		Equatorial Guinea	Mauritania	Sierra Leone	

ROSA	Argentina Bolivia Brazil Chile Paraguay Peru Uruguay
USP1	PADDI
USP2	PADDII
USP3	PADDIII
USP4	PADDIV
USP5	PADDV

A listing of the states that comprise each PADD is available in the EIA Petroleum Supply Annual.

APPENDIX B WORLD PROCESS UNITS AND KEY OPERATING MODES

* DISTILLATION UNITS

crude atmospheric distillation

- *standard base cutting scheme, heavy kero (500-550^{0}F) and heavy distillate (650-690^{0}F) trim streams*

vacuum distillation

* CRACKING AND DESULFURIZATION/HYDROTREATING UNITS

delayed coker
fluid coker
flexi coker
visbreaker/thermal cracker

fluid cat cracker

- *vacuum gasoil (hydro-fined and non-hydrofined), distillate, low sulfur/desulfurized atmospheric residual fuel oil and potential medium/high sulfur atmospheric residual fuel oil cracking*
- *conversions 65 to 85%*
- *ZSM high octane/high light olefins modes*
- *low olefin mode*
- *ultra-low sulfur on ZSM high octane, low olefin and high light olefin modes*

gas oil hydrocracker
residuum hydrocracker
naphtha hydrocracker

middle distillate deep hydrotreating (hydrogenation)

naphtha hydrotreater
distillate desulfurization

- *ultra low sulfur deep desulfurization modes*

FCC feed hydrofiner/gas oil desulfurization
* mild hydro-cracking mode
residuum desulfurizer

lube and wax units

* EXTRACTION AND DISTILLATE UNITS

middle distillate furfural extraction
middle distillate gas oil dewaxing
solvent deasphalting

jet fraction end point recut (470^{o}F)

high density jet fuel pre-fractionation
high density jet fuel hydrofining

* LIGHT ENDS AND GASOLINE UNITS

catalytic reforming

- *discrete units for*
  - *high pressure (semi regen)*
  - *low pressure (cyclic/semi regen)*
  - *low pressure continuous reforming*
- *severities (low pressure/continuous) from 90 to 105*
- *heavy (250-325^{0}F), light (175-250^0 F) and very light naphtha (158-175^0 F) feedstocks*
- *FC heavy gasoline, coker heavy naphtha and hydro-cracker heavy naphtha reforming*
- *high octane catalyst mode (UOP R-62 type)*
- *very low pressure (low benzene) operation*

naphtha splitter
butanes/butenes splitter
FCC gasoline fractionation
coker naphtha fractionation
natural gasoline fractionation

thermal cracker ethane/propane/butane feed
thermal cracker naphtha feed
thermal cracker vacuum gas oil feed

ethane/propane/butanes/pentane dehydrogenation
cryogenic ethylene fractionation

ethylene to 1-butene dimerization
n-pentene/n-hexene hydrogenation

butane isomerization
pentane/hexane isomerization
total recycle pentane/hexane isomerization
alkylation feed butylene isomerization/treating

alkylation unit
- *ethylene, propylene, butylenes, amylene alkylation*

polymerization unit
dimersol unit
cyclar unit
aromatics recovery
- *benzene and heavier aromatics extraction*

MTBE (etherol) unit
DIPE (propylene ether) unit

* UTILITIES/ANCILLARY UNITS

hydrogen generation - steam reforming
hydrogen generation - partial oxidation

hydrogen to refinery fuel
light ends to refinery fuel
refinery evaporation loss

refinery fuel pool "plant"
steam generation
power generation
H_2S and sulfur recovery

* STREAM DISPOSITIONS

stream transfers/combination control
blend component disposition control

* OXYGENATES REPRESENTED

MTBE, ETBE, TAME, THEE, TBA, Oxinol, Ethanol, Methanol, DIPE

* ADDITIVES REPRESENTED

TEL/TML[36]
MMT
diesel ignition improver
diesel pour point depressant

[36] WORLD Model incorporates leaded gasoline but is generally run with gasoline grades reduced to equivalent lead-free basis.

APPENDIX C WORLD FINISHED PRODUCTS

GASOLINES

conventional

- premium (U.S. grade)*
- regular (U.S. grade)*
- regular (foreign grade)
- local/low octane grade
- aviation gasoline

reformulated

- premium (U.S. grade)*
- regular (U.S. grade)*

JET FUELS

- naphtha jet (JP-4)
- kero jet (Jet A/A-1/JP-8)
- JP-5

DISTILLATES

- kerosene
- diesel/No.2
- No.4/Marine Diesel (foreign low grade diesel)
- low sulfur/aromatics diesel
- Arctic diesel

LPG

- mixed LPG or individual streams

RESIDUAL FUEL OILS

- < 0.3% sulfur
- 0.3 to 1.0% sulfur
- 1.0 to 2.0% sulfur
- > 2.0% sulfur

LUBES AND WAXES

PETROLEUM COKE

- low sulfur
- high sulfur

ASPHALT

OTHER

- petro-chemicals naphtha
- special naphthas
- aromatics (total/benzene/heavy)
- process gas
- sulfur

* *U.S. reformulated and conventional gasoline grades are further identified by EPA volatility class region (B or C).*

APPENDIX D BLENDING PROPERTIES AND SPECIFICATIONS

GASOLINES

research octane
motor octane
road octane (R+M/2)
lead[37]
MMT (incorporating
non-linear effect)

oxygen content (wt%)
methanol content
aromatics content
benzene content
total/light olefins content
bromine number
atmospheric (hydroxyl) reactivity

RVP
vapor lock index
evaporative index
distillation:
percent @ 212^{o}F.
257^{o}F.
356^{o}F.

gravity
sulfur (wt ppm)

emissions
VOC
TAPs
toxics
(based on proprietary EnSys methodology)

37 ***WORLD*** incorporates lead blending but is generally run with gasolines reduced to an equivalent lead-free basis.

DISTILLATES/RESIDUALS/NAPHTHAS

flash point (index)	aromatics content
freeze point (index)	paraffins content
pour point (index)	naphthenes content
cetane (index)	
luminometer no. (index)	viscosity @ 122, 104 100
	-4, -3, -40 °F.

RVP		hydrogen content
		net heat of combustion
		static surface tension
distillation:		dynamic surface tension
percent @	392	
	400	diesel ignition improver
	440	(non linear effect)
	465°F	

APPENDIX E WORLD DATA TABLES AND FILES

A. TABLES USED BY MATRIX GENERATOR

MAIN REFINERY RYM TABLES (FILE OXRYM/ENSRYM) *File names are indicative/typical.*

Table EXCAP	Streams excluded based on absence of unit in table CAP
Table EXPOL	Streams excluded based on presence of FIX 0 in a table POL row
Table MATBAL	Process streams for which balance equations are generated
Table RCP	Recipe blend control
Table GCC	Gasoline component usage control
Table DCC	Distillate/fuel oil component usage control
Table HLO	Hydrogen to fuel
Table SDA	Solvent deasphalter
Table KRD	Delayed coker
Table KRF	Fluid coker
Table VBR	Visbreaker + thermal cracker
Table NDS	Naphtha cat hydrotreater
Table DDS	Distillate hydrodesulfurizer
Table FDS	FCC feed hydrofiner
Table RDS	Residue desulfurization
Table RFH	Reformer-semi regenerative-450 psi reactor
Table RFL	Reformer-semi regen/cyclic-200 psi reactor
Table RFC	Continuous reforming
Table SPL	Naphtha splitter
Table HCN	Naphtha hydrocracker
Table OLE	Sat C3/C4 dehydrogenation - UOP Olex process
Table DHT	Distillate deep hydrotreating
Table JFP	LCCO pre-fractionation unit
Table FCC	Fluid catalytic cracker
Table FGS	FCC gasoline fractionation
Table HCR	Hydrocracker
Table HCV	Residuum hydrocracker

Table ALK	Alkylation unit
Table CPL	Polymerization plant
Table FEX	Furfural extraction
Table HDN	High density jet fuel hydroprocessor
Table DEW	Catalytic gas oil dewaxer (Mobil)
Table ETH	BP etherol unit
Table CYC	Cyclar unit
Table DIM	Dimersol unit/propylene feed
Table ARP	Aromatics recovery
Table LUB	Lube and wax units
Table PHI	Pentane/hexane isomerization
Table TRI	Total recycle pentane/hexane isomerization with molecular sieve
Table C4I	Butane isomerization
Table C4S	Butenes splitter
Table RST	Residue transfers and blending
Table H2P	Hydrogen generation by steam reforming
Table H2X	Hydrogen generation by partial oxidation
Table SUL	Sulfur plant + H2S recovery
Table FUM	Stocks to fuel mixings
Table KWG	Power generation
Table TRS	Intermediate stream transfers
Table STG	Boiler steam production, utility/blending power use
Table REL	Refinery evaporation loss
Table PFA	Produced fuel adjustment
Table GCB	Gasoline component volatility blending values
Table DCB	Naphtha/ distillate/fuel oil blending values
Table SCL	Scale factors for some rows of unit tables
Table INVGEN	Investment model parameters
Table INVUNT	Investment and fixed unit costs
Table CRC	Crudes represented by assayed crudes
Table VCU	Crude vacuum unit
Table JPS	Fractionation adjuster for JP8/JTA
Table AVC	Atmospheric crude unit

REFORMULATED-GASOLINE-RELATED ADDITIONS

Table TCG	Thermal cracker - light gas feed
Table TCN	Thermal cracker - 250-325 naphtha feed
Table TCV	Thermal cracker - desulfurized vacuum gas oil feed
Table ETS	C2 cryogenic splitter
Table C24	Dimerization of ethylene to butene-1
Table DIP	Di-isopropyl ether
Table H56	Hydrogenation of normal pentenes and hexenes
Table C4T	Isomerization of butene-1 to butene-2
Table RFMBV	Reformulated gasoline component bonuses

SHIPPING DATA - CRUDES (FILE CRDDISP)

Table CRDDISP	Permitted crude movements

SHIPPING DATA - CRUDES (FILE CRDTRAN)

Table CRDTRAN	Crude shipping costs

SHIPPING DATA - PRODUCTS (FILE PRDTRAN)

Tables (R)PRDTRAN	Finished product shipping costs ex refinery R
Tables (Q)PRDTRAN	Finished product shipping costs ex non-refining region
Tables (R)INTRAN	Intermediate product shipping costs ex refinery R
Tables (Q)INTRAN	Intermediate product shipping costs ex oxy-refinery or non-refining region

SHIPPING DATA - CAPACITIES (FILE TRMODES)

Table TRMODES	Transportation modes and losses
Table TRCAPS	Transportation mode capacities

CASE DATA - REFINING (FILE REFCAP)

Table CONTROL	Investment and specification season control flags
Table REF	Refineries and regions
Tables (R)CAP	Refining capacities - refinery R
Tables (R)POL	Refinery controls - refinery R
Tables (R)UAP	Utility purchases - refinery R
Tables (Q)CAP	Refining capacities - oxy-refinery Q
Tables (Q)POL	Refinery controls - oxy-refinery Q
Tables (Q)UAP	Utility purchases - oxy-refinery Q

CASE DATA - QUALITIES (FILE AVSPEC)

Table EXSPEC	Gasoline and distillate specs reduction
Table MMDSP	Master distillate/fuel oil specifications
Tables W(Q)DSP	Changed specs - region Q - winter
Tables S(Q)DSP	Changed specs - region Q - summer
Tables Y(Q)DSP	Changed specs - region Q - year average
Table OCTWT	Global octane weightings
Table MMGSP	Master gasoline specifications
Tables W(Q)GSP	Changed specs - region Q - winter
Tables S(Q)GSP	Changed specs - region Q - summer
Tables Y(Q)GSP	Changed specs - region Q - year average

CASE DATA CRUDE AND NON-CRUDE AVAILABILITIES (FILE CRDNCP)

Table CRDAV	Crude oil availabilities
Tables (Q)NCP	Availabilities of non-crude inputs region Q
Table YPRDMD	Availabilities of products from Eastern Bloc (treated as negative demands)
Table YINTDMD	Availabilities of intermediate products from Eastern Bloc (treated as negative demands)

The latter two tables could be multiplied for other non-refining regions.

CASE DATA	PRODUCT DEMANDS (FILE DEMAND except Table YPRDMD which is in file CRDNCP)
Tables (Q)PRDMD	Product demand in region Q

CASE DATA	BOUNDS ON SPECIFIC ACTIVITIES (FILE VECBNDS)
Table VECBNDS	Bounds on specific activities

B. TABLES CONTROLLING REPORT-WRITER (FILE MTFIXREP/RPTCTRL)

Table H2	Report headings and other lines
Table H4	Report headings for new investment report
Table A	Selects which utility purchases to report
Table E	Distinguishes material and non-material items
Table G8	Selects reported gasoline blend properties
Table D8	Selects reported distillate/fuel oil blend properties
Table REX	Specifies blends to appear on second page of blend reports (FILE RPTCTRL)
Table REPLCU	Specifies which report LCU's are to be executed (main report)
Table DEL10LCU	Specifies which report LCU's are to be executed (delta report)
Table DELSIZE	Specifies parameters for delta report
Table OBJFN	Specifies name of objective function for delta report
Table REG	Establishes Hollerith (text) for regions
Table EPA	Specifies which gasoline blends are to have emissions reported

APPENDIX F WORLD MODEL CODES BY CATEGORY

CRUDES

SPR CRUDES

SPR BRYAN MD SWEET	QBS
SPR BRYAN MD SOUR	QBR
SPR BRYAN MD MAYAN	QBM
SPR W HACK SWEET	QHS
SPR W HACK SOUR	QHR
SPR CHOCTAW SWEET	QCS
SPR CHOCTAW SOUR	QCR
SPR WEEKS IS SOUR	QWR
SPR FUTURE LL (UKN)	QLL
SPR FUTURE LM (MUR)	QLM
SPR FUTURE MM (ANS)	QMM
SPR FUTURE MH (IST)	QMH
SPR FUTURE HH (SAH)	QHH
SPR FUTURE HV (MAY)	QHV
FPR JAPAN	QJA
FPR W GERMANY	QGE
FPR OTHER	QOT

EUROPEAN CRUDES

UK NORTH SEA	UKN
NORWAY	NOR
NETHERLANDS	NET
DENMARK	DEN
W. GERMANY	GER
FRANCE	FRA
AUSTRIA	AUT
SPAIN	SPN
ITALY	ITA
GREECE	GRC
TURKEY	TUR
USSR & OTH E.EUROPE	ROM

PACIFIC CRUDES

INDONESIAN MINAS	ISM
INDONESIAN LT(ATTAKA)	ISA
MALAYSIA LABUAN	MLU
CHINA BLEND	CBL
INDIA	IND
PAKISTAN	PAK
BURMA	BUR
PHILIPPINES	PHL
BRUNEI	BRU
AUSTRALIA	ASR
NEW ZEALAND	NZL

CANADIAN CRUDES

CANADIAN FEDERAL	CNF
CANADIAN RGLD	CNR
CANADIAN CONDENSATE	CNC
INTERPROVINCIAL	CNI
LLOYDMINSTER	CNL
TRANSMOUNTAIN	CNT
CANADIAN SYNCRUDE	CSY
CAN COLD LAKE BLEND	CLD
HIBERNIA	HIB

U.S. CRUDES

PADD 5

ALASKAN SOUTH	AKC
ALASKAN NORTH	AKP
ARIZONA SWEET	AZS
CA SAN JOAQ VAL HY	CAJ
CA SAN JOAQ VAL LT	CAS

CARIBBEAN & LATIN AMERICAN

GUATEMALA	GTM
TRINIDAD SWEET LS	TDL
TRINIDAD SOUR HS	TDH
MEXICAN ISTHMUS	IST
MEXICAN MAYA	MAY
MEXICAN OLMECA	MLT
VENEZ LT/REC (LOT 17)	V17
VENEZ MED (TJ MED)	VZT
VENEZ HEAVY (BACH LT)	VZO
VENEZ XHVY (BOSCAN)	VZB
VENEZUELAN JOBO	VJO
VENEZUELAN SYNCRUDE	VSY
COLOMBIAN	CLM
ARGENTINA	ARG
CHILE	CHI
ECUADOR	ECD
BRAZIL	BZL
BOLIVIAN	BOL
PERU	PRU

NORTH AFRICAN CRUDES

ALGERIAN CONDENSATE	AGC
ALGERIAN SAHARAN	AGR
LIBYAN	LIB
EGYPT SUEZ BLEND	EGP
EGYPT BELAYIM	EBL
EGYPT GHARIB/BAKR	EBK
TUNISIA	TUN

CA WILMINGTON	CAW
CA VENTURA	CAV
CA SAN ARDO	CAA
CA LA BASIN	CAB
CA ELK HILLS	CEK
CA KERN RIVER	CKE
CA OCS HONDO	CAC
CA OUTER CONTL SHELF	COS

PADD 4

COLORADO RANGELEY	COR
MONTANA SWEET	MTR
MONTANA SOUR	MTS
UTAH	UTA
WYOMING SWEET	WYS
WYOMING SOUR	WYP

PADD 3

ALABAMA LIGHT	ALL
ALABAMA HEAVY	ALH
ARKANSAS HEAVY	AKH
LOUSIANA SOUTH MIX	LAO
LOUSIANA NORTH	LAM
LOUISIANA CONDENSATE	LAC
MISSISSIPPI HEAVY	MSH
MISSISSIPPI BAXTER	MSB
MISSISSIPPI SWEET	MSS
NEW MEXICO INT	NMI
NEW MEXICO SOUR	NMS
TEXAS CONDENSATE	TCL

WEST AFRICAN CRUDES

NIGERIAN BONNY/LIGHT	NGB
NIGERIAN MEDIUM	NGM
NIGERIAN LIGHT	NGL
NIGERIAN FORCADOS	NGF
GABON AVERAGE	GAV
GABON GAMBA	GBN
GABON MANDJI	GBM
ANGOLA	ANG
ZAIRE	ZAR
CAMEROON	CAM
BENIN	BEN
IVORY COAST	IVY
CONGO	CON
SUDAN	SUD

MIDDLE EASTERN CRUDES

IRANIAN LIGHT	IRL
IRANIAN HEAVY	IRH
IRAQ BASRAH	IBA
KUWAIT	KUW
NEUTRAL ZONE	NTZ
QATAR DUKHAN/MARINE	QTR
SAUDI ARABIAN BERRI	SAB
SAUDI ARABIAN LIGHT	SAL
SAUDI ARABIAN MEDIUM	SAM
SAUDI ARABIAN HEAVY	SAH
UAE DUBAI	DUB
ABU DHABI MURBAN/ZAKUM	AMU
OMAN	OMN
BAHRAIN	BAH
SYRIA	SYR

TEXAS GULF REF	TGR
TEXAS EAST	TXE
TEXAS HAWKINS	TEH
TEXAS WEST INTERMEDIATE	TWI
TEXAS WEST LIGHT	TWL
TEXAS WEST SCURRY	TWY
TEXAS WEST SOUR	TWS

PADD 2

ILLINOIS SWEET	ILS
ILLINOIS WEEKS	ILW
INDIANA SWEET	INS
KANSAS LT	KSL
KANSAS COMMON	KSC
KENTUCKY SWEET	KYS
MICHIGAN SWEET	MIS
MISSOURI	MOS
NEBRASKA SWEET	NES
NORTH DAKOTA SWEET	NDS
OHIO	OHL
OKLAHOMA GARBER	OKG
OKLAHOMA SOUR	OKR
OKLAHOMA CEMENT	OKM
OKLAHOMA CONDENSATE	OKC
SOUTH DAKOTA SWEET	SDS
TENNESSEE	TEN

PADD 1

FLORIDA JAY	FLJ
PENNSYLVANIA	PAL
WEST VIRGINIA	WVL
NEW YORK	NYL

NORTH YEMEN	NYM

PRODUCTS

LPG	LPG	ULTR-LOW SULFUR NO 2	DFA
PENTANES PLUS	NAT	PETCHEM GAS OIL	G O P
PREMIUM GASOLINE	PRM	NO4 FUEL	NAV
PLUS GASOLINE	UNL	RESID < .3%	N6A
REFORMULATED GASOLINE	RFM	RESID .3-1.0%	N6I
REGULAR GASOLINE	REG	RESID 1.0-2.0%	N6H
LOCAL LOW OCTANE	LOG	RESID > 2.0%	N6B
RFG EPA REGION B	RGB		
RFG EPA REGION C	RGC		
CG PREMIUM REGION B	PRB		
CG PREMIUM REGION C	PRC		
CG REGULAR REGION B	UNB		
CG REGULAR REGION C	UNC		
AVGAS	AVG	AROMATICS	ARO
JP4 NAPHTHA JET	JP4	LUBES & WAXES	LBS
PETCHEM NAPHTHA	NPA	COKE LOW SULFUR MMST/D	CKL
SPECIAL NAPHTHA	NPB	COKE HIGH SULFUR	CKH
JTA KERO	JTA	ASPHALT	AST
KEROSENE	KER	STILL GAS	PGS
DIESEL - NO2	DIE	SULPHUR MMST/D	SLP

REFINERY PROCESSES

Atmospheric crude distillation	ACU	
Vacuum distillation	VCU	
Solvent deasphalting	SDA	
Delayed coker		KRD
Fluid/flexi-coker		KRF
Visbreaker/thermal cracker	VBR	
Naphtha hydrotreater	NDS	
Distillate desulfurizer	DDS	
FCC feed hydrofiner	FDS	
Mid-distillate deep hydrotreater	DHT	
Residuum desulfurizer		RDS
Gas oil hydrocracker	HCR	
Residuum hydrocracker		HCV
Naphtha hydrocracker		HCN
Lube and wax units	LUB	
High density jet fuel prefractionation	JFP	
HP semi-regenerative reformer	RFH	
LP cyclic reformer	RFL	
LP continuous reformer		RFC
Fluid cat cracker		FCC
Alkylation		ALK
Polymerization		CPL
Dimersol		DIM
Aromatics recovery	ARP	
Pentane/hexane isomerization		PHI
Butane isomerization	C4I	
Cyclar unit		CYC
Etherol unit	ETH	
Mid-distillate furfural treating	FEX	
High density jet fuel hydrotreating	HDN	
Gas oil dewaxer		DEW
H2-steam reformer bfoe/d H2	H2P	
H2-partial oxidizer bfoe/d H2		H2X
Sulfur, short tons/day		SUL
Naphtha splitter		SPL
FCC fractionation	FGS	

PROCESSES INVOLVED IN REFORMULATED GASOLINE MANUFACTURE

C2-C5 dehydrogenation	OLE
Thermal cracker C2-C4 feed	TCG
Thermal cracker naphtha feed	TCN
Thermal cracker gas oil feed	TCV
Cryogenic C2 fractionation	ETS
C2E to C4E dimerization	C24
Di-isopropyl ether	DIP
Hydrogenation normal pentenes/hexenes	H56
Alkylation feed butene isomerizer	C4T
Total recycle isomerization	TRI
Alkymax unit	ALM

"UTILITIES AND PSEUDO-UNITS"

Recut for JTA @ 470	JPS
Steam generation, lbs/hr	STG
Fuel plant bfoe/d	FUM
Power generation Mkw	KWG
Butane splitter	C4S
Hydrogen/fuel gas from reformer hydrogen	HLO

PROCESSES REPRESENTED IN OXY-REFINERIES

Fuel plant bfoe/d	FUX
Steam generation, lbs/hr	STX
Butane isomerization	C4X
C2-C5 dehydrogenation	OLX
Etherol unit	ETX

PROCESSING CONTROLS

ACCOUNTING ROWS

Objective function	OBJ
Unit losses	LOS
FCC catalytic coke make	COK
Other variable operating costs	OVC
Light ends to fuel	APF
Evaporation loss	FRL

REFINERY OPERATIONS CONSTRAINTS

Residual oil blending	min 1%FO to HS MMbpd	ITB
Residual oil blending	min 2%FO to HS MMbpd	HTB
Refinery fuel	max H2S MMbfoepd	PFH
Refinery fuel	max VLSO MMbpd	PFL
Refinery fuel	max LSFO input MMbpd	PFU
Refinery fuel	max HSFO input MMbpd	PFB
Flexicoker	max flexicoker MMbpd	FLX
Cat cracker	max severity	SVR
Cat cracker	max ZSM lt olefin mode	MSL
Cat cracker	max lo sul resid	MSR
Cat cracker	max hi sul resid	FCR
Cat cracker	max dist feed	MSD
Cat cracker	max ZSM operation	MSZ
Cat cracker	max ultra-low sulfur	FCU
LP cyclic reformer	max average severity	SVL
LP cyclic reformer	max R-62 operation	MXU
LP cyclic reformer	max 100 severity	L00
LP cyclic reformer	max 105 severity	L05
HP reformer	max average severity	SVH
HP reformer	max 100 severity	H00
HP reformer	max 105 severity	H05
Continuous reformer	max average severity	SVC
Continuous reformer	max 105 severity	C05
Continuous reformer	max very low pressure/ low benzene operation	RCU
Etherol (oxygenate)	max non-MTBE modes	NME
Distillate desulf	max ULS K/HK feed	DKU

Distillate desulf	max ULS diesel B/diesel C/ lt cycle oil fd	DDU	

PURCHASED UTILITIES

Purchased power $/kwh		KWH
Steam lb/hr($/lb*24hr/d)	STM	
Tetraethyl lead		TEL
MMT (0-1/32 g/gal)		MN1
MMT (1/32-1/16 g/gal)		MN2
MMT (1/16-3/32 g/gal)		MN3
MMT (3/32-1/8 g/gal)	MN4	
Diesel ignition improver (.000-.025)	DI1	
Diesel ignition improver (.025-.050)	DI2	
Diesel ignition improver (.050-.100)	DI3	
Diesel ignition improver (.100-.150)	DI4	
Diesel ignition improver (.150-.200)	DI5	
Pour point depressant (0.0-0.1)	FIP	

PURCHASED NON-CRUDE HYDROCARBONS/INTERMEDIATE STREAMS

Natural gas for fuel	NGS	
C34 (NGL purchases)		C34
Propane		CC3
Iso-butane		IC4
N-butane		NC4
Propylene		UC3
Butylene		UC4
Natural gasoline		NAT
Naphtha (250-325) intermediate	NPI	
MTBE oxygenate		MTB
ETBE oxygenate		ETB
ETAE		TAE
THEE		THE
TBA oxygenate		TBA
Oxinol oxygenate		OXL
Ethanol - full blend	ETH	
Ethanol - splash blend		ETL
Purchased methanol	MET	

Reformate (95 RON)	R95
HGO (800-btms) naphthenic, lo sulf	HGL
Atmospheric reduced crude	ARC

INTERMEDIATE STREAMS

Abbreviations used in this section:

BTTMS	*bottoms*	*NAP*	*naphthenic*
CN	*cetane number*	*OHEAD*	*overheads*
FR	*freezing point*	*OLE*	*olefinic*
HI	*high*	*ON*	*octane number*
HY	*heavy*	*PAR*	*paraffinic*
HYTD	*hydrotreated*	*PP*	*pour point*
INT	*intermediate*	*SU*	*sulfur*
LT	*light*	*ULOW*	*ultra-low*
LU	*luminometer*	*WH*	*whole (= full range)*
MED	*medium*		

Total saturated C1/C2 (foe)	PGS
Total unsaturated C1/C2 (foe)	PGU
Ethylene (foe)	C2E
Gas (saturated ethane) (foe)	CC2
LPG SALES MIX	LPG
LT STRAIGHT-RUN (C5-158) INT ON	GLI
LT STRAIGHT-RUN (C5-158) HI ON	GLH
LT STRAIGHT-RUN (C5-175) LO ON	SRL
LT STRAIGHT-RUN (C5-175) INT ON	SRI
LT STRAIGHT-RUN (C5-175) HI ON	SRH
LT NAPHTHA (175-250) PAR	LNP
LT NAPHTHA (175-250) INT	LNI
LT NAPHTHA (175-250) NAP	LNN

LT NAPHTHA	(175-215) P	PTP
LT NAPHTHA	(175-215) I	PTI
LT NAPHTHA	(175-215) N	PTN
NAPHTHA	(215-250) P	PBP
NAPHTHA	(215-250) I	PBI
NAPHTHA	(215-250) N	PBN
NAPHTHA	(250-325) PAR	NPP
NAPHTHA	(250-325) NAP	NPN
HY NAPHTHA/LT JET	(325-375) PAR/LO FR	JPL
HY NAPHTHA/LT JET	(325-375) INT/LO FR	JIL
HY NAPHTHA/LT JET	(325-375) NAP/LO FR	JNL
HY NAPHTHA/LT JET	(325-375) PAR/HI FR	JPH
HY NAPHTHA/LT JET	(325-375) INT/HI FR	JIH
HY NAPHTHA/LT JET	(325-375) NAP/HI FR	JNH
KEROSENE	(375-500) LO FR/LO LU/LO SU	KLL
KEROSENE	(375-500) LO FR/LO LU/HI SU	KLH
KEROSENE	(375-500) LO FR/HI LU/LO SU	KHL
KEROSENE	(375-500) LO FR/HI LU/HI SU	KHH
KEROSENE	(375-500) HI FR/LO LU/LO SU	1LL
KEROSENE	(375-500) HI FR/LO LU/HI SU	1LH
KEROSENE	(375-500) HI FR/HI LU/LO SU	1HL
KEROSENE	(375-500) HI FR/HI LU/HI SU	1HH
HY KERO	(500-550) LO PP/LO LU/LO SU	3LL
HY KERO	(500-550) LO PP/LO LU/HI SU	3LH
HY KERO	(500-550) LO PP/HI LU/LO SU	3HL
HY KERO	(500-550) LO PP/HI LU/HI SU	3HH
HY KERO	(500-550) HI PP/LO LU/LO SU	4LL
HY KERO	(500-550) HI PP/LO LU/HI SU	4LH
HY KERO	(500-550) HI PP/HI LU/LO SU	4HL
HY KERO	(500-550) HI PP/HI LU/HI SU	4HH
DIESEL B	(550-650) LO PP/LO CN/LO SU	DLL
DIESEL B	(550-650) LO PP/LO CN/HI SU	DLH
DIESEL B	(550-650) LO PP/HI CN/LO SU	DHL
DIESEL B	(550-650) LO PP/HI CN/HI SU	DHH
DIESEL B	(550-650) HI PP/LO CN/LO SU	2LL
DIESEL B	(550-650) HI PP/LO CN/HI SU	2LH
DIESEL B	(550-650) HI PP/HI CN/LO SU	2HL
DIESEL B	(550-650) HI PP/HI CN/HI SU	2HH
DIESEL B	(550-650) LO PP/LO CN/MD SU	DLM
DIESEL B	(550-650) LO PP/HI CN/MD SU	DHM

DIESEL B	(550-650) HI PP/LO CN/MD SU	2LM
DIESEL B	(550-650) HI PP/HI CN/MD SU	2HM
DIESEL C	(650-690) LO PP/HI CN/MD SU	6HM
DIESEL C	(650-690) HI PP/LO CN/MD SU	7LM
DIESEL C	(650-690) HI PP/HI CN/MD SU	7HM
DIESEL C	(650-690) LO PP/LO CN/MD SU	6LM
DIESEL C	(650-690) LO PP/HI CN/LO SU	6HL
DIESEL C	(650-690) LO PP/HI CN/HI SU	6HH
DIESEL C	(650-690) HI PP/LO CN/LO SU	7LL
DIESEL C	(650-690) HI PP/LO CN/HI SU	7LH
DIESEL C	(650-690) HI PP/HI CN/LO SU	7HL
DIESEL C	(650-690) HI PP/HI CN/HI SU	7HH
DIESEL C	(650-690) LO PP/LO CN/LO SU	6LL
DIESEL C	(650-690) LO PP/LO CN/HI SU	6LH
LT JET HYTD PAR/LO FR		PLJ
LT JET HYTD INT/LO FR		ILJ
LT JET HYTD NAP/LO FR		NLJ
LT JET HYTD PAR/HI FR		PHJ
LT JET HYTD INT/HI FR		IHJ
LT JET HYTD NAP/HI FR		NHJ
KERO HI SU HYTD LO FR/LO LU/LO SU		LLK
KERO HI SU HYTD LO FR/HI LU/LO SU		HLK
KERO HI SU HYTD HI FR/LO LU/LO SU		LL1
KERO HI SU HYTD HI FR/HI LU/LO SU		HL1
HY KERO HI SU HYTD LO PP/HI LU/LO SU		HL3
HY KERO HI SU HYTD HI PP/LO LU/LO SU		LL4
HY KERO HI SU HYTD HI PP/HI LU/LO SU		HL4
HY KERO HI SU HYTD LO PP/LO LU/LO SU		LL3
KERO HI SU RECUT LO FR/LO LU/LO SU		LJK
KERO HI SU RECUT LO FR/HI LU/LO SU		HJK
KERO HI SU RECUT HI FR/LO LU/LO SU		LJ1
KERO HI SU RECUT HI FR/HI LU/LO SU		HJ1
HY KERO HI SU RECUT LO PP/HI LU/LO SU		HJ3
HY KERO HI SU RECUT HI PP/LO LU/LO SU		LJ4
HY KERO HI SU RECUT HI PP/HI LU/LO SU		HJ4
HY KERO HI SU RECUT LO PP/LO LU/LO SU		LJ3
DIESEL B HI SU HYTD LO PP/LO CN/LO SU		LLD
DIESEL B HI SU HYTD LO PP/HI CN/LO SU		HLD
DIESEL B HI SU HYTD HI PP/LO CN/LO SU		LL2
DIESEL B HI SU HYTD LO PP/LO CN/LO SU		HL2

DIESEL C HI SU HYTD LO PP/LO CN/LO SU	LL6
DIESEL C HI SU HYTD LO PP/HI CN/LO SU	HL6
DIESEL C HI SU HYTD HI PP/LO CN/LO SU	LL7
DIESEL C HI SU HYTD HI PP/HI CN/LO SU	HL7
KERO ULOW SU LO FR/LO LU/UL SU	LUK
KERO ULOW SU LO FR/HI LU/UL SU	HUK
KERO ULOW SU HI FR/LO LU/UL SU	LU1
KERO ULOW SU HI FR/HI LU/UL SU	HU1
HY KERO ULOW SU LO PP/LO LU/UL SU	LU3
HY KERO ULOW SU LO PP/HI LU/UL SU	HU3
HY KERO ULOW SU HI PP/LO LU/UL SU	LU4
HY KERO ULOW SU HI PP/HI LU/UL SU	HU4
DIESEL B ULOW SU LO PP/LO CN/UL SU	LUD
DIESEL B ULOW SU LO PP/HI CN/UL SU	HUD
DIESEL B ULOW SU HI PP/LO CN/UL SU	LU2
DIESEL B ULOW SU HI PP/HI CN/UL SU	HU2
DIESEL C ULOW SU LO PP/LO CN/UL SU	LU6
DIESEL C ULOW SU LO PP/HI CN/UL SU	HU6
DIESEL C ULOW SU HI PP/LO CN/UL SU	LU7
DIESEL C ULOW SU HI PP/HI CN/UL SU	HU7
KERO DEEP HYTD LO FR/LO LU/LO SU	LSK
KERO DEEP HYTD LO FR/HI LU/LO SU	HSK
KERO DEEP HYTD HI FR/LO LU/LO SU	LS1
KERO DEEP HYTD HI FR/HI LU/LO SU	HS1
HY KERO DEEP HYTD LO PP/LO LU/LO SU	LS3
HY KERO DEEP HYTD LO PP/LO LU/LO SU	HS3
HY KERO DEEP HYTD HI PP/LO LU/LO SU	LS4
HY KERO DEEP HYTD HI PP/LO LU/LO SU	HS4
DIESEL B DEEP HYTD LO PP/LO CN/LO SU	LSD
DIESEL B DEEP HYTD LO PP/HI CN/LO SU	HSD
DIESEL B DEEP HYTD HI PP/LO CN/LO SU	LS2
DIESEL B DEEP HYTD HI PP/HI CN/LO SU	HS2
LT GAS OIL (690-800) DESULF	LOH
HYTD GAS OIL/LO SU UNHYTD	GOH
HYTD GAS OIL ULOW SULF	GOU
DISTILLATE FCC FEED	DFF
LT GAS OIL (690-800) NAP,LO SU	LGL
LT GAS OIL (690-800) NAP,MED SU	LGM
LT GAS OIL (690-800) NAP,HI SU	LGH
LT GAS OIL (690-800) PAR,LO SU	LGP

HY GAS OIL	(800-BTMS) NAP,MED SU	HGM
HY GAS OIL	(800-BTMS) NAP,HI SU	HGH
HY GAS OIL	(800-BTMS) PAR,LO SU	HGP
HY GAS OIL	(800-BTMS) NAP,LO SU	HGX
REFORMER FEED	(158-175) LT	RLL
REFORMER FEED	(250-325) PAR	RFP
REFORMER FEED	(250-325) INT	RFI
REFORMER FEED	(250-325) NAP	RFN
REFORMER FEED	(250-400) FCC HY	RFF
REFORMER FEED	(175-375) COKER	RFC
REFORMER FEED	(175-250) PAR	RLP
REFORMER FEED	(175-250) IMT	RLI
REFORMER FEED	(175-250) NAP	RLN
REFORMATE (80 RON)		R80
REFORMATE (90 RON)		R90
REFORMATE (95 RON) 90 PSIG		R9L
REFORMATE (100 RON)		R10
REFORMATE (100 RON) 100 PSIG		R1L
REFORMATE (105 RON)		R1X
REFORMATE (95 RON) 175-250 FEED		L95
REFORMATE (100 RON) 175-250 FEED		L10
REFORMATE (105 RON) 175-250 FEED		L1X
REFORMATE (90 RON) 158-175 FEED		V90
REFORMATE (95 RON) 158-175 FEED		V95
REFORMATE (100 RON) 158-175 FEED		V10
REFORMATE (90 RON) 158-175 LO BENZENE		C90
REFORMATE (95 RON) 158-175 LO BENZENE		C95
REFORMATE (100 RON) 158-175 LO BENZENE		C10
REFORMATE (95 RON) 175-250 LO BENZENE		A95
REFORMATE (100 RON) 175-250 LO BENZENE		A10
REFORMATE (105 RON) 175-250 LO BENZENE		A1X
REFORMATE (90 RON) 215-250 V LO BENZENE		P90
REFORMATE (95 RON) 215-250 V LO BENZENE		P95
REFORMATE (100 RON) 215-250 V LO BENZENE		P10
REFORMATE (105 RON) 215-250 V LO BENZENE		P1X
REFORMATE (80 RON) OHEAD		T80
REFORMATE (80 RON) BTTMS		B80
REFORMATE (90 RON) OHEAD		T90
REFORMATE (90 RON) BTTMS		B90
REFORMATE (95 RON/90 PSIG) OHEAD		T9L

REFORMATE (90 RON/90 PSIG) BTTMS	B9L
REFORMATE (95 RON) OHEAD	T95
REFORMATE (95 RON) BTTMS	B95
REFORMATE (100 RON) OHEAD	T10
REFORMATE (100 RON) BTTMS	B10
REFORMATE (100 RON/90 PSIG) OHEAD	T1L
REFORMATE (100 RON/90 PSIG) BTTMS	B1L
REFORMATE (105 RON) OHEAD	T1X
REFORMATE (105 RON) BTTMS	B1X
SPLITTER OHEAD RAFF	TRA
SPLITTER BTTMS RAFF	BRA

(FOR FCC GASOLINES, NUMBERS IN PARENTHESES ARE % CONVERSIONS)
(LT FCC GASOLINE IS AFTER REMOVAL OF AMYLENES AND HEXENES)

WHOLE FCC GASO (65) HS	FI6
WHOLE FCC GASO (70) HS	FI7
WHOLE FCC GASO (80) HS	FI8
WHOLE FCC GASO (65) MS	FC6
WHOLE FCC GASO (70) MS	FC7
WHOLE FCC GASO (80) MS	FC8
WHOLE FCC GASO (65) LS	FR6
WHOLE FCC GASO (70) LS	FR7
WHOLE FCC GASO (80) LS	FR8
LT FCC GASOLINE (60)	LF6
LT FCC GASOLINE (70)	LF7
LT FCC GASOLINE (80)	LF8
HVYFCC GASOLINE (60)	HF6
HVYFCC GASOLINE (70)	HF7
HVYFCC GASOLINE (80)	HF8
LT FCC GASOLINE (60)HS	LI6
LT FCC GASOLINE (70)HS	LI7
LT FCC GASOLINE (80)HS	LI8
HVYFCC GASOLINE (60)HS	HI6
HVYFCC GASOLINE (70)HS	HI7
HVYFCC GASOLINE (80)HS	HI8
LT FCC GASOLINE (60)LS	LR6
LT FCC GASOLINE (70)LS	LR7
LT FCC GASOLINE (80)LS	LR8
HVYFCC GASOLINE (60)LS	HR6

HVYFCC GASOLINE (70)LS		HR7
HVYFCC GASOLINE (80)LS		HR8
WH FCC GSLN60 HIOCT HS	ZI6	
WH FCC GSLN70 HIOCT HS	ZI7	
WH FCC GSLN80 HIOCT HS	ZI8	
WH FCC GSLN60 HIOCT MS	ZC6	
WH FCC GSLN70 HIOCT MS	ZC7	
WH FCC GSLN80 HIOCT MS	ZC8	
WH FCC GSLN60 HIOCT LS	ZR6	
WH FCC GSLN70 HIOCT LS	ZR7	
WH FCC GSLN80 HIOCT LS	ZR8	
LT FCC GSLN60 HIOCT HS	OI6	
LT FCC GSLN70 HIOCT HS	OI7	
LT FCC GSLN80 HIOCT HS	OI8	
HVYFCC GSLN60 HIOCT HS	BI6	
HVYFCC GSLN70 HIOCT HS	BI7	
HVYFCC GSLN80 HIOCT HS	BI8	
LT FCC GSLN60 HIOCT MS	ZL6	
LT FCC GSLN70 HIOCT MS	ZL7	
LT FCC GSLN80 HIOCT MS	ZL8	
HVYFCC GSLN60 HIOCT MS	ZH6	
HVYFCC GSLN70 HIOCT MS	ZH7	
HVYFCC GSLN80 HIOCT MS	ZH8	
LT FCC GSLN60 HIOCT LS		OR6
LT FCC GSLN70 HIOCT LS		OR7
LT FCC GSLN80 HIOCT LS		OR8
HVYFCC GSLN60 HIOCT LS	BR6	
HVYFCC GSLN70 HIOCT LS	BR7	
HVYFCC GSLN80 HIOCT LS	BR8	
WH FCC GSLN60 LOOL HS	6ZI	
WH FCC GSLN70 LOOL HS	7ZI	
WH FCC GSLN80 LOOL HS	8ZI	
LT FCC GSLN60 LOOL HS	6LI	
LT FCC GSLN70 LOOL HS	7LI	
LT FCC GSLN80 LOOL HS	8LI	
HVYFCC GSLN60 LOOL HS	6HI	
HVYFCC GSLN70 LOOL HS	7HI	
HVYFCC GSLN80 LOOL HS	8HI	
WH FCC GSLN60 LOOL MS	6ZF	
WH FCC GSLN70 LOOL MS	7ZF	

WH FCC GSLN80 LOOL MS	8ZF
LT FCC GSLN60 LOOL MS	6ZL
LT FCC GSLN70 LOOL MS	7ZL
LT FCC GSLN80 LOOL MS	8ZL
HVYFCC GSLN60 LOOL MS	6ZH
HVYFCC GSLN70 LOOL MS	7ZH
HVYFCC GSLN80 LOOL MS	8ZH
WH FCC GSLN60 LOOL LS	6ZR
WH FCC GSLN70 LOOL LS	7ZR
WH FCC GSLN80 LOOL LS	8ZR
LT FCC GSLN60 LOOL LS	6LR
LT FCC GSLN70 LOOL LS	7LR
LT FCC GSLN80 LOOL LS	8LR
HVYFCC GSLN60 LOOL LS	6HR
HVYFCC GSLN70 LOOL LS	7HR
HVYFCC GSLN80 LOOL LS	8HR
WH FCC HI LT OLE/83 HS	85I
LT FCC HI LT OLE/83 HS	8OI
HVYFCC HI LT OLE/83 HS	8BI
WH FCC HI LT OLE/83 MS	85F
LT FCC HI LT OLE/83 MS	85L
HVYFCC HI LT OLE/83 MS	85H
WH FCC HI LT OLE/83 LS	85R
LT FCC HI LT OLE/83 LS	8OR
HVYFCC HI LT OLE/83 LS	8BR
WH FCC GASO (65) ULS	FQ6
WH FCC GASO (70) ULS	FQ7
WH FCC GASO (80) ULS	FQ8
LT FCC GASOL (65) ULS	LQ6
LT FCC GASOL (70) ULS	LQ7
LT FCC GASOL (80) ULS	LQ8
HVYFCC GASOL (65) ULS	HQ6
HVYFCC GASOL (70) ULS	HQ7
HVYFCC GASOL (80) ULS	HQ8
WH FCC GSLN60 HIOCT US	RC6
WH FCC GSLN70 HIOCT US	RC7
WH FCC GSLN80 HIOCT US	RC8
LT FCC GSLN60 HIOCT US	RL6
LT FCC GSLN70 HIOCT US	RL7
LT FCC GSLN80 HIOCT US	RL8

HVYFCC GSLN60 HIOCT US	RH6
HVYFCC GSLN70 HIOCT US	RH7
HVYFCC GSLN80 HIOCT US	RH8
WH FCC GSLN60 LOOL US	6RF
WH FCC GSLN70 LOOL US	7RF
WH FCC GSLN80 LOOL US	8RF
LT FCC GSLN60 LOOL US	6RL
LT FCC GSLN70 LOOL US	7RL
LT FCC GSLN80 LOOL US	8RL
HVYFCC GSLN60 LOOL US	6RH
HVYFCC GSLN70 LOOL US	7RH
HVYFCC GSLN80 LOOL US	8RH
WH FCC HI LT OLE/83 US	85U
LT FCC HI LT OLE/83 US	8OU
HVYFCC HI LT OLE/83 US	8BU
LT CYCLE OIL 0.25 SU (60)	LC1
LT CYCLE OIL 0.25 SU (80)	LC2
LT CYCLE OIL 0.85 SU (60)	LC3
LT CYCLE OIL 0.85 SU (80)	LC4
LT CYCLE OIL 2.00 SU (60)	LC5
LT CYCLE OIL 2.00 SU (80)	LC6
LT CYCLE OIL HYTD LO CONVERSION	L1S
LT CYCLE OIL HYTD HI CONVERSION	L4S
LT CYCLE OIL HYTD 0.25 SU (60)	DC1
LT CYCLE OIL HYTD 0.25 SU (80)	DC2
LT CYCLE OIL HYTD 0.85 SU (60)	DC3
LT CYCLE OIL HYTD 0.85 SU (80)	DC4
LT CYCLE OIL HYTD 2.20 SU (60)	DC5
LT CYCLE OIL HYTD 2.20 SU (80)	DC6
LT CYCLE OIL ULOW .05 SU (60)	LC7
LT CYCLE OIL ULOW .05 SU (80)	LC8
LT CYCLE OIL 70 OHEAD 0.25 SU (60)	LO1
LT CYCLE OIL 70 OHEAD 0.25 SU (80)	LO2
LT CYCLE OIL 70 OHEAD 0.85 SU (60)	LO3
LT CYCLE OIL 70 OHEAD 0.85 SU (80)	LO4
LT CYCLE OIL 70 OHEAD 2.20 SU (60)	LO5
LT CYCLE OIL 70 OHEAD 2.20 SU (80)	LO6
LT CYCLE OIL 30 BOTTS 0.25 SU (60)	LB1
LT CYCLE OIL 30 BOTTS 0.25 SU (80)	LB2
LT CYCLE OIL 30 BOTTS 0.85 SU (60)	LB3

LT CYCLE OIL 30 BOTTS 0.85 SU (80)	LB4
LT CYCLE OIL 30 BOTTS 2.20 SU (60)	LB5
LT CYCLE OIL 30 BOTTS 2.20 SU (80)	LB6
CLARIFIED OIL 0.10 SU	COX
CLARIFIED OIL 0.65 SU	COL
CLARIFIED OIL 2.20 SU	COM
CLARIFIED OIL 5.50 SU	COH
LT COKER NAPHTHA (5-175)	SRC
COKER NAPHTHA (175-375)	CKN
COKER DISTILLATE (375-620)	CKD
COKER GAS OIL (620+)	CGO
COKE SHORT TONS HI SU	CKH
COKE SHORT TONS LO SU	CKL
HYDROCRACKER FEED LO SU	HFL
HYDROCRACKER FEED HI SU	HFH
LT HYDROCRACKATE (C5-175)	LHG
MED HYDROCRACKATE (175-250) V??	MHV
MED HYDROCRACKATE (175-250) C??	MHC
HY HYDROCRACKATE GASOLINE (250-325)	HHC
HYDROCRACKATE JET (295-525) V??	HJV
HYDROCRACKATE JET (295-525) C??	HJC
JP5 HYTD (395-500) HI FR/HI LU	5HH
JP5 HYTD (395-500) HI FR/LO LU	5HL
JP5 HYTD (395-500) LO FR/HI LU	5LH
JP5 HYTD (395-500) LO FR/LO LU	5LL
N-BUTYLENES	C4E
ISO-BUTYLENE	I4E
ISOMERIZED 2-BUTYLENE	T4E
N-PENTANE	NC5
N-HEXANE	NC6
AMYLENES (NORMAL)	C5E
REACTIVE AMYLENES (ISO)	R5E
HEXYLENES (NORMAL)	C6E
REACTIVE HEXYLENES (ISO)	R6E
ALKYLATE (PROPYLENE)	ALP
ALKYLATE (BUTYLENE)	ALB
ALKYLATE (N-BUTYLENE)	ALN
ALKYLATE (ISO-BUTYLENE)	ALI
ALKYLATE (ETHYLENE)	AL2
ALKYLATE (N-AMYLENE)	AL5

ALKYLATE (ISOM 2-BUTYLENE)	A4T
ALKYLATE (ISO-AMYLENE)	A5I
LT ALKYLATE (FOR AVGAS)	LAL
HEAVY ALKYLATE	HAL
POLYMER GASOLINE	CPG
DIMERATE	DMO
BENZENE	BNZ
C7+ AROMATICS	CGL
AROMATICS	ARO
LIGHT RAFFINATE (FROM AROMATICS RECOVERY)	LRA
HEAVY RAFFINATE (FROM AROMATICS RECOVERY)	HRA
TOTAL C5/C6 ISOMERATE	ISO
C6 ISOMERATE	IC6
ISOPENTANE	IC5
DI-ISOPROPYL ETHER	DIP
TAME OXYGENATE	TAM
THME OXYGENATE	THM
NATURAL GAS (FOE)	FUL
H2 (GENERATED)	HHG
H2 (100 PCT) (FOE)	HH2
H2S (FOE)	H2S
SULFUR (SHORT TONS/CD)	SLP
DESULF ATMOSPHERIC RESIDUE	DHK
ATMOSPHERIC REDUCED CRUDE TYPE A	ARA
ATMOSPHERIC REDUCED CRUDE TYPE B	ARB
ATMOSPHERIC REDUCED CRUDE TYPE C	ARC
ATMOSPHERIC REDUCED CRUDE TYPE D	ARD
ATMOSPHERIC REDUCED CRUDE TYPE E	ARE
ATMOSPHERIC REDUCED CRUDE TYPE F	ARF
ATMOSPHERIC REDUCED CRUDE TYPE G	ARG
ATMOSPHERIC REDUCED CRUDE TYPE H	ARH
ATMOSPHERIC REDUCED CRUDE TYPE I	ARI
ATMOSPHERIC REDUCED CRUDE TYPE J	ARJ
ATMOSPHERIC REDUCED CRUDE TYPE K	ARK
ATMOSPHERIC REDUCED CRUDE TYPE L	ARL
ATMOSPHERIC REDUCED CRUDE TYPE M	ARM
VACUUM RESIDUE TYPE A	VAA
VACUUM RESIDUE TYPE B	VAB
VACUUM RESIDUE TYPE C	VAC
VACUUM RESIDUE TYPE D	VAD

VACUUM RESIDUE TYPE E	VAE
VACUUM RESIDUE TYPE F	VAF
VACUUM RESIDUE TYPE G	VAG
VACUUM RESIDUE TYPE H	VAH
VACUUM RESIDUE TYPE I	VAI
VACUUM RESIDUE TYPE J	VAJ
VACUUM RESIDUE TYPE K	VAK
VACUUM RESIDUE TYPE L	VAL
VACUUM RESIDUE TYPE M	VAM
VACUUM RESIDUE V LO (0.5) SU	RSL
VACUUM RESIDUE LO (0.9) SU	RSI
VACUUM RESIDUE INT (1.5) SU	RSM
VACUUM RESIDUE HI (2.3) SU	RSH
VACUUM RESIDUE HI (3.8) SU	RSV
VACUUM ASPHALT V HI (4.3) SU	ASP
VACUUM RESIDUE DESUL 1.0 SU	DRH
VACUUM RESIDUE DESUL 0.5 SU	DRL
VACUUM RESIDUE DESUL 0.3	SU
VACUUM RESIDUE V LO SU VISBROKEN	VRL
VACUUM RESIDUE LO SU VISBROKEN	VRI
VACUUM RESIDUE INT SU VISBROKEN	VRM
VACUUM RESIDUE MED SU VISBROKEN	VRH
VACUUM RESIDUE HI SU VISBROKEN	VRV
VACUUM ASPHALT V HI SU VISBROKEN	VSP
LUBES	LBS

HIGH DENSITY JET FUEL STREAMS

KERO FURF RAFF LO FR/LO LU/LO SU	LXK
KERO FURF RAFF LO FR/HI LU/LO SU	HXK
KERO FURF RAFF HI FR/LO LU/LO SU	LX1
KERO FURF RAFF HI FR/HI LU/LO SU	HX1
KERO FURF RAFF LO FR/LO LU/HI SU	LZK
KERO FURF RAFF LO FR/HI LU/HI SU	HZK
KERO FURF RAFF HI FR/LO LU/HI SU	LZ1
KERO FURF RAFF HI FR/HI LU/HI SU	HZ1
HY KERO FURF RAFF LO PP/LO LU/LO SU	LX3
HY KERO FURF RAFF LO PP/HI LU/LO SU	HX3
HY KERO FURF RAFF HI PP/LO LU/LO SU	LX4
HY KERO FURF RAFF HI PP/HI LU/LO SU	HX4

HY KERO FURF RAFF LO PP/LO LU/HI SU	LZ3
HY KERO FURF RAFF LO PP/HI LU/HI SU	HZ3
HY KERO FURF RAFF HI PP/LO LU/HI SU	LZ4
HY KERO FURF RAFF HI PP/HI LU/HI SU	HZ4
DIESEL B FURF RAFF LO PP/LO CN/LO SU	LXD
DIESEL B FURF RAFF LO PP/HI CN/LO SU	HXD
DIESEL B FURF RAFF HI PP/LO CN/LO SU	LX2
DIESEL B FURF RAFF HI PP/HI CN/LO SU	HX2
DIESEL B FURF RAFF LO PP/LO CN/MED SU	LYD
DIESEL B FURF RAFF LO PP/HI CN/MED SU	HYD
DIESEL B FURF RAFF HI PP/LO CN/MED SU	LY2
DIESEL B FURF RAFF HI PP/HI CN/MED SU	HY2
DIESEL B FURF RAFF LO PP/LO CN/HI SU	LZD
DIESEL B FURF RAFF LO PP/HI CN/HI SU	HZD
DIESEL B FURF RAFF HI PP/LO CN/HI SU	LZ2
DIESEL B FURF RAFF HI PP/HI CN/HI SU	HZ2
DIESEL C FURF RAFF LO PP/HI CN/LO SU	HX6
DIESEL C FURF RAFF HI PP/LO CN/LO SU	LX7
DIESEL C FURF RAFF HI PP/HI CN/LO SU	HX7
DIESEL C FURF RAFF LO PP/LO CN/LO SU	LX6
DIESEL C FURF RAFF LO PP/HI CN/MED SU	HY6
DIESEL C FURF RAFF HI PP/LO CN/MED SU	LY7
DIESEL C FURF RAFF HI PP/HI CN/MED SU	HY7
DIESEL C FURF RAFF LO PP/LO CN/MED SU	LY6
DIESEL C FURF RAFF LO PP/HI CN/HI SU	HZ6
DIESEL C FURF RAFF HI PP/LO CN/HI SU	LZ7
DIESEL C FURF RAFF HI PP/HI CN/HI SU	HZ7
DIESEL C FURF RAFF LO PP/LO CN/HI SU	LZ6
KERO FURF RAFF DESULF LO FR/LO LU/LO SU	L1K
KERO FURF RAFF DESULF LO FR/HI LU/LO SU	H1K
KERO FURF RAFF DESULF HI FR/LO LU/LO SU	L11
KERO FURF RAFF DESULF HI FR/HI LU/LO SU	H11
KERO FURF RAFF DESULF LO FR/LO LU/HI SU	L3K
KERO FURF RAFF DESULF LO FR/HI LU/HI SU	H3K
KERO FURF RAFF DESULF HI FR/LO LU/HI SU	L31
KERO FURF RAFF DESULF HI FR/HI LU/HI SU	H31
HY KERO FURF RAFF DESULF LO PP/LO LU/LO SU	L13
HY KERO FURF RAFF DESULF LO PP/LO LU/LO SU	H13
HY KERO FURF RAFF DESULF HI PP/LO LU/LO SU	L14
HY KERO FURF RAFF DESULF HI PP/LO LU/LO SU	H14

HY KERO FURF RAFF DESULF LO PP/LO LU/HI SU	L33
HY KERO FURF RAFF DESULF LO PP/LO LU/HI SU	H33
HY KERO FURF RAFF DESULF HI PP/LO LU/HI SU	L34
HY KERO FURF RAFF DESULF HI PP/LO LU/HI SU	H34
DIESEL B FURF RAFF DESULF LO PP/LO CN/LO SU	L1D
DIESEL B FURF RAFF DESULF LO PP/HI CN/LO SU	H1D
DIESEL B FURF RAFF DESULF HI PP/LO CN/LO SU	L12
DIESEL B FURF RAFF DESULF HI PP/HI CN/LO SU	H12
DIESEL B FURF RAFF DESULF LO PP/LO CN/MED SU	L2D
DIESEL B FURF RAFF DESULF LO PP/HI CN/MED SU	H2D
DIESEL B FURF RAFF DESULF HI PP/LO CN/MED SU	L22
DIESEL B FURF RAFF DESULF HI PP/HI CN/MED SU	H22
DIESEL B FURF RAFF DESULF LO PP/LO CN/HI SU	L3D
DIESEL B FURF RAFF DESULF LO PP/HI CN/HI SU	H3D
DIESEL B FURF RAFF DESULF HI PP/LO CN/HI SU	L32
DIESEL B FURF RAFF DESULF HI PP/HI CN/HI SU	H32
DIESEL C FURF RAFF DESULF LO PP/HI CN/LO SU	H16
DIESEL C FURF RAFF DESULF HI PP/LO CN/LO SU	L17
DIESEL C FURF RAFF DESULF HI PP/HI CN/LO SU	H17
DIESEL C FURF RAFF DESULF LO PP/LO CN/LO SU	L16
DIESEL C FURF RAFF DESULF LO PP/HI CN/MED SU	H26
DIESEL C FURF RAFF DESULF HI PP/LO CN/MED SU	L27
DIESEL C FURF RAFF DESULF HI PP/HI CN/MED SU	H27
DIESEL C FURF RAFF DESULF LO PP/LO CN/MED SU	L26
DIESEL C FURF RAFF DESULF LO PP/HI CN/HI SU	H36
DIESEL C FURF RAFF DESULF HI PP/LO CN/HI SU	L37
DIESEL C FURF RAFF DESULF HI PP/HI CN/HI SU	H37
DIESEL C FURF RAFF DESULF LO PP/LO CN/HI SU	L36
PYROLYSIS FUEL OIL	LPF
KERO FURF EXTRACT (375-500)	KEX
HY KERO FURF EXTRACT (550-650)	HEX
DIESEL B FURF EXTRACT (550-650)	BEX
DIESEL C FURF EXTRACT (650-690)	CEX
LT CYCLE OIL FURF RAFF	LFR
LT CYCLE OIL FURF EXTRACT	LFE
LT CYCLE OIL OHEAD MILD HYTD	LXS
LT CYCLE OIL OHEAD INT HYTD	LXI
LT CYCLE OIL OHEAD FULLY HYTD	LXF
LT CYCLE OIL FURF EXTRACT INT HYTD	LEI
LT CYCLE OIL FURF EXTRACT FULLY HYTD	LEF

LT PYROLYSIS FUEL OIL MILD HYTD	PJS
LT PRYOLYSIS FUEL OIL INT HYTD	PJI
LT PYROLYSIS FUEL OIL FULLY HYTD	PJF
KERO 375-500 FURF EXTRACT INT HYTD	KEI
KERO 375-500 FURF EXTRACT FULLY HYTD	KEF
KERO 500-550 FURF EXTRACT INT HYTD	HEI
KERO 500-550 FURF EXTRACT FULLY HYTD	HEF
KERO 550-650 FURF EXTRACT INT HYTD	BEI
KERO 550-650 FURF EXTRACT FULLY HYTD	BEF
KERO 650-690 FURF EXTRACT INT HYTD	CEI
KERO 650-690 FURF EXTRACT FULLY HYTD	CEF
COKER DISTILLATE 375-570 80% OHEAD	CCL
COKER DISTILLATE 570-620 20% BTTMS	CCH
COKER DISTILLATE 375-570 OHEAD FURF EXT	CLE
COKER DISTILLATE 375-570 OHEAD FURF RAF	CLR
COKER DISTILLATE OHEAD MILD HYTD	CLS
COKER DISTILLATE OHEAD INT HYTD	CLI
COKER DISTILLATE OHEAD FULLY HYTD	CLF
COKER DISTILLATE OHEAD FURF EXTRACT INT HYTD	CXI
COKER DISTILLATE OHEAD FURF EXTRACT FULLY HYTD	CXF

CRUDE DEPENDENT STREAMS (SPECIALTY JET ONLY)

JP8	375-570	WYOMING LAKE	LJ8
JP8	375-570	ALASKA N SLOPE	AJ8
JP8	375-570	SAN ARDO	OJ8
JP8	375-570	CAL SAN JOAQUIM VALLEY	CJ8
JP11	570-650	WYOMING LAKE	LJ2
JP11	570-650	ALASKA N SLOPE	AJ1
JP11	570-650	SAN ARDO	OJ1
JP11	570-650	CAL SAN JOAQUIM VALLEY	CJ1
JP8	375-570	ARKANSAS SMACKOVER	KJ8
JP8	375-570	TEXAS REFUGIO	TJ8
JP8	375-570	VENEZUALA QUIREQUIRE	VJ8
JP8	375-570	INDONESIA DURI	IJ8
JP11	570-650	ARKANSAS SMACKOVER	KJ1
JP11	570-650	TEXAS REFUGIO	TJ1
JP11	570-650	VENEZUALA QUIREQUIRE	VJ1
JP11	570-650	INDONESIA DURI	IJ1

JP8	375-570	HYTD ALASKA N SLOPE	AH8
JP8	375-570	HYTD SAN ARDO	OH8
JP8	375-570	HYTD CAL SAN JOAQUIM VALLEY	CH8
JP11	570-650	HYTD ALASKA N SLOPE	AH1
JP11	570-650	HYTD SAN ARDO	OH1
JP11	570-650	HYTD CAL SAN JOAQUIM VALLEY	CH1
JP8	375-570	HYTD ARKANSAS SMACKOVER	KH8
JP8	375-570	HYTD VENEZUALA QUIREQUIRE	VH8
JP11	570-650	HYTD ARKANSAS SMACKOVER	KH1
JP11	570-650	HYTD VENEZUALA QUIREQUIRE	VH1

ULTRA-LOW SULFUR DIESEL STREAMS

DIESEL B 550-650 LO PP/LO CN/L0 SU	LL8
DIESEL B 550-650 HYTD LO PP/LO CN/UL SU	LU8
DIESEL B 550-650 LO PP/HI CN/L0 SU	HL8
DIESEL B 550-650 HYTD LO PP/HI CN/UL SU	HU8
DIESEL C 650-690 LO PP/LO CN/L0 SU	LL9
DIESEL C 650-690 HYTD LO PP/LO CN/UL SU	LU9
DIESEL C 650-690 LO PP/HI CN/L0 SU	HL9
DIESEL C 650-690 HYTD LO PP/HI CN/UL SU	HU9

REGIONS AND REFINERIES

The following association of regions and refineries represents the current version of the model and may be changed by the user modifying table REF.

	REGION CODE	REFINERY CODE
PADD 1	A	1
PADD 2,3,4 + EASTERN CANADA	B	2
PADD 5 + WESTERN CANADA	W	9
EXTENDED CARIBBEAN	C	3
NORTHERN EUROPE	N	6
SOUTHERN EUROPE	S	8
NORTH AFRICA + MEDITERRANEAN	M	5
MIDDLE EAST, PERSIAN GULF	G	4
PACIFIC HIGH GROWTH	P	7
USSR, EASTERN EUROPE, CHINA	Y	none
REST OF WORLD	X	T

QUALITIES

GASOLINES

RESEARCH OCTANE NUMBER	RON
MOTOR OCTANE NUMBER	MON
ROAD OCTANE NUMBER (WEIGHTED MEAN OF RON AND MON)	CON
REID VAPOR PRESSURE (PSI)	RVP
PERCENT RECOVERED @ 212 DEG F	212
257	257
356	356
LEAD CONTENT (GRAMS PER GALLON)	TEL
VAPOR/LOCK INDEX	VLI

FOLLOWING SPECS ARE MAINLY FOR REFORMULATED GASOLINES

OXYGEN CONTENT	(WT%)	PO2
METHANOL CONTENT	(VOL%)	MET
EVAPORATIVE INDEX		EII
SULFUR CONTENT	(PPM)	SPM
OLEFIN CONTENT	(VOL%)	OLE
AROMATICS CONTENT	(VOL%)	ARO
BENZENE CONTENT	(VOL%)	BNZ
BROMINE NUMBER		BRN
REACTIVITY		REA

VLI = VAPOR LOCK INDEX = RVP + 0.13 x PCT AT 158 DEG F.

EII = EVAPORATIVE INDEX = .85 x RVP + .14 x PCT EVAP AT
200 DEG F - .32 x PCT EVAP AT 100 DEG F

The following qualities are used, when lead addition is permitted, in order to capture the non-linear response to lead. They are not individually limited.

RESEARCH OCTANE NUMBER @	0.0 GRAMS LEAD PER GALLON	R00
	0.5	R05
	1.5	R15
	3.0	R30
MOTOR OCTANE NUMBER @	0.0	M00
	0.5	M05
	1.5	M15
	3.0	M30

DISTILLATES

GRAVITY (API^{O})		GRV
SULFUR CONTENT (WT%)		SPC
FREEZING POINT INDEX		FZI
LUMINOMETER INDEX		LMI
FLASH POINT INDEX		FLI
VISCOSITY INDEX @	-40 DEG F	VB1
	-30	VB2
	- 4	VB3
	100	VB4
	104	VB5
	122	VBI
REID VAPOR PRESSURE		RVP
PERCENT RECOVERED @	392 DEG F	392
	400	400
	440	440
	465	465
POUR POINT INDEX		PRI
CETANE NUMBER INDEX		CTI
AROMATICS CONTENT		ARO
PARAFFINS CONTENT		PAR
DIESEL IGNITION IMPROVER	(0 - .025 % WT)	DP1
	(.025 - .05 % WT)	DP2
	(.05 - .1 % WT)	DP3
	(.1 - .15 % WT)	DP4
	(.15 - .2 % WT)	DP5
DIESEL POUR DEPRESSANT	(0.1 % WT)	PIF
NET HEAT OF COMBUSTION, BTU/POUND		HTC
HYDROGEN. WEIGHT PERCENT		PCH
STATIC SURFACE TENSION, DYNES PER CM		STS
DYNAMIC SURFACE TENSION, DYNES PER CM		STD
AROMATICS CONTENT (VOL%)		ARO
PARAFFINS CONTENT (VOL%)		PAR
NAPHTHENES CONTENT		NAP

APPENDIX G WORLD MODEL CODES BY ALPHABETICAL SEQUENCE

```
CODE  ENTITY
CATEGORY

1     PADD 1
REFINERY
1HH   KEROSENE (375-500) HI FREEZE/HI LUMIN/HI SULF
INTERMEDIATE
1HL   KEROSENE (375-500) HI FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
1LH   KEROSENE (375-500) HI FREEZE/LO LUMIN/HI SULF
INTERMEDIATE
1LL   KEROSENE (375-500) HI FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
2     PADD 2,3,4 + EASTERN CANADA
REFINERY
212   PERCENT RECOVERED @ 212 DEG F
QUALITY
257   PERCENT RECOVERED @ 257 DEG F
QUALITY
2HH   DIESEL B (550-650) HI POUR/HI CETANE/HI SULF
INTERMEDIATE
2HL   DIESEL B (550-650) HI POUR/HI CETANE/LO SULF
INTERMEDIATE
2HM   DIESEL B (550-650) HI POUR/HI CETANE/MD SULF
INTERMEDIATE
2LH   DIESEL B (550-650) HI POUR/LO CETANE/HI SULF
INTERMEDIATE
2LL   DIESEL B (550-650) HI POUR/LO CETANE/LO SULF
INTERMEDIATE
2LM   DIESEL B (550-650) HI POUR/LO CETANE/MD SULF
INTERMEDIATE
3     EXTENDED CARIBBEAN
REFINERY
356   PERCENT RECOVERED @ 356 DEG F
QUALITY
392   PERCENT RECOVERED @ 392 DEG F
QUALITY
```

```
3HH   HY KERO  (500-550) LO POUR/HI LUMIN/HI SULF
INTERMEDIATE
3HL   HY KERO  (500-550) LO POUR/HI LUMIN/LO SULF
INTERMEDIATE
3LH   HY KERO  (500-550) LO POUR/LO LUMIN/HI SULF
INTERMEDIATE
3LL   HY KERO  (500-550) LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
4     MIDDLE EAST, PERSIAN GULF
REFINERY
400   PERCENT RECOVERED @ 400 DEG F
QUALITY
440   PERCENT RECOVERED @ 440 DEG F
QUALITY
465   PERCENT RECOVERED @ 465 DEG F
QUALITY
4HH   HY KERO  (500-550) HI POUR/HI LUMIN/HI SULF
INTERMEDIATE
4HL   HY KERO  (500-550) HI POUR/HI LUMIN/LO SULF
INTERMEDIATE
4LH   HY KERO  (500-550) HI POUR/LO LUMIN/HI SULF
INTERMEDIATE
4LL   HY KERO  (500-550) HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
5     NORTH AFRICA + MEDITERRANEAN
REFINERY
6     NORTHERN EUROPE
REFINERY
6HH   DIESEL C (650-690) LO POUR/HI CETANE/HI SULF
INTERMEDIATE
6HL   DIESEL C (650-690) LO POUR/HI CETANE/LO SULF
INTERMEDIATE
6HM   DIESEL C (650-690) LO POUR/HI CETANE/MD SULF
INTERMEDIATE
6LH   DIESEL C (650-690) LO POUR/LO CETANE/HI SULF
INTERMEDIATE
6LL   DIESEL C (650-690) LO POUR/LO CETANE/LO SULF
INTERMEDIATE
6LM   DIESEL C (650-690) LO POUR/LO CETANE/MD SULF
INTERMEDIATE
```

6ZF WHOLE FCC GASOLINE (60) LO OLE OPERATION
INTERMEDIATE
6ZH HVYFCC GASOLINE (60) LO OLE OPERATION
INTERMEDIATE
6ZL LT FCC GASOLINE (60) LO OLE OPERATION
INTERMEDIATE
7 PACIFIC HIGH GROWTH
REFINERY
7HH DIESEL C (650-690) HI POUR/HI CETANE/HI SULF
INTERMEDIATE
7HL DIESEL C (650-690) HI POUR/HI CETANE/LO SULF
INTERMEDIATE
7HM DIESEL C (650-690) HI POUR/HI CETANE/MD SULF
INTERMEDIATE
7LH DIESEL C (650-690) HI POUR/LO CETANE/HI SULF
INTERMEDIATE
7LL DIESEL C (650-690) HI POUR/LO CETANE/LO SULF
INTERMEDIATE
7LM DIESEL C (650-690) HI POUR/LO CETANE/MD SULF
INTERMEDIATE
7ZF WHOLE FCC GASOLINE (70) LO OLE OPERATION
INTERMEDIATE
7ZH HVYFCC GASOLINE (70) LO OLE OPERATION
INTERMEDIATE
7ZL LT FCC GASOLINE (70) LO OLE OPERATION
INTERMEDIATE
8 SOUTHERN EUROPE
REFINERY
85F WHOLE FCC GASOLINE HI LT OLE/HI OCTANE (83)
INTERMEDIATE
85H HY FCC GASOLINE HI LT OLE/HI OCTANE (83)
INTERMEDIATE
85L LT FCC GASOLINE HI LT OLE/HI OCTANE (83)
INTERMEDIATE
8ZF WHOLE FCC GASOLINE (80) LO OLE OPERATION
INTERMEDIATE
8ZH HVYFCC GASOLINE (80) LO OLE OPERATION
INTERMEDIATE
8ZL LT FCC GASOLINE (80) LO OLE OPERATION
INTERMEDIATE

9 PADD 5 + WESTERN CANADA
REFINERY
A PADD 1
REGION
A4T ALKYLATE (ISOM 2-BUTYLENE)
INTERMEDIATE
A5I ALKYLATE (ISO-AMYLENE)
INTERMEDIATE
ACU ATMOSPHERIC CRUDE DISTILLATION
PROCESS UNIT
AGC ALGERIAN CONDENSATE
CRUDE
AGR ALGERIAN SAHARAN
CRUDE
AH1 JP11 570-650 H'TREATED ALASKA N SLOPE
INTERMEDIATE
AH8 JP8 375-570 H'TREATED ALASKA N SLOPE
INTERMEDIATE
AJ1 JP11 570-650 ALASKA N SLOPE
INTERMEDIATE
AJ8 JP8 375-570 ALASKA N SLOPE
INTERMEDIATE
AKC ALASKAN SOUTH
CRUDE
AKH ARKANSAS HEAVY
CRUDE
AKP ALASKAN NORTH
CRUDE
AL2 ALKYLATE (ETHYLENE)
INTERMEDIATE
AL5 ALKYLATE (N-AMYLENE)
INTERMEDIATE
ALB ALKYLATE (BUTYLENE)
INTERMEDIATE
ALH ALABAMA HVY
CRUDE
ALI ALKYLATE (ISO-BUTYLENE)
INTERMEDIATE
ALK ALKYLATION
PROCESS UNIT

ALL   ALABAMA LIGHT
CRUDE
ALN   ALKYLATE (N-BUTYLENE)
INTERMEDIATE
ALP   ALKYLATE (PROPYLENE)
INTERMEDIATE
AMU   ABU DHABI MURBAN/ZAKUM
CRUDE
ANG   ANGOLA
CRUDE
APF   LIGHT ENDS TO FUEL
PROCESS CONTROL
ARA   ATMOSPHERIC REDUCED CRUDE TYPE A
INTERMEDIATE
ARB   ATMOSPHERIC REDUCED CRUDE TYPE B
INTERMEDIATE
ARC   ATMOSPHERIC REDUCED CRUDE TYPE C
NON-CRUDE INPUT
ARD   ATMOSPHERIC REDUCED CRUDE TYPE D
INTERMEDIATE
ARE   ATMOSPHERIC REDUCED CRUDE TYPE E
INTERMEDIATE
ARF   ATMOSPHERIC REDUCED CRUDE TYPE F
INTERMEDIATE
ARG   ARGENTINA
CRUDE
ARG   ATMOSPHERIC REDUCED CRUDE TYPE G
INTERMEDIATE
ARH   ATMOSPHERIC REDUCED CRUDE TYPE H
INTERMEDIATE
ARI   ATMOSPHERIC REDUCED CRUDE TYPE I
INTERMEDIATE
ARJ   ATMOSPHERIC REDUCED CRUDE TYPE J
INTERMEDIATE
ARK   ATMOSPHERIC REDUCED CRUDE TYPE K
INTERMEDIATE
ARL   ATMOSPHERIC REDUCED CRUDE TYPE L
INTERMEDIATE
ARM   ATMOSPHERIC REDUCED CRUDE TYPE M
INTERMEDIATE

ARO   AROMATICS
FINISHED PRODUCT
ARO   AROMATICS
INTERMEDIATE
ARO   AROMATICS CONTENT
QUALITY
ARP   AROMATICS RECOVERY
PROCESS UNIT
ASP   VACUUM ASPHALT V HI (4.3) SULF
INTERMEDIATE
ASR   AUSTRALIA
CRUDE
AST   ASPHALT
FINISHED PRODUCT
AUT   AUSTRIA
CRUDE
AVG   AVGAS
FINISHED PRODUCT
AZS   ARIZONA SWEET
CRUDE
B   PADD 2,3,4 + EASTERN CANADA
REGION
BAH   BAHRAIN
CRUDE
BEF   KERO 550-650 FURF EXTRACT FULLY H'TREATED
INTERMEDIATE
BEI   KERO 550-650 FURF EXTRACT INTERM H'TREATED
INTERMEDIATE
BEN   BENIN
CRUDE
BNZ   BENZENE
INTERMEDIATE
BNZ   BENZENE CONTENT
QUALITY
BOL   BOLIVIAN
CRUDE
BRN   BROMINE NUMBER
QUALITY
BRU   BRUNEI
CRUDE

BUR   BURMA
CRUDE
BZL   BRAZIL
CRUDE
C   EXTENDED CARIBBEAN
REGION
C05   CONTINUOUS REFORMER MAX % 105 SEVERITY
PROCESS CONTROL
C24   C2E TO C4E DIMERIZATION
PROCESS UNIT
C2E   ETHYLENE (FOE)
NON-CRUDE INPUT
C34   C34 (NGL PURCHASES)
NON-CRUDE INPUT
C4E   N-BUTYLENES
INTERMEDIATE
C4I   BUTANE ISOMERIZATION
PROCESS UNIT
C4S   BUTANE SPLITTER
PROCESS UNIT
C4T   ALKYLATION FEED BUTENE ISOMERIZER
PROCESS UNIT
C4X   BUTANE ISOMERIZATION
PROCESS UNIT
C5E   AMYLENES (NORMAL)
INTERMEDIATE
C6E   HEXYLENES (NORMAL)
INTERMEDIATE
CAA   CALIFORNIA SAN ARDO
CRUDE
CAB   CALIFORNIA LA BASIN
CRUDE
CAC   CA OCS HONDO
CRUDE
CAJ   CALIFORNIA SJV HEAVY
CRUDE
CAM   CAMEROON
CRUDE
CAS   CALIFORNIA SAN JOAQ LT
CRUDE

CAV CALIFORNIA VENTURA
CRUDE
CAW CALIFORNIA WILM
CRUDE
CBL CHINA BLEND
CRUDE
CC2 ETHANE
INTERMEDIATE
CC3 PROPANE
NON-CRUDE INPUT
CCH COKER DIST 570-620 20% BTTMS
INTERMEDIATE
CCL COKER DIST 375-570 80% OHEAD
INTERMEDIATE
CEF KERO 650-690 FURF EXTRACT FULLY H'TREATED
INTERMEDIATE
CEI KERO 650-690 FURF EXTRACT INTERM H'TREATED
INTERMEDIATE
CEK CALIFORNIA ELK HILLS
CRUDE
CGL C7+ AROMATICS
INTERMEDIATE
CGO COKER GAS OIL (620+)
INTERMEDIATE
CH1 JP11 570-650 H'TREATED CAL SAN JOAQUIM VALLEY
INTERMEDIATE
CH8 JP8 375-570 H'TREATED CAL SAN JOAQUIM VALLEY
INTERMEDIATE
CHI CHILE
CRUDE
CJ1 JP11 570-650 CAL SAN JOAQUIM VALLEY
INTERMEDIATE
CJ8 JP8 375-570 CAL SAN JOAQUIM VALLEY
INTERMEDIATE
CKD COKER DIST (375-620)
INTERMEDIATE
CKE CALIFORNIA KERN RIVER
CRUDE
CKH COKE HIGH SULFUR
FINISHED PRODUCT

CKH   COKE SHORT TONS HI SULF
INTERMEDIATE
CKL   COKE LOW SULFUR MMST/D
FINISHED PRODUCT
CKL   COKE SHORT TONS LO SULF
INTERMEDIATE
CKN   COKER NAPHTHA (175-375)
INTERMEDIATE
CLD   CAN COLD LAKE BLEND
CRUDE
CLE   COKER DIST 375-570 OHEAD FURF EXT
INTERMEDIATE
CLF   COKER DIST OHEAD FULLY H'TREATED
INTERMEDIATE
CLI   COKER DIST OHEAD INTERM H'TREATED
INTERMEDIATE
CLM   COLOMBIAN
CRUDE
CLR   COKER DIST 375-570 OHEAD FURF RAF
INTERMEDIATE
CLS   COKER DIST OHEAD MILD H'TREATED
INTERMEDIATE
CNC   CANADIAN CONDENSATE
CRUDE
CNF   CANADIAN FEDERAL
CRUDE
CNI   INTERPROVINCIAL
CRUDE
CNL   LLOYDMINSTER
CRUDE
CNR   CANADIAN RGLD
CRUDE
CNT   TRANSMOUNTAIN
CRUDE
COH   CLARIFIED OIL 5.0 SULF
INTERMEDIATE
COK   FCC CATALYTIC COKE MAKE
PROCESS CONTROL
COL   CLARIFIED OIL 1.6 SULF
INTERMEDIATE

COM   CLARIFIED OIL 3.3 SULF
INTERMEDIATE
CON   CONGO
CRUDE
CON   ROAD OCTANE NUMBER (WEIGHTED MEAN OF RON AND MON)
QUALITY
COR   COLORADO RANGELEY
CRUDE
COS   CALIFORNIA OCS/HONDO
CRUDE
COX   CLARIFIED OIL 0.3 SULF
INTERMEDIATE
CPG   POLYMER GASOLINE
INTERMEDIATE
CPL   POLYMERIZATION
PROCESS UNIT
CSY   CANADIAN SYNCRUDE
CRUDE
CTI   CETANE NUMBER INDEX
QUALITY
CXF   COKER DIST OHEAD FURF EXTRACT FULLY H'TREATED
INTERMEDIATE
CXI   COKER DIST OHEAD FURF EXTRACT INTERM H'TREATED
INTERMEDIATE
CYC   CYCLAR UNIT
PROCESS UNIT
DC1   LT CYCLE OIL TREATED 0.4 SULF (60)
INTERMEDIATE
DC2   LT CYCLE OIL TREATED 0.4 SULF (80)
INTERMEDIATE
DC3   LT CYCLE OIL TREATED 1.6 SULF (60)
INTERMEDIATE
DC4   LT CYCLE OIL TREATED 1.6 SULF (80)
INTERMEDIATE
DC5   LT CYCLE OIL TREATED 2.8 SULF (60)
INTERMEDIATE
DC6   LT CYCLE OIL TREATED 2.8 SULF (80)
INTERMEDIATE
DDS   DISTILLATE DESULFURIZER
PROCESS UNIT

DDU DISTILLATE DESULF MAX % ULS DIESEL B/
PROCESS CONTROL
DIESEL C/LT CYCLE OIL
PROCESS CONTROL
FEED
PROCESS CONTROL
DEN DENMARK
CRUDE
DEW GAS OIL DEWAXER
PROCESS UNIT
DFA ULTRA-LOW SULFUR NO2
FINISHED PRODUCT
DFF DIST FCC FEED
INTERMEDIATE
DHH DIESEL B (550-650) LO POUR/HI CETANE/HI SULF
INTERMEDIATE
DHK DESULF ATMOSPHERIC RESIDUE
INTERMEDIATE
DHL DIESEL B (550-650) LO POUR/HI CETANE/LO SULF
INTERMEDIATE
DHM DIESEL B (550-650) LO POUR/HI CETANE/MD SULF
INTERMEDIATE
DHT MID-DISTILLATE DEEP HYDROTREATER
PROCESS UNIT
DI1 DIESEL IGNITION IMPROVER (.000-.025)
UTILITY
DI2 DIESEL IGNITION IMPROVER (.025-.050)
UTILITY
DI3 DIESEL IGNITION IMPROVER (.050-.100)
UTILITY
DI4 DIESEL IGNITION IMPROVER (.100-.150)
UTILITY
DI5 DIESEL IGNITION IMPROVER (.150-.200)
UTILITY
DIE DIESEL - NO2
FINISHED PRODUCT
DIM DIMERSOL
PROCESS UNIT
DKU DISTILLATE DESULF MAX % ULS K/HK FEED
PROCESS CONTROL

DLH DIESEL B (550-650) LO POUR/LO CETANE/HI SULF
INTERMEDIATE
DLL DIESEL B (550-650) LO POUR/LO CETANE/LO SULF
INTERMEDIATE
DLM DIESEL B (550-650) LO POUR/LO CETANE/MD SULF
INTERMEDIATE
DMO DIMERATE
INTERMEDIATE
DP1 DIESEL IGNITION ADDITIVE
QUALITY
DP2 DIESEL IGNITION ADDITIVE
QUALITY
DP3 DIESEL IGNITION ADDITIVE
QUALITY
DP4 DIESEL IGNITION ADDITIVE
QUALITY
DP5 DIESEL IGNITION ADDITIVE
QUALITY
DR8 VACUUM RESIDUE DESUL 0.3 SULF
INTERMEDIATE
DRH VACUUM RESIDUE DESUL 1.0 SULF
INTERMEDIATE
DRL VACUUM RESIDUE DESUL 0.5 SULF
INTERMEDIATE
DUB UAE DUBAI
CRUDE
EBK EGYPT GHARIB/BAKR
CRUDE
EBL EGYPT BELAYIM
CRUDE
ECD ECUADOR
CRUDE
EGP EGYPT SUEZ BLEND
CRUDE
EII EVAPORATIVE INDEX
QUALITY
ETB ETBE OXYGENATE
NON-CRUDE INPUT
ETH ETHEROL UNIT
PROCESS UNIT

```
ETH   ETHANOL - FULL BLEND
NON-CRUDE INPUT
ETL   ETHANOL - SPLASH BLEND
NON-CRUDE INPUT
ETS   CRYOGENIC C2 FRACTIONATION
PROCESS UNIT
ETX   ETHEROL UNIT
PROCESS UNIT
FC6   WHOLE FCC GASOLINE (60)
INTERMEDIATE
FC7   WHOLE FCC GASOLINE (70)
INTERMEDIATE
FC8   WHOLE FCC GASOLINE (80)
INTERMEDIATE
FCC   FLUID CAT CRACKER
PROCESS UNIT
FCR   CAT CRACKER          MAX % HI SULF RESID
PROCESS CONTROL
FDS   FCC FEED HYDROFINER
PROCESS UNIT
FEX   MID-DISTILLATE FURFURAL TREATING
PROCESS UNIT
FGS   FCC FRACTIONATION
PROCESS UNIT
FIP   POUR POINT DEPRESSANT    (0.0-0.1)
UTILITY
FLI   FLASH POINT INDEX
QUALITY
FLJ   FLORIDA JAY
CRUDE
FLX   FLEXICOKER           MAX FLEXICOKER MMBPD
PROCESS CONTROL
FRA   FRANCE
CRUDE
FRL   EVAPORATION LOSS
PROCESS CONTROL
FUL   NATURAL GAS (FOE)
INTERMEDIATE
FUM   FUEL PLANT BFOE/D
PROCESS UNIT
```

FUX FUEL PLANT BFOE/D
PROCESS UNIT
FZI FREEZING POINT INDEX
QUALITY
G MIDDLE EAST, PERSIAN GULF
REGION
GAV GABON AVERAGE
CRUDE
GBM GABON MANDJI
CRUDE
GBN GABON GAMBA
CRUDE
GER W. GERMANY
CRUDE
GLH LT STRAIGHT-RUN (C5-158) HI ON
INTERMEDIATE
GLI LT STRAIGHT-RUN (C5-158) INT ON
INTERMEDIATE
GOH H'TREATED GAS OIL/LO SULF UNH'TREATED
INTERMEDIATE
GOP PETCHEM GAS OIL
FINISHED PRODUCT
GRC GREECE
CRUDE
GRV SPECIFIC GRAVITY
QUALITY
GTM GUATEMALA
CRUDE
H00 HP REFORMER MAX % 100 SEVERITY
PROCESS CONTROL
H05 HP REFORMER MAX % 105 SEVERITY
PROCESS CONTROL
H11 KERO FURF RAFF DESULF HI FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
H12 DIESEL B FURF RAFF DESULF HI POUR/HI CETANE/LO SULF
INTERMEDIATE
H13 NY KERO FURF RAFF DESULF LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
H14 NY KERO FURF RAFF DESULF HI POUR/LO LUMIN/LO SULF
INTERMEDIATE

H16 DIESEL C FURF RAFF DESULF LO POUR/HI CETANE/LO SULF
INTERMEDIATE
H17 DIESEL C FURF RAFF DESULF HI POUR/HI CETANE/LO SULF
INTERMEDIATE
H1D DIESEL B FURF RAFF DESULF LO POUR/HI CETANE/LO SULF
INTERMEDIATE
H1K KERO FURF RAFF DESULF LO FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
H22 DIESEL B FURF RAFF DESULF HI POUR/HI CETANE/MED SULF
INTERMEDIATE
H26 DIESEL C FURF RAFF DESULF LO POUR/HI CETANE/MED SULF
INTERMEDIATE
H27 DIESEL C FURF RAFF DESULF HI POUR/HI CETANE/MED SULF
INTERMEDIATE
H2D DIESEL B FURF RAFF DESULF LO POUR/HI CETANE/MED SULF
INTERMEDIATE
H2P H2-STEAM REFORMER BFOE/D H2
PROCESS UNIT
H2S H2S (FOE)
INTERMEDIATE
H2X H2-PARTIAL OXIDIZER BFOE/D H2
PROCESS UNIT
H31 KERO FURF RAFF DESULF HI FREEZE/HI LUMIN/HI SULF
INTERMEDIATE
H32 DIESEL B FURF RAFF DESULF HI POUR/HI CETANE/HI SULF
INTERMEDIATE
H33 NY KERO FURF RAFF DESULF LO POUR/LO LUMIN/HI SULF
INTERMEDIATE
H34 NY KERO FURF RAFF DESULF HI POUR/LO LUMIN/HI SULF
INTERMEDIATE
H36 DIESEL C FURF RAFF DESULF LO POUR/HI CETANE/HI SULF
INTERMEDIATE
H37 DIESEL C FURF RAFF DESULF HI POUR/HI CETANE/HI SULF
INTERMEDIATE
H3D DIESEL B FURF RAFF DESULF LO POUR/HI CETANE/HI SULF
INTERMEDIATE
H3K KERO FURF RAFF DESULF LO FREEZE/HI LUMIN/HI SULF
INTERMEDIATE
H56 HYDROGENATION NORMAL PENTENES/HEXENES
PROCESS UNIT

HAL   HEAVY ALKYLATE
INTERMEDIATE
HCN   NAPHTHA HYDROCRACKER
PROCESS UNIT
HCR   GAS OIL HYDROCRACKER
PROCESS UNIT
HCV   RESIDUUM HYDROCRACKER
PROCESS UNIT
HDN   HIGH DENSITY JET FUEL HYDROTREATING
PROCESS UNIT
HEF   KERO 500-550 FURF EXTRACT FULLY H'TREATED
INTERMEDIATE
HEI   KERO 500-550 FURF EXTRACT INTERM H'TREATED
INTERMEDIATE
HF6   HY FCC GASOLINE (60)
INTERMEDIATE
HF7   HY FCC GASOLINE (70)
INTERMEDIATE
HF8   HY FCC GASOLINE (80)
INTERMEDIATE
HFH   HYDROCRACKER FEED HI SULF
INTERMEDIATE
HFL   HYDROCRACKER FEED LO SULF
INTERMEDIATE
HGH   HY GAS OIL (800-BTMS) NAPHTH,HI SULF
INTERMEDIATE
HGL   HGO (800-BTMS) NAPHTHENIC, LO SULF
NON-CRUDE INPUT
HGM   HY GAS OIL (800-BTMS) NAPHTH,MED SULF
INTERMEDIATE
HGP   HY GAS OIL (800-BTMS) PARAFF,LO SULF
INTERMEDIATE
HGX   HY GAS OIL (800-BTMS) NAPHTH,LO SULF
INTERMEDIATE
HH2   H2 (100 PCT) (FOE)
INTERMEDIATE
HHC   HY HYDROCRACKATE GASOLINE (250-325)
INTERMEDIATE
HHG   H2 (GENERATED)
INTERMEDIATE

HIB HIBERNIA
CRUDE
HJ1 KERO HI SULF RECUT HI FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HJ3 HY KERO HI SULF RECUT LO POUR/HI LUMIN/LO SULF
INTERMEDIATE
HJ4 HY KERO HI SULF RECUT HI POUR/HI LUMIN/LO SULF
INTERMEDIATE
HJC HYDROCRACKATE JET (295-525) C
INTERMEDIATE
HJK KERO HI SULF RECUT LO FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HJV HYDROCRACKATE JET (295-525) V
INTERMEDIATE
HL1 KERO HI SULF TREATED HI FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HL2 DIESEL B HI SULF TREATED LO POUR/LO CETANE/LO SULF
INTERMEDIATE
HL3 HY KERO HI SULF TREATED LO POUR/HI LUMIN/LO SULF
INTERMEDIATE
HL4 HY KERO HI SULF TREATED HI POUR/HI LUMIN/LO SULF
INTERMEDIATE
HL6 DIESEL C HI SULF TREATED LO POUR/HI CETANE/LO SULF
INTERMEDIATE
HL7 DIESEL C HI SULF TREATED HI POUR/HI CETANE/LO SULF
INTERMEDIATE
HL8 DIESEL B 550-650 LO POUR/HI CETANE/L0 SULF
INTERMEDIATE
HL9 DIESEL C 650-690 LO POUR/HI CETANE/L0 SULF
INTERMEDIATE
HLD DIESEL B HI SULF TREATED LO POUR/HI CETANE/LO SULF
INTERMEDIATE
HLK KERO HI SULF TREATED LO FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HLO HYDROGEN/GAS FROM REFORMER HYDROGEN
PROCESS UNIT
HRA HEAVY RAFFINATE (FROM AROMATICS RECOVERY)
INTERMEDIATE
HS1 KERO DEEP H'TREATED HI FREEZE/HI LUMIN/LO SULF
INTERMEDIATE

```
HS2   DIESEL B DEEP H'TREATED HI POUR/HI CETANE/LO SULF
INTERMEDIATE
HS3   HY KERO DEEP H'TREATED LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
HS4   HY KERO DEEP H'TREATED HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
HSD   DIESEL B DEEP H'TREATED LO POUR/HI CETANE/LO SULF
INTERMEDIATE
HSK   KERO DEEP H'TREATED LO FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HTB   RESID BLENDING      MIN 2%FO TO HS MMBPD
PROCESS CONTROL
HU1   KERO ULOW SULF HI FREEZE/HI LUMIN/UL SULF
INTERMEDIATE
HU2   DIESEL B ULOW SULF HI POUR/HI CETANE/UL SULF
INTERMEDIATE
HU3   HY KERO ULOW SULF LO POUR/HI LUMIN/UL SULF
INTERMEDIATE
HU4   HY KERO ULOW SULF HI POUR/HI LUMIN/UL SULF
INTERMEDIATE
HU6   DIESEL C ULOW SULF LO POUR/HI CETANE/UL SULF
INTERMEDIATE
HU7   DIESEL C ULOW SULF HI POUR/HI CETANE/UL SULF
INTERMEDIATE
HU8   DIESEL B 550-650 HYDROT'D LO POUR/HI CETANE/UL SULF
INTERMEDIATE
HU9   DIESEL C 650-690 HYDROT'D LO POUR/HI CETANE/UL SULF
INTERMEDIATE
HUD   DIESEL B ULOW SULF LO POUR/HI CETANE/UL SULF
INTERMEDIATE
HUK   KERO ULOW SULF LO FREEZE/HI LUMIN/UL SULF
INTERMEDIATE
HX1   KERO FURF RAFF HI FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HX2   DIESEL B FURF RAFF HI POUR/HI CETANE/LO SULF
INTERMEDIATE
HX3   HY KERO FURF RAFF LO POUR/HI LUMIN/LO SULF
INTERMEDIATE
HX4   HY KERO FURF RAFF HI POUR/HI LUMIN/LO SULF
INTERMEDIATE
```

HX6 DIESEL C FURF RAFF LO POUR/HI CETANE/LO SULF
INTERMEDIATE
HX7 DIESEL C FURF RAFF HI POUR/HI CETANE/LO SULF
INTERMEDIATE
HXD DIESEL B FURF RAFF LO POUR/HI CETANE/LO SULF
INTERMEDIATE
HXK KERO FURF RAFF LO FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
HY2 DIESEL B FURF RAFF HI POUR/HI CETANE/MED SULF
INTERMEDIATE
HY6 DIESEL C FURF RAFF LO POUR/HI CETANE/MED SULF
INTERMEDIATE
HY7 DIESEL C FURF RAFF HI POUR/HI CETANE/MED SULF
INTERMEDIATE
HYD DIESEL B FURF RAFF LO POUR/HI CETANE/MED SULF
INTERMEDIATE
HZ1 KERO FURF RAFF HI FREEZE/HI LUMIN/HI SULF
INTERMEDIATE
HZ2 DIESEL B FURF RAFF HI POUR/HI CETANE/HI SULF
INTERMEDIATE
HZ3 HY KERO FURF RAFF LO POUR/HI LUMIN/HI SULF
INTERMEDIATE
HZ4 HY KERO FURF RAFF HI POUR/HI LUMIN/HI SULF
INTERMEDIATE
HZ6 DIESEL C FURF RAFF LO POUR/HI CETANE/HI SULF
INTERMEDIATE
HZ7 DIESEL C FURF RAFF HI POUR/HI CETANE/HI SULF
INTERMEDIATE
HZD DIESEL B FURF RAFF LO POUR/HI CETANE/HI SULF
INTERMEDIATE
HZK KERO FURF RAFF LO FREEZE/HI LUMIN/HI SULF
INTERMEDIATE
I4E ISO-BUTYLENE
INTERMEDIATE
IBA IRAQ BASRAH
CRUDE
IC4 ISO-BUTANE
NON-CRUDE INPUT
IC5 ISO-PENTANE
INTERMEDIATE

```
IC6   C6 ISOMERATE
INTERMEDIATE
IHJ   LT JET TREATED  INTERM/HI FREEZE
INTERMEDIATE
IJ1   JP11 570-650 INDONESIA DURI
INTERMEDIATE
IJ8   JP8  375-570 INDONESIA DURI
INTERMEDIATE
ILJ   LT JET TREATED  INTERM/LO FREEZE
INTERMEDIATE
ILS   ILLINOIS SWEET
CRUDE
ILW   ILLINOIS WEEKS
CRUDE
IND   INDIA
CRUDE
INS   INDIANA SWEET
CRUDE
IRH   IRANIAN HVY
CRUDE
IRL   IRANIAN LT
CRUDE
ISA   INDONESIAN LT(ATTAKA)
CRUDE
ISM   INDONESIAN MINAS
CRUDE
ISO   TOTAL C5/C6 ISOMERATE
INTERMEDIATE
IST   MEXICAN ISTHMUS
CRUDE
ITA   ITALY
CRUDE
ITB   RESID BLENDING      MIN 1%FO TO HS MMBPD
PROCESS CONTROL
IVY   IVORY COAST
CRUDE
JFP   HIGH DENSITY JET FUEL PREFRACTIONATION
PROCESS UNIT
JIH   HY NAPHTHA/LT JET (325-375) INTERM/HI FREEZE
INTERMEDIATE
```

JIL HY NAPHTHA/LT JET (325-375) INTERM/LO FREEZE
INTERMEDIATE
JNH HY NAPHTHA/LT JET (325-375) NAPHTH/HI FREEZE
INTERMEDIATE
JNL HY NAPHTHA/LT JET (325-375) NAPHTH/LO FREEZE
INTERMEDIATE
JP4 JP4 NAPHTHA JET
FINISHED PRODUCT
JPH HY NAPHTHA/LT JET (325-375) PARAFF/HI FREEZE
INTERMEDIATE
JPL HY NAPHTHA/LT JET (325-375) PARAFF/LO FREEZE
INTERMEDIATE
JPS RECUT FOR JTA @ 470
PROCESS UNIT
JTA JTA KERO
FINISHED PRODUCT
KEF KERO 375-500 FURF EXTRACT FULLY H'TREATED
INTERMEDIATE
KEI KERO 375-500 FURF EXTRACT INTERM H'TREATED
INTERMEDIATE
KER KEROSENE
FINISHED PRODUCT
KH1 JP11 570-650 H'TREATED ARKANSAS SMACKOVER
INTERMEDIATE
KH8 JP8 375-570 H'TREATED ARKANSAS SMACKOVER
INTERMEDIATE
KHH KEROSENE (375-500) LO FREEZE/HI LUMIN/HI SULF
INTERMEDIATE
KHL KEROSENE (375-500) LO FREEZE/HI LUMIN/LO SULF
INTERMEDIATE
KJ1 JP11 570-650 ARKANSAS SMACKOVER
INTERMEDIATE
KJ8 JP8 375-570 ARKANSAS SMACKOVER
INTERMEDIATE
KLH KEROSENE (375-500) LO FREEZE/LO LUMIN/HI SULF
INTERMEDIATE
KLL KEROSENE (375-500) LO FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
KRD DELAYED COKER
PROCESS UNIT

KRF   FLUID/FLEXI COKER
PROCESS UNIT
KSC   KANSAS COMMON
CRUDE
KSL   KANSAS LT
CRUDE
KUW   KUWAIT
CRUDE
KWG   POWER GENERATION MKW
PROCESS UNIT
KWH   PURCHASED POWER $/KWH
UTILITY
KYS   KENTUCKY SWEET
CRUDE
L00   LP CYCLIC REFORMER MAX % 100 SEVERITY
PROCESS CONTROL
L05   LP CYCLIC REFORMER MAX % 105 SEVERITY
PROCESS CONTROL
L10   REFORMATE (100 RON) 175-250 FEED
INTERMEDIATE
L11   KERO FURF RAFF DESULF HI FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
L12   DIESEL B FURF RAFF DESULF HI POUR/LO CETANE/LO SULF
INTERMEDIATE
L13   NY KERO FURF RAFF DESULF LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
L14   NY KERO FURF RAFF DESULF HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
L16   DIESEL C FURF RAFF DESULF LO POUR/LO CETANE/LO SULF
INTERMEDIATE
L17   DIESEL C FURF RAFF DESULF HI POUR/LO CETANE/LO SULF
INTERMEDIATE
L1D   DIESEL B FURF RAFF DESULF LO POUR/LO CETANE/LO SULF
INTERMEDIATE
L1K   KERO FURF RAFF DESULF LO FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
L1X   REFORMATE (105 RON) 175-250 FEED
INTERMEDIATE
L22   DIESEL B FURF RAFF DESULF HI POUR/LO CETANE/MED SULF
INTERMEDIATE

L26 DIESEL C FURF RAFF DESULF LO POUR/LO CETANE/MED SULF
INTERMEDIATE
L27 DIESEL C FURF RAFF DESULF HI POUR/LO CETANE/MED SULF
INTERMEDIATE
L2D DIESEL B FURF RAFF DESULF LO POUR/LO CETANE/MED SULF
INTERMEDIATE
L31 KERO FURF RAFF DESULF HI FREEZE/LO LUMIN/HI SULF
INTERMEDIATE
L32 DIESEL B FURF RAFF DESULF HI POUR/LO CETANE/HI SULF
INTERMEDIATE
L33 NY KERO FURF RAFF DESULF LO POUR/LO LUMIN/HI SULF
INTERMEDIATE
L34 NY KERO FURF RAFF DESULF HI POUR/LO LUMIN/HI SULF
INTERMEDIATE
L36 DIESEL C FURF RAFF DESULF LO POUR/LO CETANE/HI SULF
INTERMEDIATE
L37 DIESEL C FURF RAFF DESULF HI POUR/LO CETANE/HI SULF
INTERMEDIATE
L3D DIESEL B FURF RAFF DESULF LO POUR/LO CETANE/HI SULF
INTERMEDIATE
L3K KERO FURF RAFF DESULF LO FREEZE/LO LUMIN/HI SULF
INTERMEDIATE
L95 REFORMATE (95 RON) 175-250 FEED
INTERMEDIATE
LAC LOUISIANA COND
CRUDE
LAL LT ALKYLATE (FOR AVGAS)
INTERMEDIATE
LAM LOUSIANA NORTH
CRUDE
LAO LOUSIANA S.MIX
CRUDE
LB1 LT CYCLE OIL 30 BOTTS 0.4 SULF (60)
INTERMEDIATE
LB2 LT CYCLE OIL 30 BOTTS 0.4 SULF (80)
INTERMEDIATE
LB3 LT CYCLE OIL 30 BOTTS 1.6 SULF (60)
INTERMEDIATE
LB4 LT CYCLE OIL 30 BOTTS 1.6 SULF (80)
INTERMEDIATE

LB5   LT CYCLE OIL 30 BOTTS 2.8 SULF (60)
INTERMEDIATE
LB6   LT CYCLE OIL 30 BOTTS 2.8 SULF (80)
INTERMEDIATE
LBS   LUBES & WAXES
FINISHED PRODUCT
LBS   LUBES
INTERMEDIATE
LC1   LT CYCLE OIL 0.4 SULF (60)
INTERMEDIATE
LC2   LT CYCLE OIL 0.4 SULF (80)
INTERMEDIATE
LC3   LT CYCLE OIL 1.6 SULF (60)
INTERMEDIATE
LC4   LT CYCLE OIL 1.6 SULF (80)
INTERMEDIATE
LC5   LT CYCLE OIL 2.8 SULF (60)
INTERMEDIATE
LC6   LT CYCLE OIL 2.8 SULF (80)
INTERMEDIATE
LC7   LT CYCLE OIL ULOW .05 SULF (60)
INTERMEDIATE
LC8   LT CYCLE OIL ULOW .05 SULF (80)
INTERMEDIATE
LEF   LT CYCLE OIL FURF EXTRACT FULLY H'TREATED
INTERMEDIATE
LEI   LT CYCLE OIL FURF EXTRACT INTERM H'TREATED
INTERMEDIATE
LF6   LT FCC GASOLINE (60)
INTERMEDIATE
LF7   LT FCC GASOLINE (70)
INTERMEDIATE
LF8   LT FCC GASOLINE (80)
INTERMEDIATE
LFE   LT CYCLE OIL FURF EXTRACT
INTERMEDIATE
LFR   LT CYCLE OIL FURF RAFF
INTERMEDIATE
LGH   LT GAS OIL (690-800) NAPHTH,HI SULF
INTERMEDIATE

LGL   LT GAS OIL (690-800) NAPHTH,LO SULF
INTERMEDIATE
LGM   LT GAS OIL (690-800) NAPHTH,MED SULF
INTERMEDIATE
LGP   LT GAS OIL (690-800) PARAFF,LO SULF
INTERMEDIATE
LHG   LT HYDROCRACKATE (C5-175)
INTERMEDIATE
LIB   LIBYAN
CRUDE
LJ1   KERO HI SULF RECUT HI FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LJ2   JP11 570-650 WYOMING LAKE
INTERMEDIATE
LJ3   HY KERO HI SULF RECUT LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
LJ4   HY KERO HI SULF RECUT HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
LJ8   JP8 375-570 WYOMING LAKE
INTERMEDIATE
LJK   KERO HI SULF RECUT LO FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LL1   KERO HI SULF TREATED HI FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LL2   DIESEL B HI SULF TREATED HI POUR/LO CETANE/LO SULF
INTERMEDIATE
LL3   HY KERO HI SULF TREATED LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
LL4   HY KERO HI SULF TREATED HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
LL6   DIESEL C HI SULF TREATED LO POUR/LO CETANE/LO SULF
INTERMEDIATE
LL7   DIESEL C HI SULF TREATED HI POUR/LO CETANE/LO SULF
INTERMEDIATE
LL8   DIESEL B 550-650 LO POUR/LO CETANE/L0 SULF
INTERMEDIATE
LL9   DIESEL C 650-690 LO POUR/LO CETANE/L0 SULF
INTERMEDIATE
LLD   DIESEL B HI SULF TREATED LO POUR/LO CETANE/LO SULF
INTERMEDIATE

LLK   KERO HI SULF TREATED LO FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LMI   LUMINOMETER INDEX
QUALITY
LNI   LT NAPHTHA   (175-250) INTERM
INTERMEDIATE
LNN   LT NAPHTHA   (175-250) NAPHTH
INTERMEDIATE
LNP   LT NAPHTHA   (175-250) PARAFF
INTERMEDIATE
LO1   LT CYCLE OIL 70 OHEAD 0.4 SULF (60)
INTERMEDIATE
LO2   LT CYCLE OIL 70 OHEAD 0.4 SULF (80)
INTERMEDIATE
LO3   LT CYCLE OIL 70 OHEAD 1.6 SULF (60)
INTERMEDIATE
LO4   LT CYCLE OIL 70 OHEAD 1.6 SULF (80)
INTERMEDIATE
LO5   LT CYCLE OIL 70 OHEAD 2.8 SULF (60)
INTERMEDIATE
LO6   LT CYCLE OIL 70 OHEAD 2.8 SULF (80)
INTERMEDIATE
LOG   LOCAL LO OCTANE
FINISHED PRODUCT
LOH   LT GAS OIL (690-800) DESULF
INTERMEDIATE
LOS   UNIT LOSSES
PROCESS CONTROL
LPF   PYROLYSIS FUEL OIL
INTERMEDIATE
LPG   LPG
FINISHED PRODUCT
LPG   LPG (SALES MIX)
INTERMEDIATE
LRA   LIGHT RAFFINATE (FROM AROMATICS RECOVERY)
INTERMEDIATE
LS1   KERO DEEP H'TREATED HI FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LS2   DIESEL B DEEP H'TREATED HI POUR/LO CETANE/LO SULF
INTERMEDIATE

LS3 HY KERO DEEP H'TREATED LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
LS4 HY KERO DEEP H'TREATED HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
LSD DIESEL B DEEP H'TREATED LO POUR/LO CETANE/LO SULF
INTERMEDIATE
LSK KERO DEEP H'TREATED LO FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LU1 KERO ULOW SULF HI FREEZE/LO LUMIN/UL SULF
INTERMEDIATE
LU2 DIESEL B ULOW SULF HI POUR/LO CETANE/UL SULF
INTERMEDIATE
LU3 HY KERO ULOW SULF LO POUR/LO LUMIN/UL SULF
INTERMEDIATE
LU4 HY KERO ULOW SULF HI POUR/LO LUMIN/UL SULF
INTERMEDIATE
LU6 DIESEL C ULOW SULF LO POUR/LO CETANE/UL SULF
INTERMEDIATE
LU7 DIESEL C ULOW SULF HI POUR/LO CETANE/UL SULF
INTERMEDIATE
LU8 DIESEL B 550-650 HYDROT'D LO POUR/LO CETANE/UL SULF
INTERMEDIATE
LU9 DIESEL C 650-690 HYDROT'D LO POUR/LO CETANE/UL SULF
INTERMEDIATE
LUB LUBE AND WAX UNITS
PROCESS UNIT
LUD DIESEL B ULOW SULF LO POUR/LO CETANE/UL SULF
INTERMEDIATE
LUK KERO ULOW SULF LO FREEZE/LO LUMIN/UL SULF
INTERMEDIATE
LX1 KERO FURF RAFF HI FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LX2 DIESEL B FURF RAFF HI POUR/LO CETANE/LO SULF
INTERMEDIATE
LX3 HY KERO FURF RAFF LO POUR/LO LUMIN/LO SULF
INTERMEDIATE
LX4 HY KERO FURF RAFF HI POUR/LO LUMIN/LO SULF
INTERMEDIATE
LX6 DIESEL C FURF RAFF LO POUR/LO CETANE/LO SULF
INTERMEDIATE

LX7 DIESEL C FURF RAFF HI POUR/LO CETANE/LO SULF
INTERMEDIATE
LXD DIESEL B FURF RAFF LO POUR/LO CETANE/LO SULF
INTERMEDIATE
LXF LT CYCLE OIL OHEAD FULLY H'TREATED
INTERMEDIATE
LXI LT CYCLE OIL OHEAD INTERM H'TREATED
INTERMEDIATE
LXK KERO FURF RAFF LO FREEZE/LO LUMIN/LO SULF
INTERMEDIATE
LXS LT CYCLE OIL OHEAD MILD H'TREATED
INTERMEDIATE
LY2 DIESEL B FURF RAFF HI POUR/LO CETANE/MED SULF
INTERMEDIATE
LY6 DIESEL C FURF RAFF LO POUR/LO CETANE/MED SULF
INTERMEDIATE
LY7 DIESEL C FURF RAFF HI POUR/LO CETANE/MED SULF
INTERMEDIATE
LYD DIESEL B FURF RAFF LO POUR/LO CETANE/MED SULF
INTERMEDIATE
LZ1 KERO FURF RAFF HI FREEZE/LO LUMIN/HI SULF
INTERMEDIATE
LZ2 DIESEL B FURF RAFF HI POUR/LO CETANE/HI SULF
INTERMEDIATE
LZ3 HY KERO FURF RAFF LO POUR/LO LUMIN/HI SULF
INTERMEDIATE
LZ4 HY KERO FURF RAFF HI POUR/LO LUMIN/HI SULF
INTERMEDIATE
LZ6 DIESEL C FURF RAFF LO POUR/LO CETANE/HI SULF
INTERMEDIATE
LZ7 DIESEL C FURF RAFF HI POUR/LO CETANE/HI SULF
INTERMEDIATE
LZD DIESEL B FURF RAFF LO POUR/LO CETANE/HI SULF
INTERMEDIATE
LZK KERO FURF RAFF LO FREEZE/LO LUMIN/HI SULF
INTERMEDIATE
M NORTH AFRICA + MEDITERRANEAN
REGION
M00 MOTOR OCTANE NUMBER @ 0.0 GRAMS LEAD PER GALLON
QUALITY

M05 MOTOR OCTANE NUMBER @ 0.5 GRAMS LEAD PER GALLON
QUALITY
M15 MOTOR OCTANE NUMBER @ 1.5 GRAMS LEAD PER GALLON
QUALITY
M30 MOTOR OCTANE NUMBER @ 3.0 GRAMS LEAD PER GALLON
QUALITY
MAY MEXICAN MAYA
CRUDE
MET PURCHASED METHANOL
NON-CRUDE INPUT
MET METHANOL CONTENT
QUALITY
MHC MED HYDROCRACKATE (175-250) C
INTERMEDIATE
MHV MED HYDROCRACKATE (175-250) V
INTERMEDIATE
MIS MICHIGAN SWEET
CRUDE
MLT MEXICAN OLMECA
CRUDE
MLU MALAYSIA LABUAN
CRUDE
MN1 MMT (0-1/32 G/GAL)
UTILITY
MN2 MMT (1/32-1/16 G/GAL)
UTILITY
MN3 MMT (1/16-3/32 G/GAL)
UTILITY
MN4 MMT (3/32-1/8 G/GAL)
UTILITY
MON MOTOR OCTANE NUMBER
QUALITY
MOS MISSOURI
CRUDE
MSB MISSISSIPPI BAXTER
CRUDE
MSD CAT CRACKER MAX % DIST FEED
PROCESS CONTROL
MSH MISSISSIPPI HEAVY
CRUDE

```
MSL   CAT CRACKER          MAX % LT OLEFIN MODE
PROCESS CONTROL
MSR   CAT CRACKER          MAX % LO SULF RESID
PROCESS CONTROL
MSS   MISSISSIPPI SWEET
CRUDE
MSZ   CAT CRACKER          MAX % ZSM OPERATION
PROCESS CONTROL
MTB   MTBE OXYGENATE
NON-CRUDE INPUT
MTR   MONTANA SWEET
CRUDE
MTS   MONTANA SOUR
CRUDE
MXU   LP CYCLIC REFORMER  MAX % R-62 OPERATION
PROCESS CONTROL
N     NORTHERN EUROPE
REGION
N6A   RESID < .3%
FINISHED PRODUCT
N6B   RESID > 2.0%
FINISHED PRODUCT
N6H   RESID 1.0-2.0%
FINISHED PRODUCT
N6I   RESID .3-1.0%
FINISHED PRODUCT
NAT   PENTANES PLUS
FINISHED PRODUCT
NAT   NATURAL GASOLINE
NON-CRUDE INPUT
NAV   NO4 FUEL
FINISHED PRODUCT
NC4   N-BUTANE
NON-CRUDE INPUT
NC5   N-PENTANE
INTERMEDIATE
NC6   N-HEXANE
INTERMEDIATE
NDS   NORTH DAKOTA SWEET
CRUDE
```

NDS NAPHTHA HYDROTREATER
PROCESS UNIT
NES NEBRASKA SWEET
CRUDE
NET NETHERLANDS
CRUDE
NGB NIGERIAN BONNY/LIGHT
CRUDE
NGF NIGERIAN FORCADOS
CRUDE
NGL NIGERIAN LIGHT
CRUDE
NGM NIGERIAN MEDIUM
CRUDE
NGS NATURAL GAS FOR FUEL
NON-CRUDE INPUT
NHJ LT JET TREATED NAPHTH/HI FREEZE
INTERMEDIATE
NLJ LT JET TREATED NAPHTH/LO FREEZE
INTERMEDIATE
NMI NEW MEXICO INT
CRUDE
NMS NEW MEXICO SOUR
CRUDE
NOR NORWAY
CRUDE
NPA PETCHEM NAPHTHA
FINISHED PRODUCT
NPB SPECIAL NAPHTHA
FINISHED PRODUCT
NPI NAPHTHA (250-325) INTERMEDIATE
NON-CRUDE INPUT
NPN NAPHTHA (250-325) NAPHTH
INTERMEDIATE
NPP NAPHTHA (250-325) PARAFF
INTERMEDIATE
NTZ NEUTRAL ZONE
CRUDE
NYL NEW YORK
CRUDE

NYM   NORTH YEMEN
CRUDE
NZL   NEW ZEALAND
CRUDE
OBJ   OBJECTIVE FUNCTION
PROCESS CONTROL
OH1   JP11 570-650 H'TREATED SAN ARDO
INTERMEDIATE
OH8   JP8 375-570 H'TREATED SAN ARDO
INTERMEDIATE
OHL   OHIO
CRUDE
OJ1   JP11 570-650 SAN ARDO
INTERMEDIATE
OJ8   JP8 375-570 SAN ARDO
INTERMEDIATE
OKC   OKLAHOMA COND
CRUDE
OKG   OKLAHOMA GARBER
CRUDE
OKM   OKLAHOMA CEMENT
CRUDE
OKR   OKLAHOMA SOUR
CRUDE
OLE   C2-C5 DEHYDROGENATION
PROCESS UNIT
OLE   OLEFIN CONTENT
QUALITY
OLX   C2-C5 DEHYDROGENATION
PROCESS UNIT
OMN   OMAN
CRUDE
OVC   OTHER VARIABLE OPERATING COSTS
PROCESS CONTROL
OXL   OXINOL OXYGENATE
NON-CRUDE INPUT
P   PACIFIC HIGH GROWTH
REGION
PAK   PAKISTAN
CRUDE

PAL PENNSYLVANIA
CRUDE
PAR PARAFFINS CONTENT
QUALITY
PFF REFINERY FUEL MAX HSFO INPUT MMBPD
PROCESS CONTROL
PFH REFINERY FUEL MAX H2S MM BFOEPD
PROCESS CONTROL
PFU REFINERY FUEL MAX LSFO INPUT MMBPD
PROCESS CONTROL
PGS STILL GAS
FINISHED PRODUCT
PGS GAS (SATURATED C1/C2) (FOE)
INTERMEDIATE
PGU GAS (UNSATURATED C1/C2) (FOE)
INTERMEDIATE
PHI PENTANE/HEXANE ISOMERIZATION
PROCESS UNIT
PHJ LT JET TREATED PARAFF/HI FREEZE
INTERMEDIATE
PHL PHILIPPINES
CRUDE
PIF POUR POINT DEPRESSANT
QUALITY
PJF LT PYROLYSIS FUEL OIL FULLY H'TREATED
INTERMEDIATE
PJI LT PRYOLYSIS FUEL OIL INTERM H'TREATED
INTERMEDIATE
PJS LT PYROLYSIS FUEL OIL MILD H'TREATED
INTERMEDIATE
PLJ LT JET TREATED PARAFF/LO FREEZE
INTERMEDIATE
PO2 OXYGEN CONTENT
QUALITY
PRI POUR POINT INDEX
QUALITY
PRM PREMIUM GASOLINE
FINISHED PRODUCT
PRU PERU
CRUDE

QBM SPR BRYAN MD MAYAN
CRUDE
QBR SPR BRYAN MD SOUR
CRUDE
QBS SPR BRYAN MD SWEET
CRUDE
QCR SPR CHOCTAW SOUR
CRUDE
QCS SPR CHOCTAW SWEET
CRUDE
QGE FPR W GERMANY
CRUDE
QHH SPR FUTURE HH (SAH)
CRUDE
QHR SPR W HACK SOUR
CRUDE
QHS SPR W HACK SWEET
CRUDE
QHV SPR FUTURE HV (MAY)
CRUDE
QJA FPR JAPAN
CRUDE
QLL SPR FUTURE LL (UKN)
CRUDE
QLM SPR FUTURE LM (MUR)
CRUDE
QMH SPR FUTURE MH (IST)
CRUDE
QMM SPR FUTURE MM (ANS)
CRUDE
QOT FPR OTHER
CRUDE
QTR QATAR DUKHAN/MARINE
CRUDE
QWR SPR WEEKS IS SOUR
CRUDE
R00 RESEARCH OCTANE NUMBER @ 0.0 GRAMS LEAD PER GALLON
QUALITY
R05 RESEARCH OCTANE NUMBER @ 0.5 GRAMS LEAD PER GALLON
QUALITY

R10   REFORMATE (100 RON)
INTERMEDIATE
R15   RESEARCH OCTANE NUMBER @ 1.5 GRAMS LEAD PER GALLON
QUALITY
R1X   REFORMATE (105 RON)
INTERMEDIATE
R30   RESEARCH OCTANE NUMBER @ 3.0 GRAMS LEAD PER GALLON
QUALITY
R5E   REACTIVE AMYLENES (ISO)
INTERMEDIATE
R6E   REACTIVE HEXYLENES (ISO)
INTERMEDIATE
R80   REFORMATE (80 RON)
INTERMEDIATE
R90   REFORMATE (90 RON)
INTERMEDIATE
R95   REFORMATE (95 RON)
NON-CRUDE INPUT
RDS   RESIDUUM DESULFURIZER
PROCESS UNIT
REA   REACTIVITY
QUALITY
REG   REGULAR GASOLINE
FINISHED PRODUCT
RFC   LP CONTINUOUS REFORMER
PROCESS UNIT
RFC   REFORMER FEED (175-375) COKER
INTERMEDIATE
RFF   REFORMER FEED (250-400) FCC HY
INTERMEDIATE
RFH   HP SEMI-REGENERATIVE REFORMER
PROCESS UNIT
RFI   REFORMER FEED (250-325) INTERM
INTERMEDIATE
RFL   LP CYCLIC REFORMER
PROCESS UNIT
RFM   REFORMULATED GASOLINE
FINISHED PRODUCT
RFN   REFORMER FEED (250-325) NAPHTH
INTERMEDIATE

RFP REFORMER FEED (250-325) PARAFF
INTERMEDIATE
RLI REFORMER FEED (175-250) IMTERM
INTERMEDIATE
RLL REFORMER FEED (158-175) LIGHT
INTERMEDIATE
RLN REFORMER FEED (175-250) NAPHTH
INTERMEDIATE
RLP REFORMER FEED (175-250) PARAFF
INTERMEDIATE
ROM USSR & OTH E.EUROPE
CRUDE
RON RESEARCH OCTANE NUMBER
QUALITY
RSH VACUUM RESIDUE HI (2.3) SULF
INTERMEDIATE
RSI VACUUM RESIDUE LO (0.9) SULF
INTERMEDIATE
RSL VACUUM RESIDUE V LO (0.5) SULF
INTERMEDIATE
RSM VACUUM RESIDUE INTERM (1.5) SULF
INTERMEDIATE
RSV VACUUM RESIDUE HI (3.8) SULF
INTERMEDIATE
RVP REID VAPOR PRESSURE
QUALITY
RVP REID VAPOR PRESSURE
QUALITY
S SOUTHERN EUROPE
REGION
SAB SAUDI ARABIAN BERRI
CRUDE
SAH SAUDI ARABIAN HEAVY
CRUDE
SAL SAUDI ARABIAN LIGHT
CRUDE
SAM SAUDI ARABIAN MEDIUM
CRUDE
SDA SOLVENT DEASPHALTING
PROCESS UNIT

SDS   SOUTH DAKOTA SWEET
CRUDE
SLP   SULPHUR MMST/D
FINISHED PRODUCT
SLP   SULFUR (SHORT TONS/CD)
INTERMEDIATE
SPC   SULFUR CONTENT DISTILLATES (PER CENT)
QUALITY
SPL   NAPHTHA SPLITTER
PROCESS UNIT
SPM   SULFUR CONTENT GASOLINES (PPM)
QUALITY
SPN   SPAIN
CRUDE
SRH   LT STRAIGHT-RUN   (C5-175) HI ON
INTERMEDIATE
SRI   LT STRAIGHT-RUN   (C5-175) INT ON
INTERMEDIATE
SRL   LT STRAIGHT-RUN   (C5-175) LO ON
INTERMEDIATE
STG   STEAM GENERATION, LBS/HR
PROCESS UNIT
STM   STEAM LB/HR($/LB*24HR/D)
UTILITY
STX   STEAM GENERATION, LBS/HR
PROCESS UNIT
SUD   SUDAN
CRUDE
SUL   SULFUR RECOVERY (SHORT TONS/DAY)
PROCESS UNIT
SVC   CAT REFORMER CONTINUOUS MAX SEVERITY
PROCESS CONTROL
SVH   CAT REFORMER HIGH PRESS MAX SEVERITY
PROCESS CONTROL
SVL   CAT REFORMER LOW PRESS MAX SEVERITY
PROCESS CONTROL
SVR   CAT CRACKER   MAX SEVERITY
PROCESS CONTROL
SYR   SYRIA
CRUDE

T REST OF WORLD
REFINERY
T4E ISOMERIZED 2-BUTYLENE
INTERMEDIATE
TAE ETAE
NON-CRUDE INPUT
TAM TAME OXYGENATE
INTERMEDIATE
TBA TBA OXYGENATE
NON-CRUDE INPUT
TCG THERMAL CRACKER C2-C4 FEED
PROCESS UNIT
TCL TEXAS CONDENSATE
CRUDE
TCN THERMAL CRACKER NAPHTHA FEED
PROCESS UNIT
TCV THERMAL CRACKER GAS OIL FEED
PROCESS UNIT
TDH TRINIDAD SOUR HS
CRUDE
TDL TRINIDAD SWEET LS
CRUDE
TEH TEXAS HAWKINS
CRUDE
TEL TETRAETHYL LEAD
UTILITY
TEL LEAD CONTENT (GRAMS PER GALLON)
QUALITY
TEN TENNESSEE
CRUDE
TGR TEXAS GULF REF
CRUDE
THE THEE
NON-CRUDE INPUT
THM THME OXYGENATE
INTERMEDIATE
TJ1 JP11 570-650 TEXAS REFUGIO
INTERMEDIATE
TJ8 JP8 375-570 TEXAS REFUGIO
INTERMEDIATE

TRI   TOTAL RECYCLE ISOMERIZATION
PROCESS UNIT
TUN   TUNISIA
CRUDE
TUR   TURKEY
CRUDE
TWI   TEXAS WEST INTERMED
CRUDE
TWL   TEXAS WEST LIGHT
CRUDE
TWS   TEXAS WEST SOUR
CRUDE
TWY   TEXAS WEST SCURRY
CRUDE
TXE   TEXAS EAST
CRUDE
UC3   PROPYLENE
NON-CRUDE INPUT
UC4   BUTYLENE
NON-CRUDE INPUT
UKN   UK NORTH SEA
CRUDE
UNL   PLUS GASOLINE
FINISHED PRODUCT
UTA   UTAH
CRUDE
V10   REFORMATE (100 RON) 158-175 FEED
INTERMEDIATE
V17   VENEZ LT/REC(LOT 17)
CRUDE
V90   REFORMATE (90 RON) 158-175 FEED
INTERMEDIATE
V95   REFORMATE (95 RON) 158-175 FEED
INTERMEDIATE
VAA   VACUUM RESIDUE TYPE A
INTERMEDIATE
VAB   VACUUM RESIDUE TYPE B
INTERMEDIATE
VAC   VACUUM RESIDUE TYPE C
INTERMEDIATE

VAD   VACUUM RESIDUE TYPE D
INTERMEDIATE
VAE   VACUUM RESIDUE TYPE E
INTERMEDIATE
VAF   VACUUM RESIDUE TYPE F
INTERMEDIATE
VAG   VACUUM RESIDUE TYPE G
INTERMEDIATE
VAH   VACUUM RESIDUE TYPE H
INTERMEDIATE
VAI   VACUUM RESIDUE TYPE I
INTERMEDIATE
VAJ   VACUUM RESIDUE TYPE J
INTERMEDIATE
VAK   VACUUM RESIDUE TYPE K
INTERMEDIATE
VAL   VACUUM RESIDUE TYPE L
INTERMEDIATE
VAM   VACUUM RESIDUE TYPE M
INTERMEDIATE
VB1   VISCOSITY INDEX @ -40 DEG F
QUALITY
VB2   VISCOSITY INDEX @ -30 DEG F
QUALITY
VB3   VISCOSITY INDEX @ - 4 DEG F
QUALITY
VB4   VISCOSITY INDEX @ 100 DEG F
QUALITY
VB5   VISCOSITY INDEX @ 104 DEG F
QUALITY
VBI   VISCOSITY INDEX @ 122 DEG F
QUALITY
VBR   VISBREAKER/THERMAL CRACKER
PROCESS UNIT
VCU   VACUUM DISTILLATION
PROCESS UNIT
VH1   JP11 570-650 H'TREATED VENEZUALA QUIREQUIRE
INTERMEDIATE
VH8   JP8 375-570 H'TREATED VENEZUALA QUIREQUIRE
INTERMEDIATE

VJ1   JP11 570-650 VENEZUALA QUIREQUIRE
INTERMEDIATE
VJ8   JP8 375-570 VENEZUALA QUIREQUIRE
INTERMEDIATE
VJO   VENEZUELAN JOBO
CRUDE
VLI   VAPOR/LIQUID INDEX
QUALITY
VRH   VACUUM RESIDUE MED SULF VISBROKEN
INTERMEDIATE
VRI   VACUUM RESIDUE LO SULF VISBROKEN
INTERMEDIATE
VRL   VACUUM RESIDUE V LO SULF VISBROKEN
INTERMEDIATE
VRM   VACUUM RESIDUE INTERM SULF VISBROKEN
INTERMEDIATE
VRV   VACUUM RESIDUE HI SULF VISBROKEN
INTERMEDIATE
VSP   VACUUM ASPHALT V HI SULF VISBROKEN
INTERMEDIATE
VSY   VENEZUELAN SYNCRUDE
CRUDE
VZB   VENEZ XHVY(BOSCAN)
CRUDE
VZO   VENEZ HEAVY(BACH LT)
CRUDE
VZT   VENEZ MED (TJ MED)
CRUDE
W   PADD 5 + WESTERN CANADA
REGION
WVL   WEST VIRGINIA
CRUDE
WYP   WYOMING SOUR
CRUDE
WYS   WYOMING SWEET
CRUDE
X   REST OF WORLD
REGION
ZAR   ZAIRE
CRUDE

ZC6 WHOLE FCC GASOLINE (60) HIOCT CATALYST
INTERMEDIATE
ZC7 WHOLE FCC GASOLINE (70) HIOCT CATALYST
INTERMEDIATE
ZC8 WHOLE FCC GASOLINE (80) HIOCT CATALYST
INTERMEDIATE
ZH6 HY FCC GASOLINE (60) HIOCT CATALYST
INTERMEDIATE
ZH7 HY FCC GASOLINE (70) HIOCT CATALYST
INTERMEDIATE
ZH8 HY FCC GASOLINE (80) HIOCT CATALYST
INTERMEDIATE
ZL6 LT FCC GASOLINE (60) HIOCT CATALYST
INTERMEDIATE
ZL7 LT FCC GASOLINE (70) HIOCT CATALYST
INTERMEDIATE
ZL8 LT FCC GASOLINE (80) HIOCT CATALYST
INTERMEDIATE

APPENDIX H MAINFRAME JOB CONTROL

SAMPLE WORLD EIA MAINFRAME JOB CONTROL STREAM

```
//DB2UNCOK  JOB (6134,FOR,1,60,,,01),'OXYMAGEN',TIME=(9,59),
//*           CLASS=S,
//            MSGCLASS=A,MSGLEVEL=(2,1),NOTIFY=DB26134
//*******************************************************************
//*   WORLD LOGISTICS MODEL - RUN NOTES
//*
//*   AS AUG20 EXCEPT CKH @ $10/T AND H2P PUL CHANGED TO 50%
//*   MERCHANT MTBE T/PS FORCED
//*   $0.60 ADDED TO OVC ON FCC HI LIGHT OLEFIN OPERATIONS
//*   G TO P SHIPMENT COSTS LOWERED TO PREVENT ENTREPOT VIA X
//*
//*   SEP10 RUN - CANADIAN CRUDES INTO P234ECAN FIXED IN VECBND
//*   SEP11 RUN - AS SEP10 BUT US MOGAS & DIESEL DMDS 100% CONV
//*   SEP21 RUN - NPC CASE LO DMD SEV SPECS FUEL SUBSTITUTION
//*
//*******************************************************************
//*
//* UTILITIES PRINT OUT ALL CASE DATA INPUT FILES
//*
//REGLCU    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(REGLCU),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//CRPROD    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(CRDNCP2V),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*
//CRDISP    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(CRDISP20),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*
//CRTRAN    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(CRTRAN2V),
//          DISP=SHR
```

```
//SYSUT2   DD SYSOUT=A
//*
//*
//PRTRAN    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(PRTRAN2V),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*
//VECBND2V    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(VECBND2V),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*
//DEMAND    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(DEMCOK2N),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*
//REFCAP    EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//*
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(REFCAP2B),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*
//*
//SPECOUT   EXEC PGM=IEBGENER
//SYSIN     DD DUMMY
//SYSPRINT  DD SYSOUT=A
//SYSUT1    DD DSN=CN6134.PRJ.CEM.W20DATA(AVSPEC2B),
//*SYSUT1    DD DSN=CN6134.PRJ.CEM.W10DATA(WSPECW10),
//          DISP=SHR
//SYSUT2   DD SYSOUT=A
//*
//*   MATRIX GENERATION
//*
//W10GEN   EXEC PGM=OMNI,REGION=2048K
//STEPLIB  DD DSN=SYS3.OMNI.V0.LOADLIB,DISP=SHR
//HSILP360 DD DSN=SYS3.OMNI.V0.SYSLIB,DISP=SHR
//DICTDATA DD DSN=&&LPDICT,DISP=(,PASS),
//          UNIT=SYSDA,SPACE=(CYL,5,,CONTIG)
//*
//*        JCL STREAM SAVES MATRIX BCDOUT FILE
//*
//MAGENOUT DD DSN=CN6134.PRJ.CEM.W10BCD,
//         DISP=SHR
```

```
//*PFILE    DD DSN=CN6134.PRJ.CEM.W10PFIL,DISP=SHR
//PFILE    DD DSN=&REPORT,DISP=(NEW,PASS),
//         UNIT=SYSDA,SPACE=(CYL,(1,1),RLSE,CONTIG),
//         DCB=(LRECL=133,BLKSIZE=2926,RECFM=FB)
//LCUFILE  DD UNIT=SYSDA,SPACE=(TRK,(60,10),,CONTIG),
//         DISP=(NEW,PASS),DSN=&&LCUFIL
//*
//*        CLASSES
//*
//CLASSES  DD DSN=CN6134.PRJ.CEM.W20DATA(W10CLASS),
//         DISP=SHR
//*
//*        DATA TABLES
//*
//*   CONCATENATION OF ALL DATA FILES
//*
//REFTAB   DD DSN=CN6134.PRJ.CEM.W20DATA(CRDNCP2V),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(CRDISP20),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(CRTRAN2V),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(PRTRAN2V),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(VECBND2V),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(DEMCOK2N),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(REFCAP2B),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(OXRYMW20),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(AVSPEC2B),
//*         DD DSN=CN6134.PRJ.CEM.W10DATA(WSPECW10),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(REGLCU),
//         DISP=SHR
//         DD DSN=CN6134.PRJ.CEM.W20DATA(MTFIXREP),
//         DISP=SHR
//*
//*   OMNI SOURCE CODE FILES
//*
//GENCOD DD DISP=SHR,DSN=CN6134.PRJ.CEM.W20DATA(OXYMAGN2)
//*
//REPCOD DD DISP=SHR,DSN=CN6134.PRJ.CEM.W20DATA(OXRWJL)
//*
//UTLCOD DD DISP=SHR,DSN=CN6134.PRJ.CEM.DNDDATA(LCU4JQ5)
//       DD DISP=SHR,DSN=CN6134.PRJ.CEM.DNDDATA(TAB)
//       DD DISP=SHR,DSN=CN6134.PRJ.CEM.DNDDATA(LCU940)
//*
//PRNTFILE DD SYSOUT=A
//CARDFILE DD *
*
*  OMNI MATRIX GENERATION CONTROL
*
OMNI,NUDD,NULCU
     ALLOCATE,DID=1024,DAD=24576,P1=53000,NV=4096,EX=64000,SD=2048
*
     DICTIONARY
*
```

```
*
        CLASS REPLCU  REP. NO.  NAME                         > PAGE
*
              205   1.0 - CRUDE CATEGORIZATION                 1.01
              210   2.0 - ECONOMIC SUMMARY                     2.01
              211   3.0 - ACCOUNTING SUMMARY/TRANSFERS         3.01
              245   4.0 - GASOLINE,FUEL OIL BLENDS             4.01
              246   5.0 - FUEL OIL BLENDS, EXTENSION           5.01
*             INVESTMENT REPORT MODULE SWITCHED OFF
              280   6.0 - INVESTMENT REPORT                    6.01
*
*
*
        CLASS DESCX     SCENARIO DESCRIPTION
*
*       1     1     2                            5                6
*234567890123456789012345678901234567890123456789012345678901234567
              P2345 - - - - - - - - - - - - - - - - - - - - - - - -*
              PBLNK *                                               *
              TL1   ENSYS  -  WORLD  -  MODEL
              TL2   10 REGION VERSION
              TL3   YEAR 2000 2B SEVERE NO NES COKE $10
              MODEL    WORLD     M O D E L   R E P O R T
              CNAME    ENSYS   WORLD  11 REGION 10 REFINERY
              PBL11 *                                               *
              P11   BASIS FOR THIS SCENARIO IS:
              R12   YEAR 2000 WORLD MODEL
              PBL22 *                                               *
              R13   PRODUCT DEMANDS AND CRUDE INPUTS
              R14   BASED ON AEO/IEO/1991
              R15
              PBL33 *                                               *
              LI50  END       OF    SCENARIO DESCRIPTION
              P9995 - - - - - - - - - - - - - - - - - - - - - - - -*
*
*
    LIST,EJECT
*
*
*                           GET INPUT TABLES
*
    LIST,OFF
    SWITCH TO T,CLASSES
    SWITCH TO T,REFTAB
    LIST,OFF
*
*
    LIST,LCUOFF
    LIST,CALLOFF
    MODE,COMPILE
    COMPILE,MAGENIV
    SWITCH TO T,GENCOD
    END
    SWITCH TO T,REPCOD
    END
    COMPILE
    SWITCH TO T,UTLCOD
    END
*
*            EXECUTE MATRIX (CEM) LCU'S
```

```
*
*    EXECUTE,50
     EXECUTE,75
     EXECUTE,99
     EXECUTE,(100,125)
     TIME
     ENDJOB
END JOB
/*
//*
//*  MPS 3 STEP TO SOLVE
//*
//MPSSOLV  EXEC MPS3,VERS=0,TIME.EXEC=(9,59),REGION=4000K,
//         SCRATCH=1000,ETA=800,MATRIX=1000,PROBFIL=1000,
//*        COND=(16,NE,W10GEN)
//         COND=(0,NE,W10GEN)
//CPC.SYSPRINT DD SYSOUT=A
//CPC.SYSIN DD *
         PROGRAM('ND')
         TITLE('"NPC" CASE LO DMD NO SUBSTIT SEV SPEC - LOW CKL DMD')
         INITIALZ
         ASSIGN('CEMMPS','CEMMPS','CARD')
         MOVE(XDATA,'CEM')
         MOVE(XPBNAME,'CEMREGD')
         CONVERT('FILE','CEMMPS')
         WRITE('*** CONVERT COMPLETE ***')
         MOVE(XOBJ,'OBJ')
         MOVE(XRHS,'RHS')
*  XSETLB =0 SETS NON BASIC VECTORS AT UB, =-1 AT LB
*  USED TO SET INV VECTORS NOT IN BASIS AT ZERO NOT UB
         XSETLB=-1
         XFREQINV=50
         SETUP('BOUND','BND','MAX')
         WRITE('*** SETUP COMPLETE  ***')
         XFREQLGO=200
         XFREQLGA=200
*        XFREQ1=20000
*        XFREQ1=5
*        XEPS=.00001
         MVADR(XDONFS,LOOK)
*        MVADR(XDOFREQ1,SAVBAS)
*        MAPIN ('FILE','INBASIS')
*        CRASH
         WHIZMAPN
         WHIZARD('NOFE','MERIT','STABLE',STBIT,'FREQ',SAVIT)
*        WHIZARD('NOFE','TRACE','STABLE',STBIT,'FREQ',SAVIT)
*        WHIZARD('NOFE','MERIT','STABLE',STBIT,'FREQ',SAVIT)
*        WHIZARD('NOFE','MERIT','FREQ',SAVIT)
*        WHIZARD('NOFE','MERIT','DUAL','FREQ',SAVIT)
*        WHIZARD('NOFE','TRACE','FREQ',SAVIT)
*        WHIZARD('DUAL','NOFE','TRACE','FREQ',SAVIT)
*        WHIZARD('DUAL','NOFE','TRACE')
*        WHIZARD('NOFE','TRACE')
*        PRIMAL
         MAPOUT('FILE','BASIS')
         WRITE('*** WHIZARD COMPLETE ***')
         CLOSEF('BASIS')
         WRITE(' *** BASIS SAVED ***')
         SOLUTION('ACTIVE')
*        SOLUTION
```

```
          EXEC(PERUZIT)
          EXIT
LOOK      WRITE('NO FEASIBLE.. SOLUTION')
*         SOLUTION('ACTIVE')
          SOLUTION('NAMES')
*         EXEC(PERUZIT)
          XCCODE=1
          EXIT
PERUZIT   WRITE('BEGIN PERUSAL')
          SOLUTION('STANDARD','FT03F001')
          STEP
SAVBAS    WRITE('SAVE BASIS   ')
*         SOLUTION('ACTIVE','NAMES')
*         XCCODE=1
*         EXIT
*         MAPOUT('FILE','BASIS')
          CONTINUE
SAVIT     DC(5000)
STBIT     DC(5)
          PEND
/*
//*  MPSIII FILES

//*XEC.PROBFILE DD SPACE=(CYL,5,,CONTIG),UNIT=SYSDA
//*XEC.ETA1     DD SPACE=(CYL,5,,CONTIG),UNIT=SYSDA
//*XEC.MATRIX1  DD SPACE=(CYL,30,,CONTIG),UNIT=SYSDA
//*XEC.SCRATCH1 DD SPACE=(CYL,5,,CONTIG),UNIT=SYSDA
//*XEC.SCRATCH2 DD SPACE=(CYL,5,,CONTIG),UNIT=SYSDA
//EXEC.SYSPRINT DD SYSOUT=A
//EXEC.SYSUDUMP DD DUMMY
//EXEC.CEMMPS  DD DSN=CN6134.PRJ.CEM.W10BCD,DISP=SHR
//EXEC.BASIS   DD DSN=CN6134.PRJ.CEM.W20BNPCN,
//             DISP=SHR
//*EXEC.INBASIS   DD DSN=CN6134.PRJ.CEM.W20INBAS,
//EXEC.INBASIS   DD DSN=CN6134.PRJ.CEM.SEP31R.NPCLOCKL.OPTBAS,
//             DISP=SHR
//EXEC.WHIZFILE  DD DSN=CN6134.PRJ.CEM.W10WHIZ.NPCOK,
//             UNIT=DASD,
//*            UNIT=SYSDA,
//             DISP=SHR
//*            DISP=(NEW,CATLG),SPACE=(6440,(1024,112))
//*            DISP=(NEW,CATLG,DELETE),SPACE=(6440,(1024,112))
//*            DISP=(NEW,CATLG),SPACE=(6440,(2048,112))
//*EXEC.FT03F001 DD  DSN=CN6134.PRJ.CEM.W10SOL2,DISP=SHR
//EXEC.FT03F001 DD  DSN=CN6134.PRJ.CEM.W10SOL2,
//             UNIT=SYSDA,DISP=(,PASS),
//             SPACE=(CYL,(4,1),RLSE,CONTIG),
//             DCB=(RECFM=VBS,LRECL=204,BLKSIZE=2044)
//*
//*  EXECUTE OMNI LCU'S FOR REPORT GENERATION
//*
//W10REP   EXEC PGM=OMNI,REGION=2048K,PARM='FREE=64',TIME=9,
//         COND=((0,NE,W10GEN),(0,NE,MPSSOLV.EXEC))
//*        COND=((16,NE,W10GEN),(16,NE,MPSSOLV.EXEC))
//STEPLIB  DD DSN=SYS3.OMNI.V0.LOADLIB,DISP=SHR
//HSILP360 DD DSN=SYS3.OMNI.V0.SYSLIB,DISP=SHR
//PFILE    DD DSN=*.W10GEN.PFILE,DISP=(OLD,PASS)
//DICTDATA DD DSN=*.W10GEN.DICTDATA,DISP=(OLD,PASS)
//MAGENOUT DD DSN=*.W10GEN.MAGENOUT,DISP=SHR
//LCUFILE  DD DSN=*.W10GEN.LCUFILE,DISP=(OLD,PASS)
```

```
//*
//*        REFERS TO WORLD SOLUTION
//*
//MPSSOLUT DD DSN=CN6134.PRJ.CEM.W10SOL2,DISP=SHR
//PACKSOLN DD UNIT=SYSDA,SPACE=(CYL,6,RLSE,CONTIG)
//SCRATCH  DD UNIT=SYSDA,SPACE=(CYL,12,,CONTIG)
//PRNTFILE DD SYSOUT=A
//CARDFILE DD *
OMNI,UPDD,RDLCU
*
     ALLOCATE,DID=1024,DAD=24576,P1=35000,NV=25600,EX=64000,SD=2048
     ALLOCATE,WA=17000
*
     DICTIONARY
*
     LIST,EJECT
*
*                            GET INPUT TABLES
*
     LIST,OFF
     DATA
*
     LIST,LCUON
     LIST,CALLOFF
*
*
     SOLUTION,S,NOMTX
CEM
*    EXECUTE LCU'S
     LIST,CALLOFF
     EXECUTE,4800
*          EXECUTE OMNI LCU'S TO LIST DATA TABLES AND CLASSES
**   EXECUTE,(4990,4991)
*
* EXECUTE REPORT SEQUENCE AS DESIGNATED IN TABLE REPLCU
*
     BYPASS,EXCEPT TABLE REPLCU(R,L199),GO TO 500
**INFEASIBILITIES REPORT - CURRENTLY INOPERATIVE
     EXECUTE,199
 500 BYPASS,EXCEPT TABLE REPLCU(R,L200),GO TO 501
**INITIALIZATION - MUST BE EXECUTED
     EXECUTE,200
 501 BYPASS,EXCEPT TABLE REPLCU(R,L205),GO TO 502
**REPORTS GROUPING REGIONAL AND REFINERY CRUDES BY TYPE/SOURCE
     EXECUTE,205
 502 BYPASS,EXCEPT TABLE REPLCU(R,L211),GO TO 600
**CRUDE TRANSPORTATION COST REPORT
     EXECUTE,211
 600 BYPASS,EXCEPT TABLE REPLCU(R,L212),GO TO 700
**CRUDE SHIPMENT REPORT
     EXECUTE,212
 700 BYPASS,EXCEPT TABLE REPLCU(R,L213),GO TO 800
**CRUDE MARGINAL COST REPORT
     EXECUTE,213
 800 BYPASS,EXCEPT TABLE REPLCU(R,L214),GO TO 900
**REGIONAL PRODUCT BALANCE
     EXECUTE,214
 900 BYPASS,EXCEPT TABLE REPLCU(R,L215),GO TO 901
**REGIONAL PRODUCT SALES REPORT
     EXECUTE,215
```

```
 901 BYPASS,EXCEPT TABLE REPLCU(R,L216),GO TO 902
**PRODUCT MARGINAL COST REPORT
     EXECUTE,216
 902 BYPASS,EXCEPT TABLE REPLCU(R,L217),GO TO 903
**PRODUCT COST TO REGIONAL CUSTOMERS REPORT
     EXECUTE,217
 903 BYPASS,EXCEPT TABLE REPLCU(R,L218),GO TO 904
**PRODUCT TRANSPORTATION COST REPORT
     EXECUTE,218
 904 BYPASS,EXCEPT TABLE REPLCU(R,L219),GO TO 905
**PRODUCT SHIPMENT REPORT
     EXECUTE,219
 905 BYPASS,EXCEPT TABLE REPLCU(R,L220),GO TO 906
**INTERMEDIATE STREAM TRANSPORTATION COST REPORT
     EXECUTE,220
 906 BYPASS,EXCEPT TABLE REPLCU(R,L221),GO TO 907
**INTERMEDIATE STREAM SHIPMENT REPORT
     EXECUTE,221
 907 BYPASS,EXCEPT TABLE REPLCU(R,L225),GO TO 098
**CRUDE/PRODUCT SUMMARY REPORT BALANCE
     EXECUTE,225
 098 BYPASS,EXCEPT TABLE REPLCU(R,L226),GO TO 908
**CAPACITY UTILIZATION REPORT
     EXECUTE,226
 908 BYPASS,EXCEPT TABLE REPLCU(R,L239),GO TO 909
**ECONOMIC SUMMARY REPORTS
     EXECUTE,239
 909 BYPASS,EXCEPT TABLE REPLCU(R,L240),GO TO 910
**ACCOUNTING SUMMARY REPORTS
     EXECUTE,240
 910 BYPASS,EXCEPT TABLE REPLCU(R,L245),GO TO 911
**BLEND REPORTS, INCL GASOLINE
     EXECUTE,245
 911 BYPASS,EXCEPT TABLE REPLCU(R,L246),GO TO 912
**BLEND REPORT EXTENSION, TABLE REX
     EXECUTE,246
 912 BYPASS,EXCEPT TABLE REPLCU(R,L280),GO TO 913
**INVESTMENT REPORTS
     EXECUTE,280
 913 BYPASS,EXCEPT TABLE REPLCU(R,L300),GO TO 914
**GLOBAL ECONOMIC SUMMARY
     EXECUTE,300
 914 BYPASS
     ENDJOB
UTILITY,PRINT
END JOB
/*
//*
//
```

APPENDIX I MODIFICATIONS TO MODEL SINCE 9/21/92

The changes described below have been incorporated into this *Version 1.1* of the manual. The rationale for each change is described in italics.

1. CAPACITATED TRANSPORTATION

R Feature added to allow multiple transportation modes with capacity. Mode types, streams carried on each mode both fully under user control.

2. DISCRETE REGION TYPES AND FUNCTIONS

R ***Table REF*** revised:

1. row NR (non-refining region) replaced by rows DM (demand region) and SD (supply/demand region). A DM region has a ***Table (Q)PRDMD*** in which positive quantities denote regional demands. An SD region denotes a "foreign" region with a ***Table (Q)PRDMD*** and a ***Table (Q)INTDMD*** which may have positive or negative entries denoting a demand for exports or a supply of imports. A demand for a finished product causes generation of a regional demand (PD) row and a bounded sales (SA) vector. In the case of a negative entry, the SA vector has a negative bound. The same arrangement has been extended to unfinished products (intermediates) using ID for the row code and SI for the vector.
   Affects REFCAP, CRDNCP, OXYMAGEN and OXRWJL files.

2. row CR added to designate crude supply regions. Used for report generation. Affects OXRW file.

The four region types allow the user full flexibility to formulate a model with

- *all regions coincident*

*i.e. a region "A" would be used for crude supply (CR), non-crude supply (OX), demand (DM) and would have one or more refineries attached, as in the current **WORLD** model*

- *no regions coincident*
  *e.g. as in the **WORLD** "Detailed Refinery Model" where crude supply regions are EIA supply regions, refining (and OX) regions are by PADD and demand regions are by Census District*

- *some regions coincident*

Table REG** provides six character descriptions for crude supply, non-crude supply (oxy-refinery), supply/demand and refining regions. **Note, the sequence of regions in Table REG must be the same as that for Table REF.

3. REGIONALLY VARIABLE PRODUCT SPECIFICATIONS

R Generation of "make" vectors suppressed and generation of product specifications is by demand region. Their function is now taken over by product shipments from refinery to local demand region.

Refinery balance "E" rows removed and replaced by same row name without "E" for spec blended products. All products, spec blended or not, now have refinery balance rows of the type (R)(PRD) only.

Tables (R)PRDTRAN must now explicitly allow shipping of all products in ***Tables (Q)PRDMD*** if only to local demand region. Otherwise, some products will have no outlet from the refinery (e.g. sulfur, coke).

Generator code changed to form ***Tables (R)GBLND*** and ***(R)DBLND*** so that refineries can blend streams and qualities required in all possible destination regions. This means that it is now possible to have different spec levels in different regions supplied by the same refinery. However, a specification that is necessary only for some regions (e.g. diesel aromatics) <u>must</u> be present and active at realistic levels <u>for all demand regions</u>, otherwise the quality impacts on the source-refinery blend pools will not be correctly formulated

Note that, in the specific instance of modelling future EPA "anti-dumping" baseline quality regulations - where U.S. refiners will be subject to individual baselines by production region, whereas foreign refiners importing to the U.S. will generally be subject to the standard EPA published baseline - a model REVISE is necessary so that the OMNI-generated specifications for U.S. conventional gasoline at EPA baseline specifications can be modified for the U.S. refinery production regions to individual baselines.

Affects PRDTRAN and OXYMAGEN files.

NOTE: The fact that product shipping movements are now represented as taking place between refinery balance rows and regional demand rows (whereas in earlier versions they were from one regional demand row to another), means that "entrepot" shipments (i.e. moving product from A to C by two stages, from A to B and then from B to C) are no longer possible, unless there is a demand for the product in region B. In that case, the refinery which would normally supply B can supply C instead, leaving B to be supplied by the refinery normally supplying A. This means that the ***(R)PRDTRAN tables*** *must permit all possible movements directly and not just by implication.*

4. REFINING TECHNOLOGY ENHANCEMENTS

R Several changes have been made to improve representation of reformulated gasoline production and quality representation. These include:

- reworking FCC yield structures under essentially all catalyst modes to make product sulfurs more accurately reflect feed sulfur. The main driving force here is more accurate representation of gasoline sulfur to which FCC gasolines are the prime contributor.

- introducing an ultra low sulfur mode on the FDS unit, to produce ultra-low sulfur vacuum gasoil FCC feedstock, then associated advanced ULS FCC catalyst modes and yields. ***Table POL*** limit FCU added to allow user to control or lock out ULS FCC modes. The main driving force here is meeting potentially very low sulfur requirements of CARB II gasoline.

- introducing a coker naphtha stream (SRC) which is a very high sulfur gasoline blendstock

- adding pre-fractionation of naphthas for reformer feed to reduce benzene production in reformate from low and ultra low pressure reformers. ***Table (R)POL*** limit RCU added to optionally limit or eliminate continuous reforming advanced operations for very low pressure and low benzene. *(Useful for short term runs.)*

- adding ***Table (R)POL*** limit NME to limit or eliminate non-MTBE feedstock modes on the Etherol (in-refinery oxygenate production) unit.
  (This is necessary for short term runs.)

- introducing a gasoline specification (C4N) which requires a minimum ratio of butane in gasoline to relative light streams (such as FCC gasoline) which typically have a C_5+ cut which can be expected to contain some C_4 at typical fractionation efficiencies. The main driving force is to avoid making low RVP gasoline too easy to produce by backing out all the butane when other light streams are present. Under this formulation, minimum butane content drops progressively with light streams content in the blend.

- Coker gas oil (CGO) hydrotreating operation added to gasoil desulfurization unit. Reflects opportunity/need to improve quality (including sulfur) of coker gas oil routed to the FCC unit.

The above changes variously affect ***Tables FDS, FCC, FGS, GCC, GCB, MCO, xxxBV, SPL, RFL, RFC, DCC, DCB, EXPOL*** in ENSRYM and SPEC files; ***(R)POL*** in REFCAP files.

5. LINEARIZED EPA SIMPLE MODEL EQUATIONS

R Simulation of linearized EPA Simple Model equations for gasoline emissions control added using proprietary EnSys methodology. (Linearized Complex Model equations can be added in the future.) Derived proprietary linearized coefficients included in ***Table GCB*** for all gasoline components for Summer VOC's and TAP's (EPA volatility regions B and C) and for Winter VOC's and TAP's (all regions).

LCU added to generate reports on gasoline blend qualities and emissions, including comparison of linearized emissions with post-optionally calculated rigorous emissions.

Table EPA added to identify which blends to be reported on for emissions purposes. Note, such three-character blend designators must have B or C as last character.

Affects ENSRYM, SPEC, RWCTRL and OXRW files.

6. MISCELLANEOUS CLARIFICATIONS AND ENHANCEMENTS

A. System and Table Changes

R Column ROW removed from ***Tables (R)POL*** and replaced by column PCT which enables POL constraints to be expressed as % of throughput. Generator code modified accordingly. Note that SVR (and corresponding new controls on cat reformer) will always be expressed as % irrespective of entry in column PCT.
Affects REFCAP, ENSRYM and OXYMAGEN files.

The PCT column allows the user the option of defining certain POL constraints in absolute terms (blank under PCT) or in percentage terms (1 under PCT).

R All references to SPF removed.
Affects REFCAP, MTFIXREP, ENSRYM, OXYMAGEN files.

SPF was an old control on sulfur plant feed and is redundant under the current model formulation.

R Generator modified so that, in change spec tables, an entry in a 4-character row, column "A" has no effect.
Affects OXYMAGEN file.

Entries under column A in change spec tables are designed only to activate (or deactivate with a blank entry) blends (such as LOG) which are entered as 3 character rows. Note also that, under latest code, specifications can be *entered in change spec tables in order to activate particular specs for Winter or Summer only, i.e. the specification will not have appeared in the master spec table.*

R In ***Tables (Q)NCP***, column A changed to column GAS and now used to distinguish non-crudes of natural gas origin from "other liquids" for reporting purposes.

In generator, generation of regional non-crude balances, NB rows, suppressed. Non-crude purchases, NP vectors, go straight to oxy-refinery balance rows. Non-crude transfers, NT vectors, suppressed.
Former IT vectors transferring intermediates from oxy- to conventional refineries re-coded to NT.

Affects CRDNCP and OXYMAGEN files.

Changes undertaken as part of reorganization of region types in the model to fully distinguish between crude supply, non-crude supply, refining and demand region types.

R Generator modified so as to not generate lower bounds of zero.
Affects OXYMAGEN file.

Vectors, by default, are implicitly lower bounded at zero, therefore such explicit bounds are unnecessary.

R MTB removed from ***(Q)NCP tables*** (hitherto only commented out). All MTB is now manufactured.
Affects CRDNCP file.

Nonetheless, the user could, if desired, reinstate explicit purchase of MTBE as a non-crude feedstock.

R ***Tables DELSIZE*** and ***REG*** simplified.
Affects RPTCTRL file.

R Coding of ACU vectors changed to conform with other process vectors (region designator dropped).
Affects OXYMAGEN file.

R Rows with no entries removed from all process tables.
Affects ENSRYM file.

R Master spec ***Tables MGSP*** and ***MDSP*** renamed to ***MMGSP*** and ***MMDSP*** to avoid confusion with area M tables.
Affects AVSPEC and OXYMAGEN files.

R Generator code changed to allow use of any single-character code for regions in columns of ***Table REF***. Hitherto, codes I,L,R were barred because of confusion with first characters of columns IN,LOC,REC. Necessary because DRM requires use of separate refinery, oxy-refinery, demand, and crude supply regional codes.
Affects OXYMAGEN and OXRWJL files.

R Section 6.4 of this manual has been somewhat simplified, as has the representation of sulfur quality constraints. Affects OXYMAGEN file.

B. Refinery Technology Changes

R Re-code process gas representation
PGS -> PGU (high unsaturates process gas) in ***Tables KRD,KRF,FCC***
PGS -> PGS elsewhere
Add disposal of PGU to FUM.
CC2 (ethane) only made in ETS, only disposed to TCG, FUM.
Affects CRDNCP and ENSRYM files.

The former model could only meet PGS demand by building ETS units to convert process gas (formerly PGT) into ethane. In addition, only the coking and FCC units generate process gas that is high in unsaturates and thus suited to ethylene extraction.

R Merchant ETX plant activity vectors altered to agree with ETH.
Affects ENSRYM file.

Corrections to data coefficients.

R Error in generator corrected whereby oxy process tables escaped scaling of steam, power and cost data.
Affects OXYMAGEN file.

R ***Table DEFFAC*** removed - function now fulfilled by ***INVGEN***.
Affects ENSRYM file.

*Nelson inflation factors in **Table INVGEN** are now used to adjust OVC costs to current time horizon.*

R POL constraint MPX removed from ***Tables (R)POL*** and process ***Table H2X***.
Affects REFCAP and ENSRYM files.

MPX limit was left over from when H2X unit (hydrogen production via partial oxidation) was modelled as a mode under H2P not as a discrete unit.

R ***Table CPL*** re-scaled to unit yield of poly gasoline (and unit capacity usage).
Affects ENSRYM file.

Ensures consistency with other table formats and with investment costs.

R Yield pattern of unit SDA changed to more realistic volume, weight and sulfur balances.
Affects ENSRYM file.

R Crudes and atmospheric residuum yields in ***Tables AVC and VCU*** reviewed and adjusted to achieve accurate weight and volume balances. Includes adjustment to residuum gravities.

Corrects certain unbalanced yields although more rigorous balancing on all units would be beneficial.

C. Report Writer Changes

R Report on world total crude by type and source added.
Affects OXRWJL file.

R Regional input/output summary balance report transposed so that format agrees with subsequent reports. Report modified to conform to revised matrix structure.
Affects OXRWJL file.

R Regional product balance report modified to distinguish between LPG and NAT from natural gas sources and from refinery production.
Affects OXRWJL file.

R Where TABCHECK program showed differences between qualities in ***Tables GCB*** and ***DCB***, latter altered to agree with former.
Affects ENSRYM file.

R TABCHECK program extended to perform sulfur as well as weight and volume balances. Also generation of ***Tables EXCAP*** and ***EXPOL*** extended to exclude streams which derive exclusively from already excluded streams. Prevents generation of empty rows.

APPENDIX J MATHEMATICAL FORMULATION

This section describes the mathematical formulation for the **WORLD** model in terms of a table of column activity definitions and row constraints that incorporate certain premises:

- Each refinery region may import non-crude oil refinery feedstocks including oxygenates and unfinished oils.

- Refinery purchases of domestic non-crude oil raw materials (natural gas, NGL streams, oxygenates, traditional blending stocks, and unfinished oils) are made at the gate.

- The shipment of NGL streams, clean products, dirty products and crude oil are segregated by transport link identification. Inter-refinery-region shipments of intermediate streams are allowed.[38]

- Capacity expansion will occur by processing unit, starting from base year capacities. Expansion are determined by the solution to the linear program. Onsite plant and equipment, location, utilities, storage, offsites, supplies, contingency, and working capital are included in the investment costs.

- The model operates under a combination of self-generated and purchased utilities.

Column Definitions

The required column definitions for the **WORLD** model are highlighted in the following table.

---

[38] The total volume of U.S. inter-PADD shipments of intermediate streams comprises about one-sixth of one percent of U.S. produced refined products. These streams are both exchanged and purchased. The exchange may be done on a cross-product basis or straight but with quality and location difference make-ups in either case.

Column Definition Table

Column Notation	Description
$A_{q,r}$	Volume of type (q) refinery fuel made at refinery region (r).
$B_{g,b,r}$	Specification blending for blend (g) of blending component (b) at refinery region (r) with b $\in$ non-crude oil inputs and g $\in$ products (p).
$D_{h,d,r}$	Recipe blending of blend (h) of blending component (d) at refinery region (r) with d $\in$ s and h $\in$ p.[39]
$E_{v,r}$	Purchase of type of utility (v) at refinery region (r). Refinery utilities will include fuel, steam, and electric power. In addition to liquid and gaseous fuel produced by the refinery, fuel sources will include natural gas and coal.
$H_{s,r}$	Purchase of domestic non-crude input(s) in refinery region (r).
$M_{p,r}$	Manufacture of product (p) at refinery region (r).
$P_{c,n}$	Production of crude oil (c) in producing region (n).
$Ra_{c,r}$	Processing of crude oil (c) in the atmospheric tower at refinery region (r).
$R_{m,o,r}$	Processing, including stream transfer operations, in mode (m)[40] in downstream unit (o) at refinery region (r).
$R_{k,u,r}$	Operation of utility generating unit (u) in mode (k)[41] at refinery region (r).
$S_{p,j}$	Domestic sales of product (p) in demand region (j).
$S_{p,r}$	Domestic sales of product (p) from refinery region (r).
$T_{c,n,r,l}$	Transport of crude oil (c) from producing region (n) to refinery region (r) via link (l).
$T_{c,n,e,l}$	Transport of export crude oil (c) from producing region (n) to port (e) via link (l).

[39] *Blending components (b) are a different subset of p than blending components (d), because b are created by specification and d are created by recipe.*

[40] *Modes of operation in downstream refinery processing units vary according to the intermediate streams used in the units.*

[41] *Modes of operation at utility generating units vary according to the kind(s) of fuel used in the units.*

$T_{c,i,r,l}$	Transport of imported crude oil (c) from port (i) to refinery region (r) via link (l).
$T_{s,i,r,l}$	Transport of imported non-crude input(s) from port (i) to refinery region (r) via transport link (l).
$T_{p,r,j,l}$	Transport of product (p) from refinery region (r) to demand region (j) via link (l).
$T_{p,r,e,l}$	Transport of product (p) from refinery region (r) to export port (e) via link (l).
$T_{p,i,j,l}$	Transport of product (p) from import port (i) to product demand region (j) via transport link (l).
$U_{c,i}$	Purchase of imported crude oil (c) at port (i).
$U_{s,i}$	Purchase of imported non-crude inputs (s) at port (i).
$U_{p,j}$	The import of product (p) into demand region (j).
$V_{c,e}$	Sale of export crude oil (c) at port (e).
$V_{p,r}$	Export of product (p) from refinery region (r).
Xa_r	Capacity expansion activity for the atmospheric tower at refinery region (r).
$X_{o,r}$	Capacity expansion activity for downstream processing unit (o) at refinery region (r).
$X_{u,r}$	Capacity expansion activity for utility generating unit (u) at refinery region (r).
X_l	Capacity expansion activity for transport link (l).
$Y_{t,r}$	Creation of air pollutant (t) at refinery region (r). These columns are bounded to examine the impact of pollution constraints.

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 **WORLD**.

Given:

$C_{g,b,r}$ is the unit cost of blending component (b) into specification blend (g) at refinery region (r). Similarly, each of the other 'C' coefficients represents the unit cost of the activity it is associated with.

The objective function is represented as a minimization of the following cost terms:

$$\Sigma_g \Sigma_b \Sigma_r [B_{g,b,r} * C_{g,b,r}] + \Sigma_h \Sigma_d \Sigma_r [D_{h,d,r} * C_{h,d,r}] + \Sigma_v \Sigma_r [E_{v,r} * C_{v,r}]$$

$$+ \Sigma_s \Sigma_r [H_{s,r} * C_{s,r}] + \Sigma_c \Sigma_n [P_{c,n} * C_{c,n}] + \Sigma_c \Sigma_r [Ra_{c,r} * C_{c,a,r}]$$

$$+ \Sigma_m \Sigma_o \Sigma_r [R_{m,o,r} * C_{m,o,r}] + \Sigma_k \Sigma_u \Sigma_r [R_{k,u,r} * C_{k,u,r}] + \Sigma_c \Sigma_n \Sigma_r \Sigma_l [T_{c,n,r,l} * C_{c,n,r,l}]$$

$$+ \Sigma_c \Sigma_n \Sigma_e \Sigma_l [T_{c,n,e,l} * C_{c,n,e,l}] + \Sigma_c \Sigma_i \Sigma_r \Sigma_l [T_{c,i,r,l} * C_{c,i,r,l}]$$

$$+ \Sigma_s \Sigma_i \Sigma_r \Sigma_l [T_{s,i,r,l} * C_{s,i,r,l}] + \Sigma_p \Sigma_r \Sigma_j \Sigma_l [T_{p,r,j,l} * C_{p,r,j,l}]$$

$$+ \Sigma_p \Sigma_i \Sigma_j \Sigma_l [T_{p,i,j,l} * C_{p,i,j,l}] + \Sigma_p \Sigma_r \Sigma_e \Sigma_l [T_{p,r,e,l} * C_{p,r,e,l}]$$

$$+ \Sigma_c \Sigma_i [U_{c,i} * C_{c,i}] + \Sigma_s \Sigma_i [U_{s,i} * C_{s,i}] + \Sigma_p \Sigma_i [U_{p,j} * C_{p,j}] + \Sigma_a \Sigma_r [Xa_r * Ca_r]$$

$$+ \Sigma_o \Sigma_r [X_{o,r} * C_{o,r}] + \Sigma_u \Sigma_r [X_{u,r} * C_{u,r}] + \Sigma_l [X_l * C_l]$$

Row Constraints

1. Material balance at crude oil producing regions

$$P_{c,n} - \Sigma_e \Sigma_l T_{c,n,e,l} - \Sigma_r \Sigma_l T_{c,n,r,l} = 0 \quad \forall \text{ c and n}$$

i.e. the production of crude oil (c) in producing region (n) equals the amount of such crude (c) shipped to all export ports (e) over all links (l) plus the transport of such crude oil (c) to all refinery regions (r) over all links (l)

2. Material balance of crude oil at refineries:

$$\Sigma_n \Sigma_l T_{c,n,r,l} - Ra_{c,r} = 0 \quad \forall \text{ c and r}$$

i.e. the transport of crude oil (c) from all producing regions (n) to refinery region (r) via all transport links (l) equals the volume of crude oil (c) processed in the atmospheric tower at refinery region (r)

3. Material balance of non-crude oil feedstocks at refineries:

$$\Sigma_i \Sigma_l T_{s,i,r,l} + H_{s,r} + \Sigma_c Ra_{c,r} * Fa_{s,c,r}$$

$$+ \Sigma_m \Sigma_o R_{m,o,r} * F_{s,m,o,r} + \Sigma_k \Sigma_u R_{k,u,r} * F_{s,k,u,r}$$

$$- \Sigma_g B_{g,s,r} * F_{g,s,r} - \Sigma_h D_{h,s,r} * F_{h,s,r} = 0 \quad \forall \text{ s and r}$$

where:

$Fa_{s,c,r}$ is the distilled volume fraction of inputs per unit of crude oil (c) that are processed in the atmospheric tower at refinery region (r).

$F_{s,m,o,r}$ is the manufactured or consumed volume fraction of inputs per unit of mode (m) operation in processing unit (o) at refinery region (r).

$F_{s,k,u,r}$ is the manufactured or consumed volume fraction of inputs per unit of mode (k) operation in utility generating unit (u) at refinery region (r).

$F_{g,s,r}$ equals one if input (s) is permitted in specification blend (g) at refinery region (r), otherwise it is empty. Note, this term is inactive unless input (s) is one of the allowed blending components (b).

$F_{h,s,r}$ equals the negative of the volume fraction that input(s) contributes to recipe blend (h) at refinery region (r). Note that the term is inactive unless input (s) is one of the allowed blending components (d).

i.e. intermediate input (s) volume transported to refinery region (r) plus purchased volume plus volume generated (or less consumption) in refinery processing including utility processing equals the amount blended into products for each refinery region (r) and each input(s).

4. Utility balance at refineries:

$$E_{v,r} + \Sigma_c Ra_{c,r} * Fa_{v,c,r} + \Sigma_m \Sigma_o R_{m,o,r} * F_{v,m,o,r}$$

$$+ \Sigma_k \Sigma_u R_{k,u,r} * F_{v,k,u,r} = 0 \quad \forall \ v \text{ and } r$$

where:

$Fa_{v,c,r}$ is the quantity of a type of utility (v)--i.e. fuel, steam, or power--consumed per unit of crude oil (c) distilled in the atmospheric tower at refinery region (r).

$F_{v,m,o,r}$ is the quantity of utility (v) consumed per unit of mode (m) of operation in processing unit (o) at refinery region (r).

$F_{v,k,u,r}$ is the quantity of utility (v) generated or consumed per unit of mode (k) of operation in utility generating unit (u) at refinery region (r).

i.e. for each refinery region (r) and each type of utility (v), the purchase of that utility plus the refinery manufacture of that utility in a utility generating unit equals the consumption of the utility in the various refinery processing units.

5. Refinery fuel by type:

$$\Sigma_s R_{s,q,r} * F_{s,q,r} - A_{q,r} = 0 \quad \forall \ q \text{ and } r$$

where:

$F_{s,q,r}$ is the volume fraction on a Fuel Oil Equivalent basis that a unit of fuel component (s) makes of fuel type (q) at refinery region (r). F is zero when the component (s) is not allowed to be used as refinery fuel.

and,

$R_{s,q,r}$ $\in R_{k,u,r}$, i.e. fuel making is a utility function.

i.e. for each refinery region and each fuel type, the fuel quantity is calculated.

6. Refinery emissions:

$$\Sigma_c Ra_{c,r} * Fa_{t,c,r} + \Sigma_m \Sigma_o R_{m,o,r} * F_{t,m,o,r}$$

$$+ \Sigma_k \Sigma_u R_{k,u,r} * F_{t,k,u,r} - Y_{t,r} = 0 \quad \forall \quad t \text{ and } r$$

where:

$Fa_{t,c,r}$ is the quantity of air pollutant (t) generated per unit of crude oil (c) distilled in the atmospheric tower at refinery region (r).

$F_{t,m,o,r}$ is the quantity of air pollutant (t) generated per unit of mode (m) operation in processing unit (o) at refinery region (r).

$F_{t,k,u,r}$ is the quantity of air pollutant (t) generated per unit of mode (k) operation in utility generating unit (u) at refinery region (r).

i.e. for each refinery region (r) and each air pollutant type (t), the total emitted quantity of pollutant is the sum of emissions from the refinery processing plants.

7. Material balance of specification blends at refineries:

$$\Sigma_b D_{g,b,r} - M_{g,r} = 0 \quad \forall \quad g \text{ and } r$$

where:

$b \in s$ some of the intermediate inputs are motor gasoline blending inputs

$g \in p$ some of the refined products are motor gasolines

i.e. summed specification blending input volume equals available product for each specification blend (g) at each refinery (r).

8. Quality control for specification blends at refineries:

$$\Sigma_b [B_{g,b,r} * Q_{y,b,r}] - [M_{g,r} * Q_{y,g,r}] \geq 0 \quad \forall \quad y, g \text{ and } r$$

where:

$Q_{y,b,r}$ is the value of quality (y)[42] for blending component (b) at refinery region (r).

$Q_{y,g,r}$ is the minimum value required of quality (y) for blended product (g) at refinery region (r).

i.e. the minimum quality specifications (y) for all spec blended products (g) must be complied with at all refineries (r).

Note: Reverse the inequality for maximums. (Some blending properties, like octane, require minimum specifications; some, like sulfur or benzene content, require maximums.)

9. Material balance of recipe blends at refineries:

$$\Sigma_d D_{h,d,r} - M_{h,r} = 0 \quad \forall \text{ h and r}$$

i.e. for each product (h) manufactured by recipe, the summed recipe blending input volume (d) equals available product at each refinery region (r).

10. Material balance of domestic shipment of refined products:

$$S_{p,r} - \Sigma_j \Sigma_l T_{p,r,j,l} = 0 \quad \forall \text{ p and r}$$

i.e. for each refinery region (r) and product (p), volume of manufactured product (p) for domestic sales equals shipments to domestic demand regions (j) via all transport links (l).

11. Material balance of refined products at refineries:

$$M_{p,r} - S_{p,r} = 0 \quad \forall \text{ p and r}$$

i.e. volume of manufactured product (p) equals domestic sales of that product (p) at each refinery region (r).

12. Processing capacity limitations at refineries:

For atmospheric distillation,

$$\Sigma_c Ra_{c,r} - Xa_r \leq Fca_r \quad \forall \text{ r}$$

---

[42] *Qualities are blending properties, like octane, benzene content, or sulfur. See Classification Plan for Blending Properties.*

where:

Fca_r is the current capacity for atmospheric distillation at refinery region (r).

i.e. at each refinery region (r), the volume of crude oil (c) processed is limited to the crude oil processing capacity.

Similarly, for downstream processing,

$$\Sigma_m [R_{m,o,r} * F_{m,o,r}] - X_{o,r} \leq Fc_{o,r} \quad \forall \text{ o and r}$$

where:

$F_{m,o,r}$ is the fraction of capacity consumed per unit of operating mode (m) in processing unit (o) at refinery region (r). This may be different from unity due to severity level.

and for utility generation,

$$\Sigma_k [R_{k,u,r} * F_{k,u,r}] - X_{u,r} \leq Fc_{u,r} \quad \forall \text{ u and r}$$

13. Crude oil transportation capacity constraints:

$$\Sigma_c \Sigma_n \Sigma_r T_{c,n,r,l} + \Sigma_c \Sigma_n \Sigma_e T_{c,n,e,l} + \Sigma_c \Sigma_i \Sigma_r T_{c,i,r,l} - X_l \leq Fc_l \quad \forall \text{ l}$$

where:

Fc_l is the current capacity transportation link (l).

i.e. aggregated crude shipments over a particular link (l) may not exceed current capacity plus new capacity additions.

Note: In practice, the links are divided not only between region to region connections but also by clean product and dirty product plus crude oil via input. Therefore all applicable streams will participate in each constraint. LPG sales are assumed to be made at the gate.

14. Raw material stream transportation capacity constraints:

$$\Sigma_s \Sigma_i \Sigma_r T_{s,i,r,l} - X_l \leq Fs_l \quad \forall \text{ l}$$

15. Refined products transportation capacity constraints:

$$\Sigma_p \Sigma_r \Sigma_j T_{p,r,j,l} + \Sigma_p \Sigma_r \Sigma_e T_{p,r,e,l} + \Sigma_p \Sigma_i \Sigma_j T_{p,i,j,l} - X_l \leq Fp_l \quad \forall\ l$$

16. Material balance of refined products imports:

$$\Sigma_i \Sigma_l T_{p,i,j,l} - U_{p,j} = 0 \quad \forall \text{ p and j}$$

i.e. imports of each refined product (p) to each demand region (j) must equal the summed shipments of that product (p) from all import ports (i) over all transport links (l).

17. Material balance of refined products sales:

$$\Sigma_r \Sigma_l T_{p,r,j,l} - \Sigma_r \Sigma_e \Sigma_l T_{p,r,e,l} + U_{p,j} - S_{p,j} = 0 \quad \forall \text{ p and j}$$

i.e. sales of each product (p) at each demand region (j) equals shipments received from the refinery regions (r) over all links (l) plus imports of that product minus exports of that product (p).

Capacity Expansion

The cost of capacity expansion is determined based on calculating the investment required to build a specific process unit, of a typical size, and then converting the investment to a daily charge per barrel of capacity added.

The investment required per barrel of new capacity for a given process unit is given by the following formula which includes offsite costs plus other fixed costs for site preparation, taxes, start-up costs:

1. $TAI_{o,r} = TONI_{o,r} + TOFI_{o,r} + TOTH_{o,r}$

When the TAI is multiplied by the variable $X_{o,r}$, which represents new capacity built, the result is the daily cost of adding the new capacity. Where each term in the above equation is defined as follows:

o	=	process unit
r	=	refining region
TAI	=	Total Investment, $/BBL
TONI	=	Onsite Investment, $/BBL
TOFI	=	Offsite Investment, $/BBL
TOTH	=	Other Investment, $/BBL

The total onsite investment is given in Equation 2. The annual investment is converted from units of dollars per barrel per day to dollars per barrel by multiplying by 1/365. This puts the investment cost figure in the same units as other costs in the refinery.

2. TONI = CVI * REC * (1/365)

The current value of investment, in units of $/BBL/DAY, is based on U.S. Gulf Coast (INV91) cost, and is then multiplied by a location factor LOC for other regions:

3. CVI = LOC * (INV91/SIZE)

The annual investment charge REC is given by:

4. REC = $(1\text{-}RECD)/(((1+CCP)^{ELF\text{-}1}) * (1\text{-}TAX)) * (CCP*(1+CCP)^{ELF})$

The depreciation recovery factor RECD is given by:

5. RECD = $(1/DLF) * ((1+CCP)^{DLF\text{-}1}) * TAX/(CCP*(1+CCP)^{DLF})$

The total offsite investment is given by:

6. TOFI = TONI * OFF

The total other investment is given by:

7. TOTH = TONI * OTHR

Where the terms are:

CCP	=	Cost of capital, percent
CVI	=	Current Value of the investment
DLF	=	Depreciation life, years
ELF	=	Economic life,years
INV91	=	Investment, MM$, 1991
LOC	=	Location factor, U.S. Gulf Coast = 1.0
OFF	=	Offsite investment, percent of onsite investment
OTH	=	Land, buildings, initial catalyst, environmental costs, insurance as a percent of onsite investment

REC	=	Annual return on capital investment
RECD	=	Depreciation term
SIZE	=	Typical size for process unit, MB/CD
TAX	=	Tax rate, percent

APPENDIX K BLOCK DIAGRAM OF MATRIX

The following page presents a block diagram of the **WORLD** matrix in symbolic form. Each block represents a sub-matrix that is repeated for each region in the model.

INDEX