



Executive Summary

Petroleum Storage & Transportation

National Petroleum Council • April 1989

NATIONAL PETROLEUM COUNCIL

1625 K Street, N.W., Washington, D.C. 20006 (202) 393-6100

April 18, 1989

The Honorable
James D. Watkins
Secretary of Energy
Washington, D.C. 20585

My dear Mr. Secretary:

I am pleased to transmit herewith the National Petroleum Council's five-volume report, entitled Petroleum Storage & Transportation. The principal conclusion of the Council is that the complex but flexible oil and natural gas supply and distribution network can be expected to continue to meet the nation's oil and gas needs under a wide range of conditions. This report is in response to a request from the Secretary of Energy to update the Council's 1979 and 1984 studies on these subjects. The Council's earlier work is expanded to include a volume on the dynamics of the nation's oil and gas supply and distribution systems. This new volume includes an analysis, as requested, of "...the capabilities of distribution networks to move products...during periods of stress."

It is important to point out that even under typical conditions, the system responds to a constant stream of minor stresses such as refinery down-time, missed pipeline deliveries, unexpected changes in weather, swings in sales and the like. Occasionally, the system is faced with more serious stress conditions. A degree of stress is normal in the industry but few stress situations result in serious supply problems. In fact, the consumer rarely feels the impact. Industry reactions to stress situations of all magnitudes are the aggregate result of thousands of independent, competing company decisions and reflect classic supply-and-demand economics. Strained supply results in higher prices, and the higher prices call out incremental supply from a variety of sources that might otherwise not be attractive. Incremental oil and gas supply can come from storage, peak-shaving, imports, or increased refinery production. Higher prices also make it economic to move product from adjacent areas or to switch to alternative fuels, effectively rebalancing supply and demand. The flexibility and interconnections of the system allow very prompt response to most stress situations.

As part of this analysis, the Council constructed several hypothetical stress situations. The most difficult of these cases for the system to resolve turned out to be the disruption of deliveries of oil from the Trans-Alaska Pipeline System (TAPS) to markets in the Lower-48 States. This hypothetical case was paralleled in many ways following the grounding of the Exxon Valdez in Prince William Sound on March 24, 1989. For almost two weeks, shipments of oil from Alaska were disrupted. This unfortunate, real-world situation strongly validated the conclusions contained in this report. The system worked and consumers received an uninterrupted supply of products.

While national attention was focused on the tragic events in Prince William Sound, petroleum suppliers, particularly those on the West Coast, immediately began rebalancing their systems with crude oil and refined products from inventories, as well as shipments from other parts of the nation and overseas. These rebalancing actions are continuing, even

An Advisory Committee to the Secretary of Energy

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today as the system works toward an equilibrium state. Temporary changes in normal spot price differentials between the West Coast and other markets proved to be a necessary and effective mechanism for avoiding shortages by attracting, at added cost, incremental supplies from alternative sources. However, it is worth noting that prices to the consumer were much less affected than spot prices within the petroleum industry.

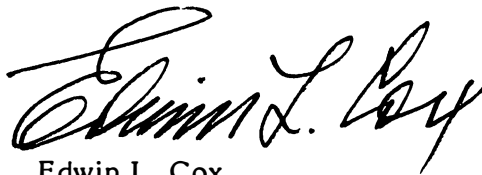
When the disruption occurred, the supply situation was already tight on the West Coast, with product prices rising and inventories falling, particularly for gasoline. There were a number of factors that contributed to this situation including several refineries undergoing planned maintenance and unplanned shutdowns, the beginning of peak driving season, seasonal reduction in gasoline vapor pressure (RVP), and continued strong demand. These factors as well as major increases in world crude oil prices, which had not yet been fully reflected in product prices, were exerting substantial upward pressure on product prices.

It is also important to note that perceptions are as important as facts in major stress situations. Uncertainty about the scope and duration of the TAPS disruption probably caused a stronger industry response than was warranted by the actual loss of Alaskan North Slope production. However, the consumer's perception that gasoline supplies were plentiful, despite increasing retail prices, reduced potential demand pressures on the supply system.

Based on our analysis of the hypothetical case and confirmed by the events of the last few weeks, the NPC concludes that the shutdown of TAPS for a prolonged period would be difficult at present and substantially more so in 1992. Nevertheless, the NPC believes that the system could cover such a loss, maintaining necessary supplies to consumers. The public would be affected by higher prices for a time and the inconvenience of scattered runouts, particularly in 1992, at terminals and service stations for a brief period. Fast, decisive action by the industry is required in a stress situation of this magnitude. Cooperation of governments at every level is essential to the resolution of the problem.

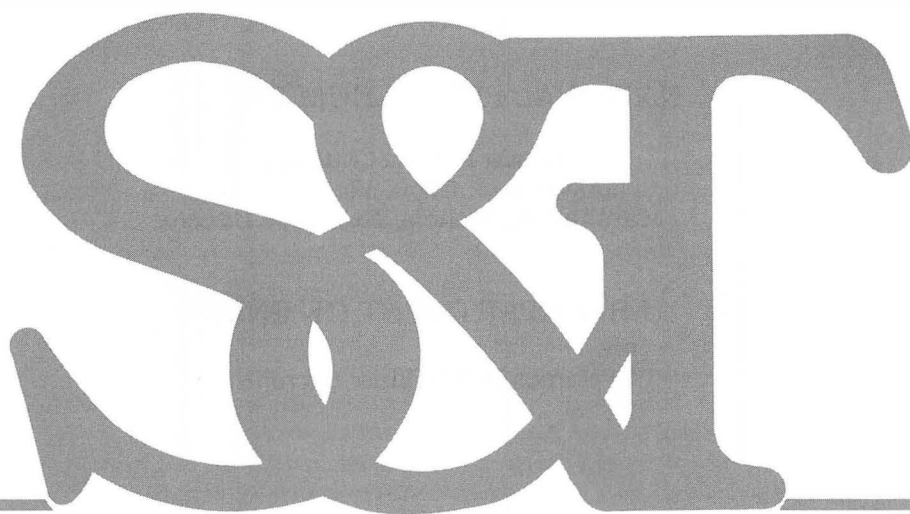
In conclusion, Mr. Secretary, it is the Council's privilege and pleasure to provide you this report that details the complexity and flexibility of the U.S. oil and gas supply and distribution systems. We believe that this flexibility, driven by the clear signals of the marketplace and protected against catastrophic events by the Strategic Petroleum Reserve, provides the American consumer with a very high level of assurance that essential supplies will continue to be available.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Edwin L. Cox", written in a cursive style.

Edwin L. Cox
Chairman

Enclosure



Executive Summary

Petroleum Storage & Transportation

National Petroleum Council • April 1989

William E. Swales, Chairman, Committee on Petroleum Storage & Transportation

NATIONAL PETROLEUM COUNCIL

Edwin L. Cox, *Chairman*
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U.S. DEPARTMENT OF ENERGY

James D. Watkins, *Secretary*

The National Petroleum Council is a federal
advisory committee to the Secretary of Energy.

The sole purpose of the National Petroleum Council
is to advise, inform, and make recommendations to
the Secretary of Energy on any matter requested
by the Secretary relating to
petroleum or the petroleum industry.

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EXECUTIVE SUMMARY**

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INTRODUCTION

In February 1987, the Secretary of Energy requested the National Petroleum Council (NPC) to determine the capacities of the nation's petroleum and gas storage and transportation facilities as part of the federal government's overall review of emergency preparedness planning. The Council has conducted similar studies at the request of the federal government since 1948. The most recent reports are the 1979 report entitled Petroleum Storage and Transportation Capacities and the 1984 report entitled Petroleum Inventories and Storage Capacity. In addition to updating the 1979 and 1984 reports, the NPC was requested to place more emphasis on describing the dynamics and interrelationships of the petroleum and natural gas delivery systems. Specifically, the Secretary requested that:

Emphasis should be given to the re-examination of minimum operating inventory levels, the location of storage facilities, and availability of inventories in relation to local demand, and the capabilities of distribution networks to move products from refining centers to their point of consumption particularly during periods of stress.

(See Appendix A for the complete text of the Secretary's request letter and a description of the National Petroleum Council.)

To respond to the Secretary's request, the NPC established the Committee on Petroleum Storage & Transportation, chaired by William E. Swales, Vice Chairman - Energy, USX Corporation. The Honorable H. A. Merklein, Administrator of the Energy Information Administration, served as Government Cochairman of the Committee. To assist the committee, a Coordinating Subcommittee was formed. This Subcommittee was chaired by Riad N. Yammine, President of Emro Marketing Company, a subsidiary of Marathon Oil Company. Jimmie L. Petersen, Director of the Office of Oil and Gas, Energy Information Administration, served as Government Cochairman of the Subcommittee. In addition, four task groups were formed to assist in specific areas of the study. (Rosters of the study groups are contained in Appendix B.)

Over 100 experts, representing a broad diversity of views, from various segments of the energy industry served on the various study groups. These participants, in turn, were supported by numerous individuals within their organizations. The Council also acknowledges the considerable time and effort of over 1,000 companies in the U.S. storage and transportation industry who responded to the various surveys conducted during the course of this study.

The results of the NPC study are presented in this comprehensive report, Petroleum Storage & Transportation, which is being issued in five volumes:

- Volume I -- Executive Summary
- Volume II -- System Dynamics
- Volume III -- Natural Gas Transportation
- Volume IV -- Petroleum Inventories and Storage
- Volume V -- Petroleum Liquids Transportation.

In addition, detailed profiles of the companies that participated in the natural gas transportation and petroleum pipeline surveys are available from the NPC.

This Executive Summary volume presents the study's principal conclusions, a brief description of the oil and natural gas distribution system, and summaries of the detailed volumes.

CONCLUSIONS

In this report, the National Petroleum Council has evaluated the past performance and future potential of the nation's oil and gas storage and transportation systems. The NPC study found the nation's existing supply and storage system, for both petroleum and natural gas, to be both efficient and economical, reflecting the industry's highly competitive environment. From this analysis, the NPC has drawn the following specific conclusions.

INFRASTRUCTURE

In looking ahead through the year 1992, the NPC concludes that the complex oil and natural gas supply and distribution network can continue to meet the nation's oil and gas needs.

Despite the turbulence of the past decade -- with shifts in demand patterns, volatile price swings, declining exploration and production activity, and shifting product mix -- the storage and transportation system was able to supply the nation's needs for oil and gas with minimal interruption or inconvenience to the consumer. To ensure continued efficient service, economically feasible modifications and additions to the present network should be permitted and made to the system (crude oil and product pipelines; natural gas transmission; water, rail, and truck transportation; and terminals and storage). One exception to privately financed expansion and modification to maintain viability is the need for major public works investments to modernize and upgrade deteriorating and outmoded inland waterways and harbor facilities.

This study emphasizes the value of the flexibility and interconnectability of the nation's current network of oil and natural gas supply, storage, and transportation systems. This flexibility allows for prompt and efficient adjustments in response to either gradually shifting supply-demand patterns or abrupt changes in the marketplace. The supply system has the ability to respond with a variety of alternatives to resolve potential local, regional, or national shortages.

This ability of the system to supply oil and gas to the consumer in an emergency is demonstrated by this study's analyses of a variety of "unlikely-to-occur" situations. Barring a severe disruption of world petroleum supply, extended supply shortfalls in the United States are extremely unlikely.

MARKET FORCES

The dynamics of the free market have been vital to the industry's successful performance in the past, and will be equally critical in the future.

Investments to accommodate changing supply patterns, as well as readjustments to more volatile shifts in supply-demand patterns, are more likely to occur promptly when free-market forces are not distorted by price and/or allocation regulation or regulatory delays. The major concerns raised in this study are possible constraints on the industry's ability to adapt to a changing business environment; they are generally related to the uncertainties growing out of ongoing or proposed legislative and regulatory initiatives.

The operation of the supply system is enormously complex and reflects the independent actions of thousands of individual companies, many of whom are in direct competition. Competing companies make independent decisions based on their own economics and their own views of the future. Nevertheless, the aggregate system reacts predictably to economic incentive. History indicates that the system responds vigorously to fuel price differentials as small as a fraction of a percent.

NATURAL GAS SYSTEM

The ongoing process of deregulation is increasing competition within the natural gas industry, and should ensure a flexible system that would allow natural gas to assume a growing role in meeting the nation's future energy needs.

The nation's natural gas delivery and storage system, from the wellhead to the ultimate consumer, has demonstrated its ability to respond to changing regional demand patterns. Significant new natural gas markets are developing. Where the construction of new pipelines is required to serve these markets, such as in the Northeast, Florida, and the West Coast, numerous regulatory approvals need to be issued promptly, to preclude bottlenecks.

Seasonal demand levels for gas fluctuate more dramatically than for petroleum products, and the system cannot rely on imports to meet peak demand levels. This results in the need for substantial peak storage but at significant capital, inventory, and operating costs. A key issue is the allocation of these costs. The nation's existing pipeline network has sufficient capability to meet natural gas demands through at least 1992. This assumes that supplies are available to fill seasonal storage at beginning of peak seasons, new pipelines/debottlenecks proposed by industry are constructed without undue permitting or litigation delay, and supplies to customers with interruptible supply contracts may be curtailed during peak days in some areas. However, for the longer term the issue of storage must be addressed to ensure that peak seasonal supplies will be available.

INVENTORIES

Liquid petroleum inventory levels have proven to be an adequate cushion against short-run supply and demand imbalances.

Inventories of crude oil and the principal petroleum products have declined slightly since 1983. The study examined minimum operating inventories -- the level below which operating problems and shortages would begin to appear in the distribution system. In aggregate, minimum operating inventories have changed less than one percent since 1983 although those for fuel oils have decreased while those for gasoline, jet fuel, and crude oil have increased. Although available inventories -- those above minimum operating level -- have decreased, they should be sufficient to provide flexibility during times of stress on the system, as resupply patterns adjust in response to needs. The change in inventory levels reflects more diversified domestic and global supply sources, the speed with which the system can respond, and increasingly sophisticated inventory management.

STRATEGIC PETROLEUM RESERVE

The Strategic Petroleum Reserve (SPR) provides valuable insurance against a major supply disruption, and the NPC concurs with the Department of Energy (DOE) policy of early and maximum release of SPR oil in emergency situations.

A prompt decision to draw down SPR oil is essential to minimize supply disruptions, as is the rapid implementation of bidding/award procedures. In the event of a major curtailment of crude oil imports, the nation's network of crude oil distribution and refining facilities has the capability of accommodating both the current (3.6 million barrels per day) and projected (4.5 million barrels per day) SPR drawdown rates. Pipeline and marine transportation allow the great majority of refining capacity to physically receive SPR oil. Through trading, SPR oil can in effect be made available to virtually every U.S. refinery. The NPC believes that such free-market trading is vital to the timely and efficient distribution of SPR oil to refineries, and that unnecessary regulation or allocation must be avoided.

A BRIEF DESCRIPTION OF THE OIL AND NATURAL GAS DISTRIBUTION SYSTEM

This section provides a brief primer on the oil and natural gas distribution system and provides a basic framework for understanding the summaries that follow.

CRUDE OIL AND PRODUCT DISTRIBUTION SYSTEM

The U.S. crude oil and product distribution system is comprised of networks of terminals, refineries, other storage facilities, pipelines, tankers, barges, rail tank cars, and tank trucks. These elements move crude oil from its source, convert it into consumer products, and ultimately deliver the products to consumers' facilities for their use. All of these components store oil.

As shown in Figure 1, the petroleum distribution system has three segments -- the primary distribution system, the secondary distribution system, and the tertiary storage segment. The primary system gathers crude oil, transports it to refineries, refines it into products, and delivers those products in bulk to the secondary distribution system. (In some cases, deliveries are made directly to the storage of large end-users, i.e., tertiary storage.) The secondary system distributes these bulk quantities in smaller lots to the receiving tanks of the end-users (consumers). The tertiary segment is the storage capacity and inventory held by all end-users. The gasoline stored in the tank of the family car is a common example.

Primary Distribution System

Crude Oil

For domestic crude oil, the primary distribution system begins with a lease tank in which oil from a producing well is accumulated. Crude oil from these lease tanks is collected mainly by small-pipeline gathering systems, although tank cars, tank trucks, and even barges are also used. This crude oil is delivered directly to refineries or into intermediate storage for further movement to refining facilities. Crude oil from foreign sources enters the primary system via tankers at marine terminals and refineries or, in the case of Canadian crude oil, via pipeline and overland transportation.

Major crude oil pipeline systems (trunk lines) link gathering systems and import points to storage terminals and refineries. Trunk lines are generally routed through focal points, or hubs, where a number of pipelines converge. At such points, transfers of crude oil to carriers with other destinations may be made. Examples of such locations are Midland and Odessa, in western Texas; Longview, in eastern Texas; Cushing, Oklahoma; Fort Laramie and Guernsey, Wyoming; and Patoka, Illinois. At such locations, a large amount of storage capacity has been built to accommodate various types and qualities of crude oils from numerous producing regions, and to permit the segregation, batching, and storing that support the continuous movement of oil through the system. From these locations, crude oil moves to other hubs or to smaller pipelines for delivery to refineries.

A great deal of storage capacity is also needed at marine terminals to permit prompt unloading of cargos as large as 3 million barrels. This storage requirement applies also to refineries that accept marine shipments directly. Tankage is also required at refineries to receive and hold crude oil supplies prior to processing.

Crude oil stored by the U.S. government in the SPR is part of the primary distribution system but is intended only for use in emergency situations.

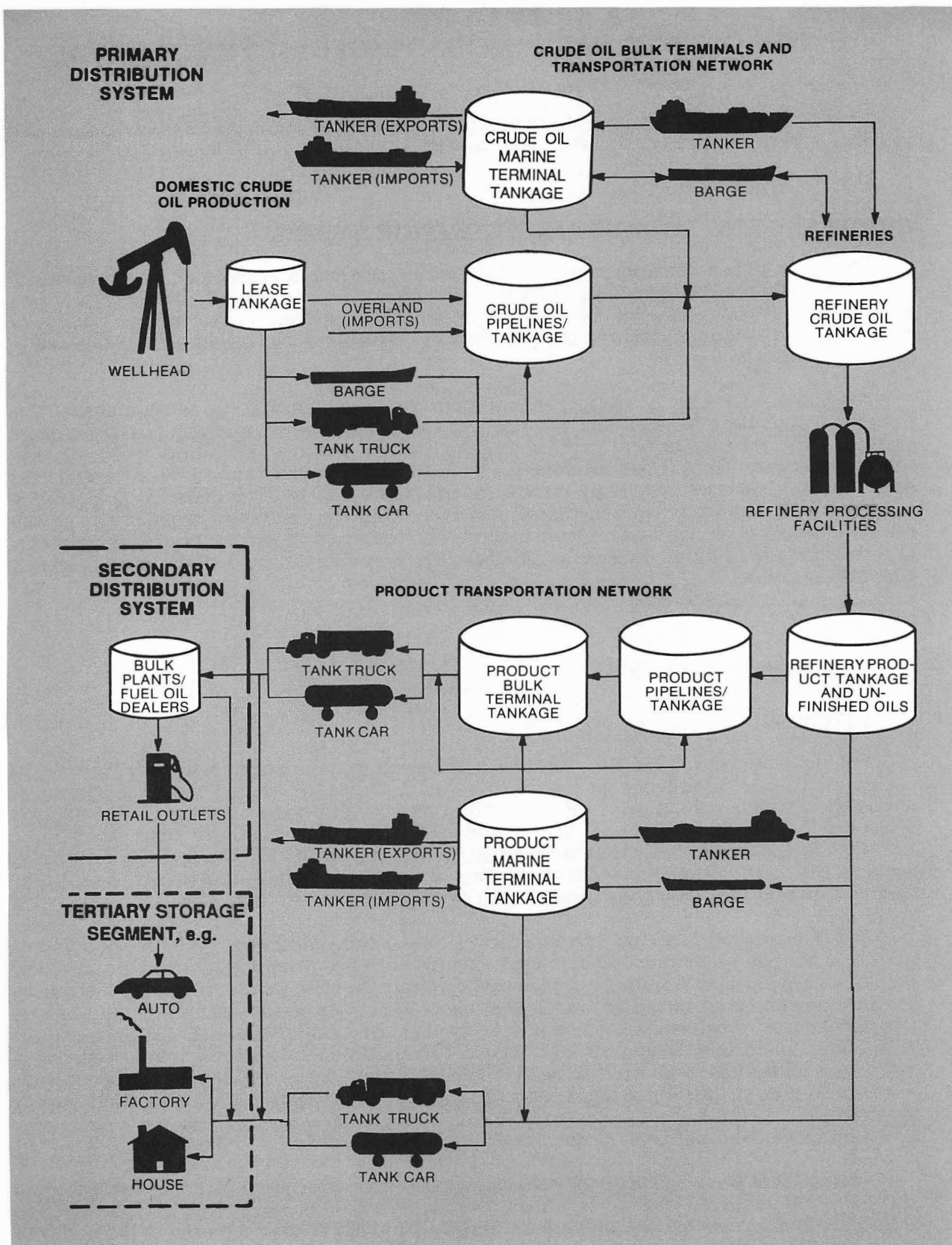


Figure 1. Simplified Diagram of the Crude Oil and Product Distribution System.

Petroleum Products

Once delivered to a refinery, crude oil is processed into various products, including motor gasoline, jet fuel, distillate fuel oil, and residual fuel oil. Tankage is required at refineries to receive and hold both unfinished oils and finished products.

Finished products exit the refinery through the primary product distribution system, which consists of facilities similar to those in the crude oil distribution system: product pipelines, barges and tankers, and bulk terminals to store product for further distribution. Product imports and exports also flow through the primary distribution system.

While products are still in refinery tanks, there is usually a choice as to the location to which the products may move and the mode of transport. Once a product is on its way, it is committed to a geographic area, although some delivery options remain. For example, the Colonial Pipeline, which extends from the Houston-Beaumont, Texas area to the New York Harbor area, passes through the Baton Rouge, Atlanta, Greensboro, Richmond, Washington, Baltimore, and Philadelphia areas. Products can be delivered at numerous locations along the pipeline route. Storage capacity for each of the products carried is provided at shipper bulk terminals, also located along the route.

The terminus of the primary product distribution system is usually a large bulk terminal. Products leave the primary system from these bulk terminals and, at this point, the ability to divert a product to another region becomes much more limited.

Secondary Distribution System

Petroleum products typically flow in bulk from the primary distribution system into the secondary system before delivery in smaller quantities to consumers. A large portion of secondary product storage is located at small, wholesale bulk plants that receive product only by tank car or truck. Also included in the secondary system is tankage at retail motor fuel outlets, such as service stations, truck stops, and convenience stores, as well as storage at retail fuel oil dealers. (See Figure 1.)

Although each facility in the secondary system tends to be much smaller than in the primary system, there are many more secondary distribution points. Taken together, capacities and inventory levels in the secondary system are substantial.

Tertiary Storage Segment

The tertiary storage segment includes storage capacity and inventory of products held by end-users. Examples of the seven sectors into which the tertiary storage segment has been divided for this study are as follows:

- Agricultural -- Farm diesel fuel and gasoline storage tanks
- Commercial -- Office building residual fuel oil tanks
- Electric Utilities -- Fuel tanks for electric generating plants
- Industrial -- Fuel tanks for boilers at factories
- Military/Government -- Government fuel depots
- Residential -- Home heating distillate fuel oil tanks
- Transportation -- Airline jet fuel storage; personal vehicle fuel tanks.

Petroleum products are usually transferred into the tertiary segment from the secondary system, although some product is supplied directly by the primary system. For example, while gasoline for automobiles generally comes from the secondary distribution system through retail gasoline service stations, commercial or rental fleet vehicles may be fueled from product storage that a company itself owns. Fuels used in the industrial sector may be supplied by jobbers or distributors (the secondary system) or, for larger companies, perhaps directly from the primary system via pipeline or barge deliveries. Similarly, many smaller airports are supplied with jet fuel by jobbers, while large commercial airlines frequently receive products directly by pipeline.

NATURAL GAS TRANSPORTATION SYSTEM

The various components of a typical gas system from wellhead to consumer are shown in Figure 2. The natural gas transportation system begins with the gathering segment, a grid of pipelines spreading throughout the gas-producing fields. This pipeline grid picks up gas either at individual wells, at the outlet of processing plants, or at points of connection with producer-owned pipelines. Compressor stations are located where needed throughout the grid to move the gas through the system.

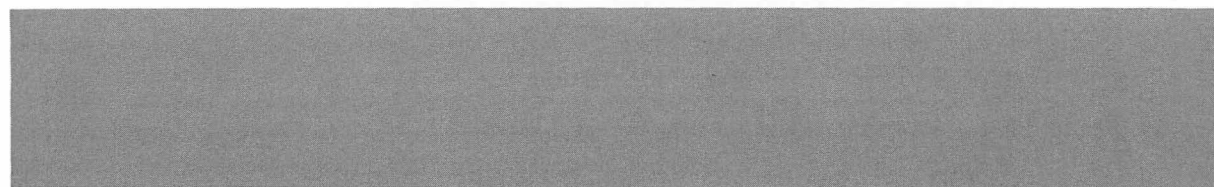
Gathering pipelines funnel into the main line transmission portion of the system. It is the main line segment, often consisting of a single line and at most four or five parallel lines with compressor stations every 40 to 130 miles, which spans the distance between the gas field and the market area. In contrast to the web of gathering lines, the main line follows a relatively straight course.

Once at the market area, gas is sold and delivered to various distribution companies, local utilities, or directly to industrial customers. Often the delivery points are located directly on the main line. It is also common for deliveries to be made through a lateral line that branches out from the main line to link up with the buyer's distribution system.

The physical natural gas pipeline network is mature, with virtually every area of the country being served by at least one pipeline. Although there have been changes in the pattern of demand and regions of supply over the years, the nation's pipeline capacity has essentially remained the same. While on a national basis there is adequate capacity, pipeline capacity issues are a concern in certain areas of the United States.

By the early 1950s, the majority of the natural gas pipelines in the United States had already established their supply and market territories. As traditional reserves and deliverability began to decline, pipeline companies began to acquire system supply from areas in which they did not have existing facilities. To avoid duplication of facilities that gave access to the same supply areas, a pipeline company would interconnect with another crossing pipeline and would negotiate a transportation/exchange agreement in order to obtain new reserves.

Additionally, interconnections were installed to provide pipeline companies with access to natural gas storage fields and markets otherwise not available to them, thus eliminating the need for costly main line transmission extensions. Interconnections linking pipeline companies together made it possible for natural gas to be transported from one part of the nation to another. The extent and magnitude of these interconnected facilities give the industry tremendous flexibility, enabling the system generally to respond to unanticipated increases in demand in a matter of hours or days.



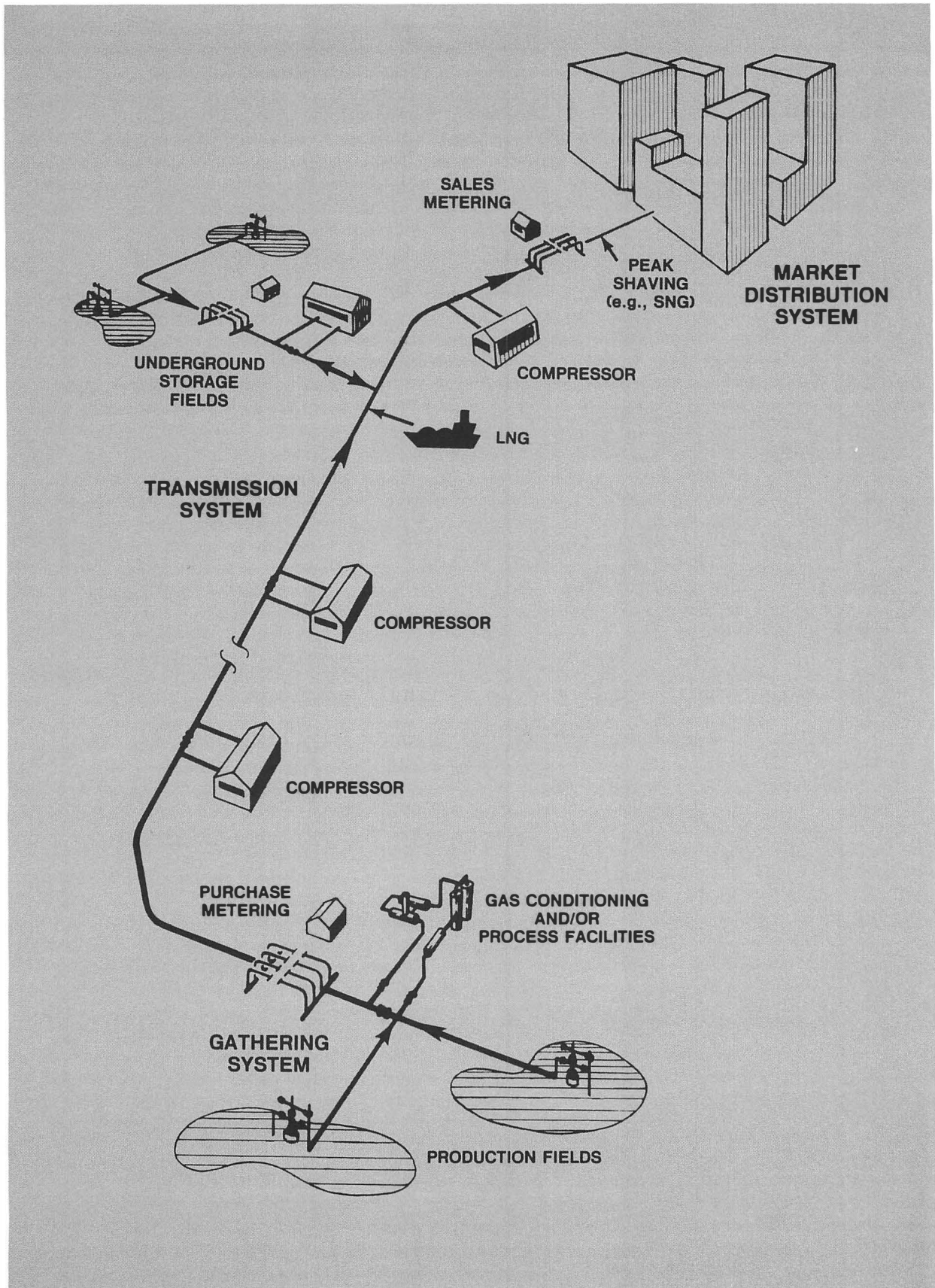


Figure 2. Typical Natural Gas Pipeline System.

VOLUME SUMMARIES

This section contains brief summaries of Volumes II–V of the overall report. The principal findings of these detailed volumes are presented in these summaries.

References are provided in the columns next to the text to direct the reader to the sections in the detailed volumes from which the summary points were drawn.

SUMMARY OF VOLUME II -- SYSTEM DYNAMICS

ABSTRACT

The System Dynamics volume is a detailed analysis of how the U.S. oil and natural gas system works, both in normal times and during periods of "stress" -- when unusual occurrences severely hamper normal system operation. The volume summarizes major changes to the distribution system since 1979, and the evolving petroleum industry conditions that stimulated these changes. This volume assesses the adequacy of the oil and gas distribution system to meet not only actual 1987 needs but those arising from the Energy Information Administration (EIA) projections of 1992 oil and gas demands.

This volume of the study is not statistical but analytical in nature, building on the detailed description and capacity data found in the Natural Gas Transportation, Petroleum Inventories and Storage, and Petroleum Liquids Transportation volumes (III, IV, and V).

In this study, the oil and gas "supply" or "distribution" system definition was extended to include refineries, imports, and trading, as well as transportation and storage facilities. In describing how the system operates under normal conditions, the study summarizes these facilities and functions and briefly discusses some of the economics that control their utilization. Fuel switching and electric utility flexibility are also addressed. Tables, graphics, and maps are included to illustrate recent petroleum industry history and current storage and transportation of oil and gas. Data for these are taken from the other volumes, or from the EIA.

The System Dynamics volume also includes an examination of several historical system stress situations as background for the detailed analyses of the range of possible industry responses to six unlikely but highly stressful situations. The supply system's ability to maintain consumer oil and gas supply under these stress conditions, now and in 1992, is assessed. These six scenarios include:

- (1) A widespread oil import disruption initiating a drawdown of the SPR
- (2) An extended period of severe cold weather
- (3) A 30-day interruption of natural gas imports from Canada
- (4) A 30-day shutdown of a major Gulf Coast to Midwest petroleum products pipeline
- (5) A 30-day shutdown of deliveries from the Trans-Alaska Pipeline System (TAPS)
- (6) A 30-day shutdown of a crude oil pipeline from Canada.

HIGHLIGHTS

This volume examines the dynamic response of the supply and distribution system and concludes that the system has proven its resilience and flexibility in recent years as it adjusted to long-term shifts in the petroleum market and to potentially disruptive short-term supply stresses. If not artificially constrained, the system should be capable of meeting normal U.S. supply needs economically. Likewise, it should be capable of responding effectively to even highly unlikely supply "stress" situations through 1992 (the period examined).

Trends Since 1979

VOLUME II
Chapter 1
pp. 18-31

Oil

Since 1979, the refining and transportation industry has seen two significantly different economic periods. The first was a period of decline and consolidation as high oil prices depressed petroleum demand, which created a substantial refining capacity surplus (Figure 3). From a high of 18.8 million barrels per day (MMB/D) in

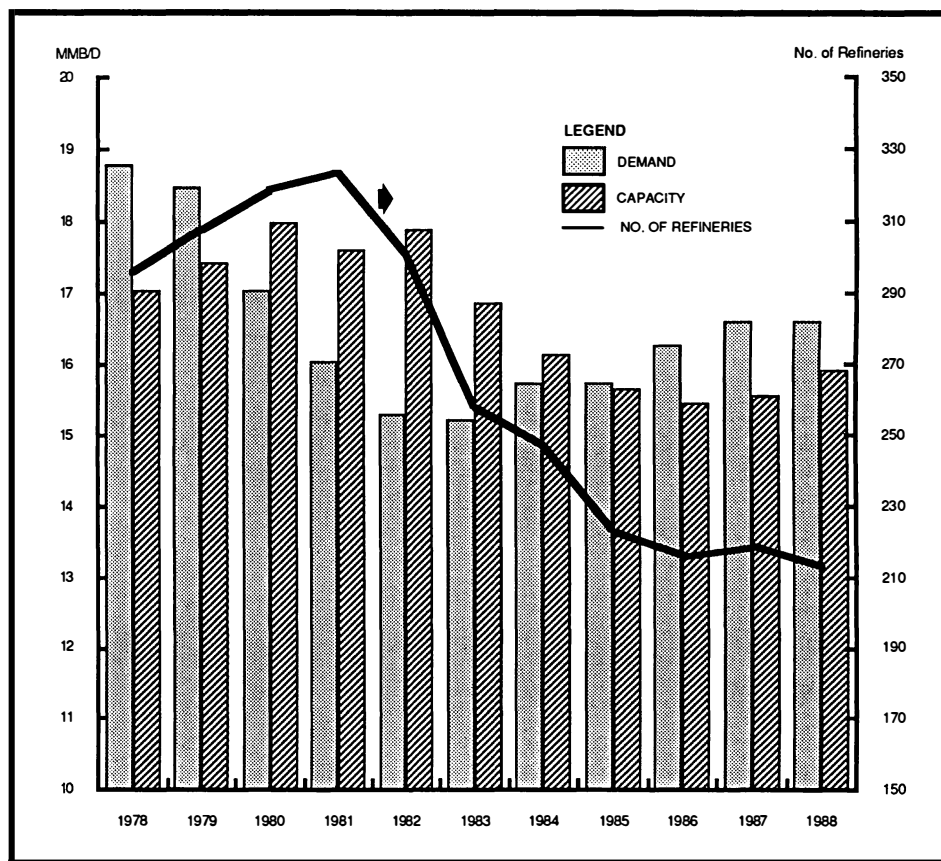


Figure 3.
Oil Demand and
Refinery Capacity vs.
Number of Refineries.

1978, petroleum demand in the United States fell to 15.2 MMB/D in 1983. For the industry, the consequences of this decline were:

- More than 100 refineries and a net of 3 MMB/D of refining capacity were shut down.
- Pipelines and other distribution facilities designed for higher volumes became significantly underutilized. Two major crude oil lines were shut down and converted to natural gas service.

- Worldwide surplus crude oil production eventually resulted in a sharp reduction in crude oil prices. The average crude oil price paid by U.S. refiners declined from about \$37.50 per barrel for March of 1981 to about \$11.50 per barrel for July of 1986. At this level, inflation-adjusted crude oil prices were only slightly above the prices of 1973, prior to the first oil crisis prompted by the Arab Oil Embargo (Figure 4).

The industry's second economic stage began in 1984, when petroleum demand again began to increase in the United States and the free world. By 1987, U.S. demand had risen 1.4 MMB/D above the low of 1983. Oil prices also have risen somewhat from their lows, but domestic oil production and reserves have continued to decline.

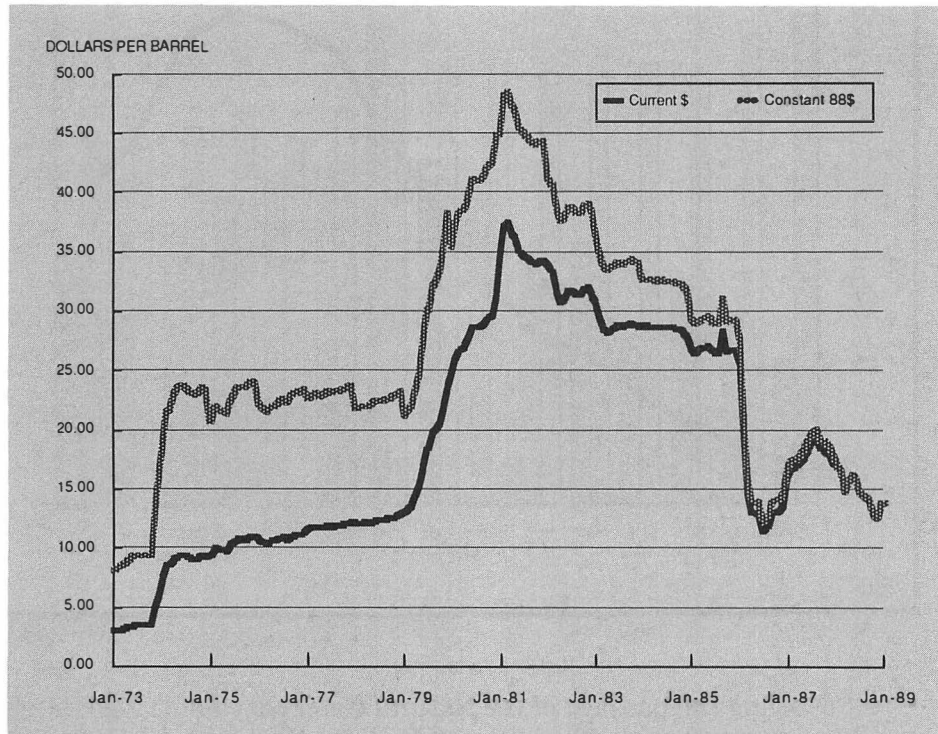


Figure 4.

Crude Oil Prices --
January 1973-1989
(Composite Refiners'
Acquisition Costs).

The economic health of the supply system has improved in the last few years. Refineries generally are running at efficient levels again and improved margins have encouraged some investment in new distillation and product upgrading capacity. Increased crude oil and product demands have improved throughput volumes for at least some pipelines.

Natural Gas

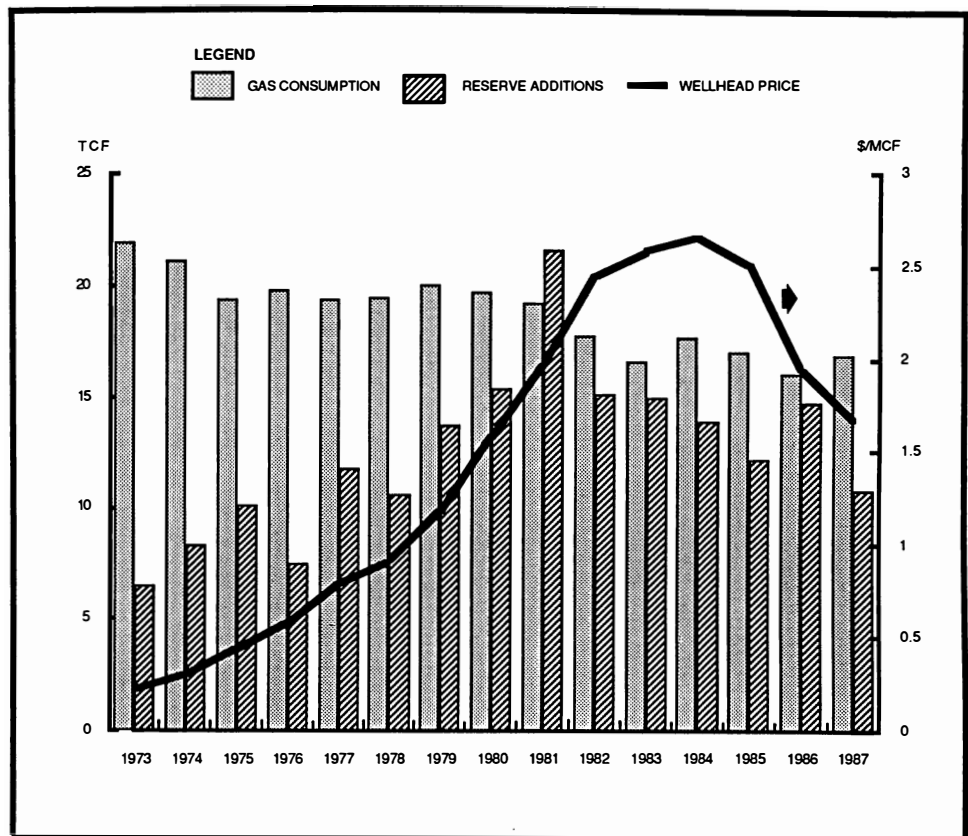
The natural gas industry also experienced significant swings in supply-demand and price. Regulation has traditionally played a dominant role in the natural gas industry. The gas industry is now evolving from a highly regulated environment into a competitive market in which gas suppliers compete with each other and alternative energy supplies for a share of energy demand.

Gas consumption attained a high of nearly 22 trillion cubic feet (TCF) in 1972, driven by low regulated wellhead prices. In 1973, wellhead prices averaged \$0.22 per thousand cubic feet (MCF). Such low

VOLUME II
Chapter 1
pp. 31-36

prices led to a fall in proved natural gas reserves, from almost 300 TCF in 1967 to about 200 TCF by 1978. The relationships between gas consumption, reserve additions, and wellhead price are shown in Figure 5.

Figure 5.
Natural Gas
Consumption and
Reserve Additions
vs. Wellhead Price.



Following the passage of the Natural Gas Policy Act (1978), average wellhead gas prices reached \$2 per MCF in 1981 and \$2.50 in 1982, while prices of some deregulated categories of gas ran up to \$10 per MCF at the time. Average U.S. consumer gas prices peaked in 1984 at \$4.85 per MCF, when wellhead prices peaked at \$2.66 per MCF.

Natural gas consumption declined during the late 1970s and early 1980s, reaching a low of about 16 TCF in 1986. Pipelines and other distribution facilities became significantly underutilized. Also, decreasing demand resulted in a substantial surplus of domestic production capacity (the so-called "gas bubble"). Competition resulted in gas prices falling below regulatory ceilings.

Demand for natural gas has increased in recent years. In 1987, natural gas consumption rose 1 TCF and it appears to have exceeded 18 TCF in 1988. New or expanded markets for natural gas are developing in some areas such as Florida, New England, and the oil fields of California.

For the future, the Energy Information Administration is projecting modest growth in demand and prices for both oil and natural gas.

System Under Normal Conditions

VOLUME II
Chapter 2
pp. 43-129

The study examined the operation of the supply and distribution systems under normal conditions with the dual purpose of:

- Determining the capability of the system to meet anticipated consumer requirements for oil and gas through 1992 and to provide a basis for analyzing the study's stress scenarios.
- Providing a description of the operation of the existing supply system and the dynamic economics that drive it.

Despite the volatility of supply and demand and prices, the uncertainties related to OPEC, the rapid build-up and equally steep fall-off of domestic exploration and production activity, and increasing reliance on imports, American consumers -- commercial and individual -- have felt only minimal supply disruptions. Brief gasoline lines in certain parts of the country in 1979 stand out as the only memorable sign of disruption.

The study concludes that system capacity is adequate to meet existing demand as well as projected demand if anticipated environmental specifications for petroleum products are phased in on a reasonable time schedule and system capacity additions are permitted. History indicates that the industry will adapt to a changing environment. If not restricted by undue regulatory constraints, the system should remain flexible enough to accommodate a fairly wide variance in product mix or geographical distribution patterns, and demand can be met without abnormal stress.

Petroleum refining and transportation has been aptly described as a high-volume, low-margin business in which efficiency is essential to survival. Efficient, low-cost crude oil and product transportation facilities permit refineries to compete effectively in distant markets. Imported product also can be transported or effectively traded into any major market at costs that ensure that consumer prices will normally be at or near parity with world markets.

The "system" is highly fragmented. Functional segments of the system (e.g., refiners, transporters, traders) operate independently and compete with other segments for a share of the overall profit margins, even within integrated companies. Within each function, companies compete vigorously for market share, for improved efficiency, and for higher earnings. Competing companies make independent decisions based on their own economics and their own view of the future.

Despite the enormous complexity of the system, it responds rapidly and predictably to economic incentive. Historically, the system has demonstrated that it responds vigorously to fuel price differentials as small as a fraction of a percent.

System Under Stress Conditions

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The study also examined the potential of the system to resolve situations of supply stress (e.g., abnormal demands, supply disruptions). The industry is constantly responding to stress situations of varying magnitudes, the impacts of which are rarely even felt by the

consumer. Industry reactions to stress situations reflect classic supply-and-demand economics. Strained supply results in higher prices, and the higher prices call out incremental supply from a variety of sources that might otherwise not be attractive. Incremental oil and gas supply can come from storage, peak-shaving, imports, or increased refinery production. Higher prices also make it economic to move product from adjacent areas or to switch to alternative fuels, effectively rebalancing supply and demand. The flexibility and interconnections of the system allow very prompt response to most stress situations.

Historical Stress Situations

System response to stress is illustrated by a review of some actual situations of recent years. Since the end of World War II, no serious petroleum shortages have occurred at the consumer level except gasoline lines in the era of price and allocation controls. In recent years, however, there have been situations where abnormal conditions have led to significant stress in the supply system.

- In the summer of 1988, various refinery problems reduced gasoline production in the U.S. Gulf Coast and California. The drought lowered the Mississippi river, reducing product barge movements and causing additional problems at some refineries. Concerns about gasoline supply were exacerbated when two hurricanes hit the Gulf Coast, closing several refineries for days and disrupting crude oil production and shipments to many refineries for weeks.
- In mid-1986, rapidly falling oil prices induced industrial and utility consumers to switch from natural gas to oil. This switch combined with an East Coast heat wave to create a surge in demand for residual fuel oil. The surge lasted 4 months during which residual fuel oil demand averaged 32 percent higher than 1985 -- an increase of more than 41 million barrels over the same period in 1985.
- In the winter of 1983-1984, a cold wave hit Texas and Louisiana, affecting crude oil production and refining. Overall, the freeze reduced refinery production by about 35 million barrels in December and January.

While these events had their economic cost and produced a high level of discomfort for the industry, they did not prove in any way disruptive to the consumer -- convincing testimony to the flexibility and adaptability of the supply system.

Hypothetical Stress Scenarios

In addition, the study examined the potential ability of the system to resolve six hypothetical stress scenarios of varying severity. The study essentially concludes that each of these disruptions could be handled with varying degrees of problems, but without major hardship, because of the resiliency and flexibility of the nation's supply system.

It is important to recognize that these stress scenarios examine the ability of the system to move crude oil, product, and natural gas. In all the scenarios, supply is assumed to be available to the system. The

system cannot resolve situations where there is not adequate supply available to it.

The study also did not consider situations that were beyond the practical ability of the system to solve (e.g., a situation that triggers international obligations under the IEA treaty). These are problems for governments to address with industry input; but even in these situations, the supply system would provide flexibility to efficiently distribute available supplies.

Each scenario is briefly described below, along with suggestions as to how the industry could effectively handle the situation.

Scenario 1: Oil Import Disruption

This scenario tests the system's ability to handle a 90-day disruption in foreign crude oil and product imports, totaling 3 MMB/D in 1987 and 4.5 MMB/D in 1992.

The capacity of the Strategic Petroleum Reserve and the enormous flexibility of the inventory and supply system are adequate to overcome even such an extensive loss of crude oil. The product loss could be made up from both domestic and foreign refineries.

As the scenario is designed, the crude oil loss would vary by region. The most serious supply problem would occur on the East Coast. However, crude oil and product can be shifted to meet these needs. Free-market trading is vital to the efficient distribution of SPR oil.

In brief, the combination of SPR inventory back-up and the ability of the system to shift product from other parts of the system permit coping with even such large crude oil losses.

Scenario 2: Colder-Than-Normal Weather

This scenario examines how the supply system might cope with an unusually severe winter with temperatures averaging either 10 percent colder than normal for 90 days or 20 percent colder than normal for 30 days throughout the nation. While we have experienced one or the other of these conditions on average once in every five years, these conditions have not been significantly exceeded in the last 50 years.

Both of these conditions could be handled by a combination of inventory drawdowns and a variety of resupply alternatives. This solution would hold both today and for the demand projected for 1992. The point of heaviest stress in this scenario is the deliverability of natural gas to the East Coast, with the area of greatest concern being New England. In that area, some dual-fuel boilers would shift from gas to oil. Construction projects have been proposed, however, to eliminate natural gas pipeline capacity bottlenecks.

In short, the current supply system with the improvements now in progress is fully capable of handling the severest weather conditions we have experienced in over 50 years.

Scenario 3: Canadian Gas Import Disruption

This scenario analyzes the effects of a 50 percent loss in gas imports for the month of January at each of the five entry points

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between Canada and the United States. The assumed reductions for purposes of this scenario are about 2.3 billion cubic feet per day.

This gas loss would be met by calling upon the built-in cushion and flexibility in the system. First, the system inventory would be tapped to meet a large percentage of the shortfall. Second, some fuel switching would take place in the East Coast industrial and electric utility sectors, primarily by drawing on available inventories of residual fuel oil.

In brief, the system could weather the loss of 50 percent of the gas normally imported from Canada for 30 days without significant difficulty. However, the Canadian natural gas shut-off scenario may pose a temporary problem for the West Coast if sufficient natural gas is not in storage at the time of the shut-off. This scenario, therefore, emphasizes the important role of seasonal gas storage in meeting abnormal demands.

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Scenario 4: Midwest Product Pipeline Disruption

This scenario tests supply system capability to respond to a major disruption in a products pipeline flow. For the purposes of this study, the NPC examined the consequences of Explorer Pipeline being shut down for 30 days. This pipeline delivers about 360 thousand barrels per day (MB/D) to the Midwest from the U.S. Gulf Coast area. This is an important product supply for a high-consumption area. This scenario represents an unlikely stress condition, because product pipelines are repaired quickly; normally only a few days of down time would be expected for a pipeline problem.

Available inventory is usually adequate to cover this assumed product loss. The assumed loss of pipeline deliveries for 30 days would amount to about 10.8 million barrels: roughly equivalent to three days' supply. This is less than the amount of inventory typically available above minimum operating inventory levels in this area. In addition to drawing inventories, a number of alternative means exist to increase product supply, including increased refining runs, use of spare capacity in other pipelines, and reduced shipments of product out of the area to regions that can receive product from other sources.

In summary, the loss of a single pipeline into the Midwest for a 30-day period could be handled by a combination of normal industry operating practices.

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Scenario 5: TAPS Disruption

This scenario examines the shutdown of deliveries from the Trans-Alaska Pipeline System for 30 days. TAPS is the largest throughput crude oil pipeline in the United States, carrying an average of about 2 MMB/D for transshipment to the West Coast, the Gulf Coast, the Virgin Islands, and Hawaii. This constitutes about 15 percent of total U.S. crude oil demand.

The loss of 2 million barrels of production is a major disruption even in the world market; the loss of 2 million barrels of Alaskan crude oil is particularly difficult because most of the crude oil is consumed on the West Coast, remote from other major crude oil logistics systems. Given current levels of worldwide inventories and

surplus foreign production capacity, acquisition of replacement supply for the West Coast should not be a major obstacle; the problem is to maintain continuity of supply until replacement crude oil supply can be delivered.

Replacement of the East-of-Rockies supply poses no major problem, but the situation on the West Coast would be more difficult. The West Coast crude oil loss could be managed by a combination of measures, including: drawdown of inventories, diversion of ships carrying Alaskan crude oil from their intended destinations, and increasing imports of crude oil and product.

Thus, while the disruption of TAPS would result in higher cost to the marketplace, essential supply needs would be met, assuming normal world crude oil supply availability, especially in a current disruption. However, the loss of TAPS supply for 30 days in 1992 could pose a substantially more serious problem, which would be felt by West Coast consumers for several weeks. The West Coast re-supply problem will become more difficult in later years as projected Alaskan production drops and West Coast consumption increases, leaving significantly less oil in transit to provide continuity in the early days of the cut-off.

Scenario 6: Canadian Crude Oil Import Disruption

The final stress scenario tests options available in case of a 30-day disruption of Canadian crude oil imports delivered via Inter-Provincial Pipeline. This would result in a 500 MB/D crude oil loss in the Upper Midwest.

Supply to cover a 30-day Canadian crude oil disruption is normally available from primary crude oil inventories in the Midwest and Gulf Coast. Pipeline capacity to move the crude oil to the affected areas is also available. Inventories would be replenished with increased non-Canadian imports later in the stress response cycle. The system also retains the flexibility to supply significant volumes of finished product into the affected areas. By 1992, projected growth in refinery crude oil demand will make replacement of the Canadian volume in kind more difficult. Incremental product supply and product inventory draw would be required to bridge a 30-day loss of Canadian crude oil.

For most of the Midwest, the lost Canadian crude oil could be replaced quickly except for the Twin Cities area.

Observations

A key ingredient in responding to these scenarios is the inventory available at key points in the distribution system, and the system's capacity to obtain crude oil and petroleum products from alternative supply sources. Interconnectability throughout the system allows for shifting and diverting product from many sources to virtually any point of ultimate consumption. Only the foreign import disruption scenario factored in SPR volumes in calculating how the problem could be resolved. Implementation of the declared federal government plan and policy of rapidly and massively releasing SPR oil, given an emergency of large enough magnitude, provides a potentially important supply source in most situations where alternative supply is projected to be unavailable for an extended period.

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(Continued)

Four factors have been vital in minimizing supply problems over the past decade, and they are equally critical to the industry's ability to respond to the anticipated volatility of the years ahead:

- The far-reaching petroleum supply system of pipelines allows a built-in supply cushion or reserve; in addition, inventory storage at strategic points, such as pipeline intersections, can absorb short-term fluctuations. The Strategic Petroleum Reserve can alleviate the impact of larger and longer-term disruptions. However, its effectiveness is conditional on the rapid release of this stockpile of oil shortly after a crisis occurs. Such a release is part of stated government policy.
- The natural gas system of pipelines, storage fields, and peak-shaving and LNG facilities provides a wide range of supply options. As natural gas demand is far more seasonal than oil, storage and peak-shaving alternatives are more critical to the continuity of supply. This ability to move large volumes of gas into market during peak periods gives added flexibility to adjust to periods of stress. Natural gas markets are also unique in that they have built-in mechanisms for demand reduction, such as interruptible contracts with customers, most of whom have dual-fuel capabilities.
- The industry has demonstrated its ability to overcome mechanical disruptions, such as a pipeline breakdown. The system can generally be repaired quickly, and inter-connectability affords alternative supply routes.
- Longer-term trends afford financial incentives to invest in projects designed to meet new demand. Pipeline flow can be reversed, new or parallel lines constructed, and deep-water oil and LNG import facilities developed.

Driving the system's capacity to readjust are the incentives provided by market forces. Supply shortages and rising demand lead to higher prices, encouraging efforts to rebalance the delivery of oil and gas. Regulatory and other artificial constraints, such as new pipeline approval delays, keep the natural balancing, self-correcting process from working as effectively as it could.

SUMMARY OF VOLUME III -- NATURAL GAS TRANSPORTATION

ABSTRACT

The Natural Gas Transportation volume describes the industry as it exists today and analyzes a series of "stress cases" for 1992. Sections on the history of the industry and its changing regulatory environment are used to provide a perspective for the analyses.

To establish baseline data for the analyses, the NPC surveyed approximately 80 natural gas transmission and storage companies to determine the capacities of major pipeline segments, interconnections, and storage sites, as well as peakshaving/LNG information. The surveys also collected data on the BTU content of the gas in each system and the relationship between average January day requirements and peak January day requirements. Most of the major interstate transmission companies and large storage companies responded. Information from available Federal Energy Regulatory Commission (FERC) reports and American Gas Association (A.G.A.) publications was utilized to supplement the data. These data provide the basis for many of the maps and tabular material found in the volume, as well as input to the linear programming model utilized in the analyses.

The ability of the national natural gas pipeline network to satisfy demand, without considering fuel switching capabilities, was modeled under a set of cases comprised of a typical winter and a series of assumed stress conditions within a broad range of supply and demand projections. Conditions for both 1988 and 1992 were analyzed. The Low Demand projection, 16.5 TCF, was derived from a forecast prepared by Data Resources Inc. (DRI), and the High Demand projection, 18.7 TCF, was derived from an A.G.A. forecast (see Figure 6). The Low Supply and High Supply projections assumed annual Lower-48 production to be 15 TCF and 17 TCF, respectively.

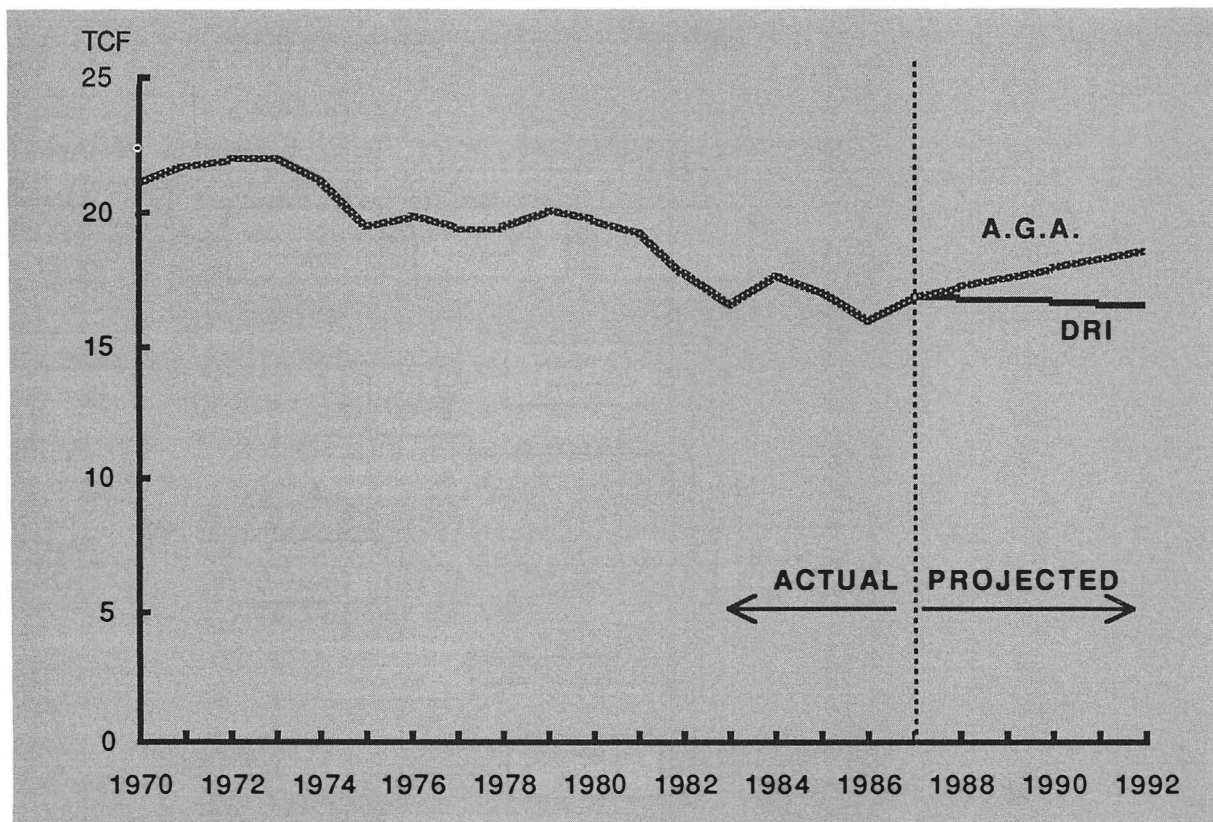


Figure 6. Natural Gas Consumption -- Lower-48 States (TCF/Year).

HIGHLIGHTS

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also, Appendix C

Structural Changes in the Industry

The last decade has been a period of major transition for the natural gas industry. The transformation of the industry has grown out of:

- Reduced federal regulation
- A dramatic decline in oil and gas prices
- The so-called "gas bubble" (the surplus of connected production capacity over demand)
- The advent of open-access transportation
- The competitive environment for new, developing gas markets.

Responding to the Natural Gas Policy Act of 1978 and FERC Orders 380 (1984), 451 (1986), and 500 (1987), the gas industry has made structural changes affecting the way its business is conducted. Figure 7 highlights this transformation as industry reacts to less regulation, more competition, open-access transportation, elimination of the minimum-bill obligation, and the opening of new markets for the producers, pipelines, local distribution companies, and other industry participants. Today's environment has less centralized control, more price volatility, risk, and fragmentation, coupled with more opportunity (for consumers, local distribution companies, pipeline companies, and producers).

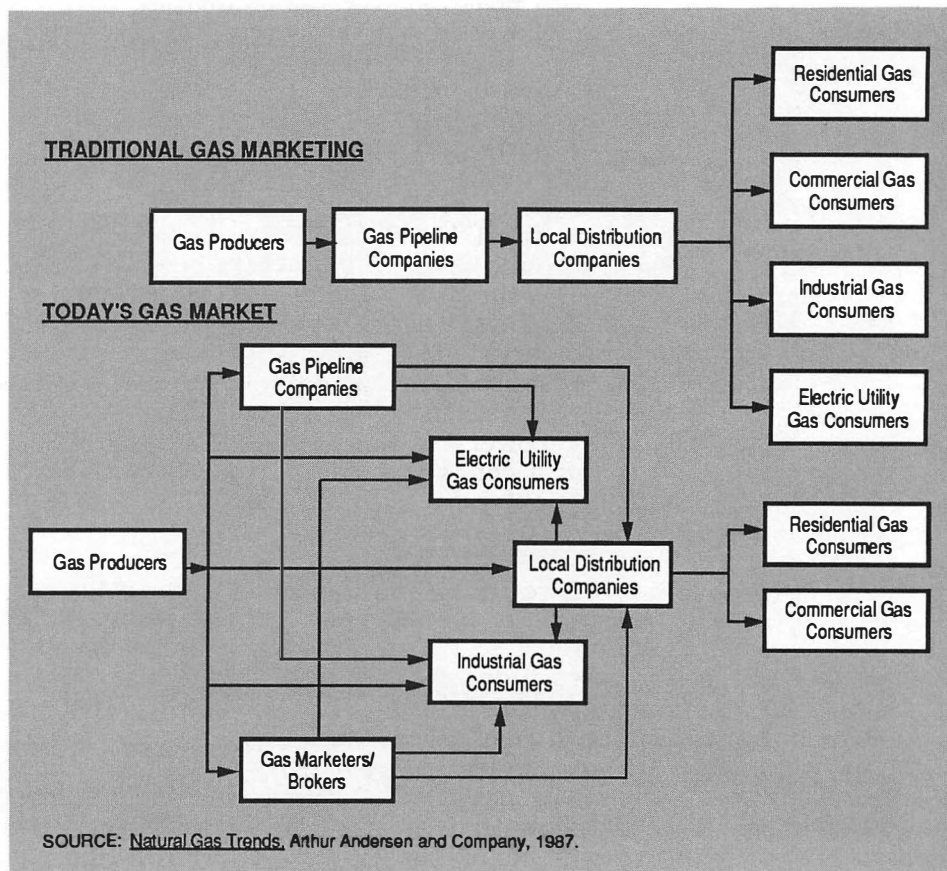


Figure 7.
Traditional vs. Today's
Gas Marketing.

An active spot market for gas has evolved simultaneously with the unbundling of services rendered by the gas pipeline industry. Another factor contributing to the development of a spot market has been the partial deregulation of wellhead prices. As deregulation continues, this should enhance the marketplace's ability to send pricing signals of relative gas availability between the gas-supply and the gas-consuming sectors of the nation. The energy market of the 1980s has become increasingly sophisticated and competitive. Many electric utilities, as well as industrial users, have the ability to switch fuel with very short notice. In addition, local gas distribution companies have the option to receive gas from various suppliers. With the volatility in today's energy market, most customers have developed fuel acquisition programs that provide accurate and timely information about energy markets and the strategic opportunities they present. With the "gas bubble" and falling oil prices, the competition between oil and gas and even between gas marketers to retain market share has intensified immensely. The move towards decontrol has produced positive results, but its implementation has caused confusion and uncertainties, which are gradually being resolved among regulatory authorities and segments of the industry.

Supply and Demand

The turnaround in natural gas demand occurred in 1987, with demand increasing by 6 percent. Continuing growth brought 1988 demand to an estimated 18 TCF, about 1 TCF over the prior year. In the cases analyzed, demand in 1992 for the Lower-48 States is projected to be as high as 18.7 TCF, with peak-day demand as high as 104 billion cubic feet, over 200 percent of average-day demand.

In 1988, U.S. Lower-48 natural gas production was approximately 14.3 TCF. This domestic supply was supplemented by 1.3 TCF of imports. While U.S. gas imports are mainly from Canada, additional supplies can come via pipeline from Mexico and are imported in the form of LNG from Algeria. There exists substantial uncertainty about the total size of the U.S. natural gas resource base, particularly that portion which will be discovered in the future and will be economical to produce. At year-end 1987, the United States had 154 TCF of proved natural gas reserves in the Lower-48 States. While estimates of the recoverable resource base vary, a 1988 DOE study estimates that a technically recoverable resource base (including proved reserves, inferred reserves, and resources) of over one quadrillion cubic feet of natural gas exists in the Lower-48 States. This resource estimate represents more than half a century's supply at 1988 consumption levels. By comparison, current proved reserves equate to less than a decade's supply.

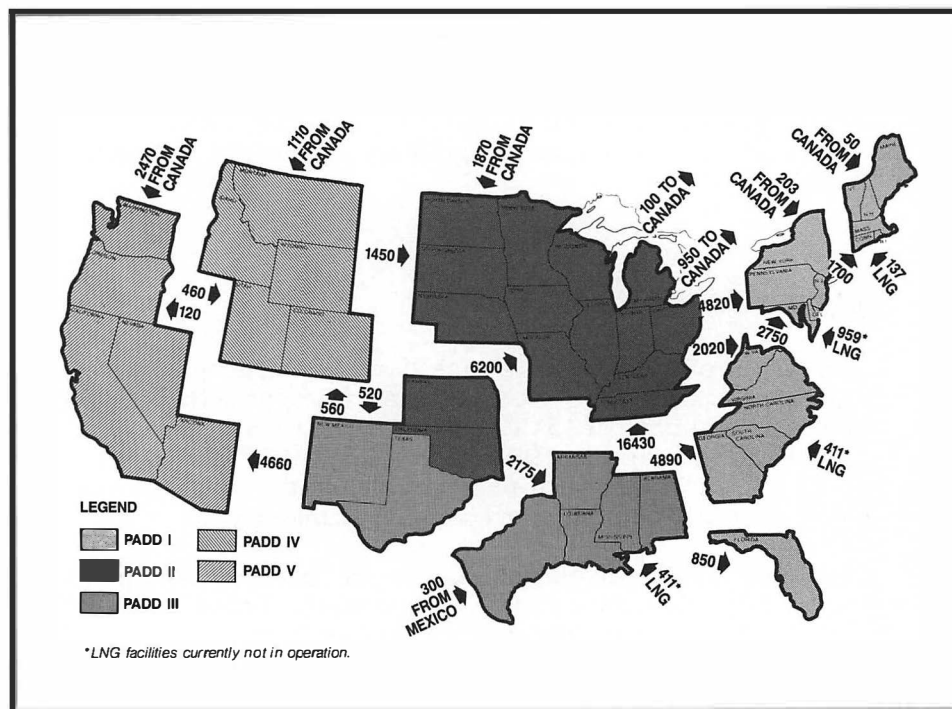
In the DOE study, more than half of the total resources in the Lower-48 States, 583 TCF, is judged economically recoverable at wellhead prices of less than \$3.00 per MCF (in 1987 dollars). An additional 174 TCF of gas is judged economically recoverable at a price range of \$3.00 to \$5.00 per MCF, bringing the total to 757 TCF at prices up to \$5.00 per MCF. The price of gas for 1988 averaged \$1.71 per MCF at the wellhead, well below the level needed to support significant new reserve additions. The maintenance of U.S. gas production will require a much higher level of drilling than at present. A healthy service and supply infrastructure will be necessary to support this increased drilling activity.

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Pipeline System Capacity

The industry's pipeline system reaches from coast to coast and border to border. Interconnections within the system afford access to virtually every supply and market area in North America, including Mexico and Canada. Figure 8 shows gross transportation capacities into and out of major producing and consuming regions of the United States. Capacity to move gas out of major supply regions, under peak winter conditions, is approximately 33.7 billion cubic feet per day (BCF/D); the system can handle net peak-day volumes of 4.6 BCF/D of Canadian gas; new lines with 2 BCF/D of capacity have been built or converted to gain access to new supply areas.

Figure 8.
 Gross
 Inter-Regional
 Natural Gas
 Transportation
 Capacities -- 1988
 (MMCF/D).



The system's ability to respond to changing regional demand patterns is enhanced by the ongoing progress of deregulation. The A.G.A. projects an increase in demand of approximately 1.9 BCF/D for New England, the Mid-Atlantic states, and Florida by 1992. The industry has already proposed projects, most of which await regulatory approvals, with a capacity of 2.7 BCF/D, to serve new markets in these regions and California. Other projects to open up new or capacity-constrained supply areas such as Oklahoma and offshore Alabama have also been proposed.

Storage Capacities

Pipeline capacities are supplemented during peak-demand periods by almost 52 BCF/D of withdrawal capability from large underground gas storage facilities, and by almost 8 BCF/D of available peak-shaving supply, located strategically throughout the country. (Figure 9 shows the location of these storage facilities and the table provides capacity and peak-day deliverability data for these storage facilities.) The issue of the allocation of the costs of such storage under deregulation has not yet been fully resolved.

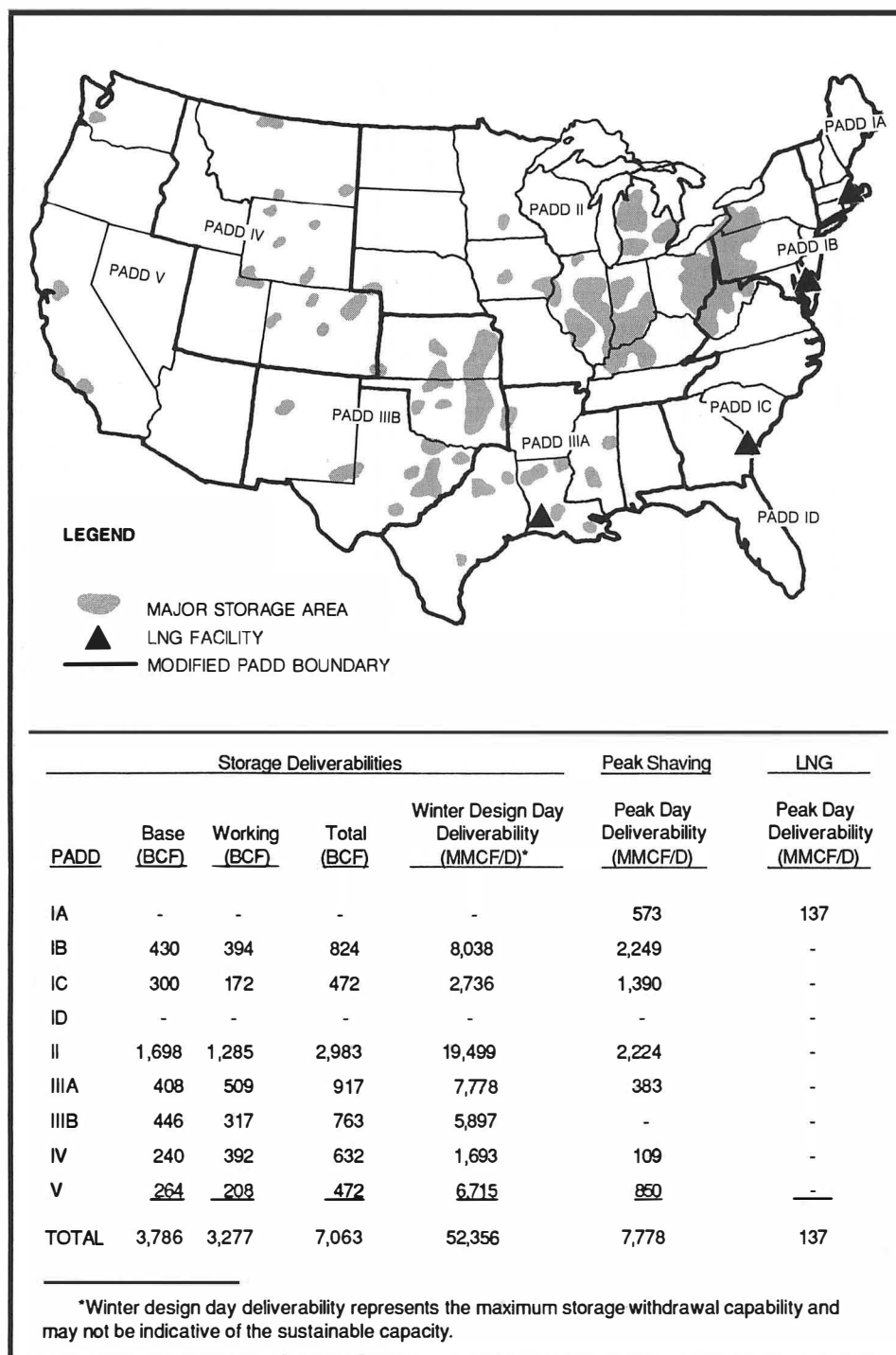


Figure 9.
1988 Survey of
Natural Gas Storage
Facilities.

Observations

The study concludes that the existing flexible and dynamic transportation and supply system can meet virtually all current U.S. "normal" demand requirements and most "peak" demand requirements. Likewise, pipelines and regional natural gas storage facilities are adequate, in nearly all areas of the country, to meet needs for the foreseeable future.

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also, Appendix H

In the natural gas peak-demand and stress scenarios assumed in this analysis -- which allow for no proposed facilities being developed -- most normal demand situations would be met without interruption. Partial supply curtailment is anticipated in some areas, during peak-demand periods and extreme stress periods, due to a lack of pipeline capacity. These partial curtailments would impact only the utility and industrial/commercial sectors, which are occasionally affected under interruptible gas contracts. In either case, however, the study concludes that the demands of residential and other non-interruptible high priority consumers would be met.

Considerable fuel-switching capacity in the electric utility and industrial sector allows natural gas to substitute for oil, and vice versa, in a matter of hours, giving lower priority users an alternative to shutting down. Recently, FERC has approved some proposals for new pipelines that were not considered in the scenarios. If remaining approvals are granted and the new pipelines are built, more flexibility will be added to the system.

The industry's capability of serving the nation's needs will be enhanced by such market-driven improvements in the system. But producers, pipelines, local distribution companies, and other industry participants must continue to work with federal and state regulators and legislators to facilitate the evolution towards a totally free marketplace.

SUMMARY OF VOLUME IV -- PETROLEUM INVENTORIES AND STORAGE

ABSTRACT

The Petroleum Inventories and Storage volume analyzes inventories and storage capacities for crude oil and the principal petroleum products in the:

- Primary distribution system -- refineries, pipelines, and terminals
- Secondary distribution system -- bulk plants and retail motor fuel outlets
- Tertiary storage segment -- consumers/end-users.

The objective of this volume was to determine the amount of petroleum that could be available in an emergency, estimate new minimum operating inventory levels for the primary system, and determine the amount of petroleum storage capacity in the United States. Additionally, the impact of petroleum futures and forward markets and the SPR on inventories were examined.

Inventories and storage capacities in the primary distribution system and part of the secondary distribution system were determined by survey. In the primary system, each of the 381 companies was surveyed for detailed information on inventories and storage. In the secondary system, a statistical sampling technique was used; 1,995 of the approximately 15,000 companies believed to be in the secondary system were surveyed for data on inventories and storage. Estimates for retail motor fuel outlets were based on published literature and discussion with industry experts.

The tertiary (consumer) segment was divided into seven sections -- Agricultural, Commercial, Electric Utilities, Industrial, Military/ Government, Residential, and Transportation -- and estimates of inventories and storage capacity were made using available public data.

The inventory and storage capacity estimates are compared to the NPC's 1983 estimates. The changes along with the reasons for the changes were used to describe the forces that shape inventory and storage management.

HIGHLIGHTS

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The U.S. petroleum distribution systems are comprised of networks of terminals, refineries, other storage facilities, pipelines, tankers, barges, tank cars, and tank trucks. These elements move crude oil from its source, convert it into consumer products, and deliver the products to consumers' facilities for their use. All of these components store oil.

Total Inventories

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pp. 51-52

The NPC has completed 10 inventory studies since 1948 to aid the federal government in emergency planning. The three studies prior to this one estimated minimum primary crude oil and selected product inventory levels, below which shortages and operating problems would begin to surface in a given distribution area. Inventories of crude oil and the principal fuel products in the primary distribution system on March 31, 1988 are shown below (in millions of barrels):

	Primary Inventories	
	March 31, 1988	Change from March 31, 1983
Crude Oil*	343	-1
Motor Gasoline	231	+8
Kero-Jet Fuel	40	+5
Distillate Fuel Oil	89	-29
Residual Fuel Oil	<u>44</u>	<u>-2</u>
Total	747	-19

*Excludes 545 million barrels of SPR crude oil and 10.6 million barrels of lease stocks.

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pp. 51-52, also 59-74

For refined products, this study has gone beyond the historical focus on primary distribution, since the secondary distribution system and tertiary storage are closely interrelated and contain almost 45 percent of the combined system inventory of products. The estimated total U.S. inventories of major products on March 31, 1988 are shown below (in millions of barrels):

	March 31, 1988	
	Primary	Secondary & Tertiary
Gasoline	231	111
Kero-jet Fuel	40	11
Distillate Fuel	89	128
Residual Fuel	<u>44</u>	<u>62</u>
Total	404	312

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pp. 42-49

Minimum Operating Inventories

The current study estimated industry-wide minimum operating inventory for crude oil and the principal products in the primary

distribution system. Minimum operating inventories are defined as the level below which operating problems and shortages would begin to appear in the distribution system.

At the time of the 1983 study, falling demand was the driving force behind a decline in minimum operating volumes for all products, as compared to the 1979 estimates. In this study, minimum operating inventories have been increased for crude oil, motor gasoline, and kerosine-type jet fuel; they have declined for distillate fuel oil and residual fuel oil.

The estimates of 1988 total U.S. minimum operating inventory for the primary distribution system are as follows (in millions of barrels):

	<u>Minimum Operating Inventories</u>	
	<u>1988</u>	<u>Change from 1983</u>
Crude Oil	300	+15
Gasoline	205	+5
Kero-jet Fuel	30	+5
Distillate Fuel	85	-20
Residual Fuel	<u>30</u>	<u>-10</u>
Total	650	-5

These estimates recognize trends moving in opposite directions:

For Higher Inventories

- Increasing reliance on long-haul foreign crude oil using large, deep-draft tankers
- Increasing petroleum demand.

For Lower Inventories

- Reduction in refining, pipeline, and tankage capacity
- Increasingly sophisticated inventory management.

Primary Inventories

At March 31, 1988, the system contained primary inventories of 747 million barrels of crude oil and surveyed products. The study also notes that days' supply of crude oil or product calculations, based on total inventory, do not present a valid indication of the adequacy of inventory levels. A better way to judge adequacy is to look at availability -- the volume of inventory above the inventory required to run the system.

To illustrate, for March 31, 1988, the following table shows total days' supply of inventory ranges from 3 to 25 times the true available inventory above minimum:

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	March 31, 1988	
	<u>Total Days' Supply</u>	<u>Days' Supply Above Minimum</u>
Crude Oil	27	4
Gasoline	32	4
Kero-jet Fuel	33	8
Distillate Fuel	25	1
Residual Fuel	31	10

Inventories above minimum were generally lower in the 1988 calculation than in 1983. However, a seemingly low number of days' supply above minimum should not cause concern in times of normal operation. The overall flexibility of the supply, refining, and distribution system provides ample ability to meet all but the most extreme demand peaks over time. The potential drawdown of inventory in the secondary distribution system and tertiary storage segment can provide additional flexibility in times of tight supply.

While the primary distribution system operates with lower inventories today than in 1983, several factors could mitigate against potential product supply disruptions impacting the consumer.

For example, a significant proportion of imported crude oil has a long in-transit time (30-50 days). This allows time for the fast-moving global supply network to locate alternative, nearby crude oil and products to compensate for an import disruption, if that supply is interrupted at the source. (No consideration was given to a politically motivated interruption of in-transit crude oil or products.) The combined systems (primary, secondary, and tertiary) capacity for holding petroleum products can moderate short-term "demand surges."

In recent years, substantial refinery capital investment has upgraded processing capability and increased flexibility to handle various grades of crude oil and produce a greater percentage of light products.

And finally, SPR crude oil stocks are available for drawdown. The Strategic Petroleum Reserve had crude oil stocks of 545 million barrels as of March 31, 1988, and a potential drawdown rate of 3.6 MMB/D. The drawdown rate is expected to increase to 4.5 MMB/D in 1992. By 1996, stocks are scheduled to reach 750 MMB/D.

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Appendix E

Primary system total tankage for crude oil and surveyed products amounted to 1,419 million barrels in 1988, down slightly since 1983. The percentage of utilization of tank capacity over the 40-year span covered by NPC inventory reports has ranged from a high of 53 percent in 1969 to a low of 40 percent in 1983; the average has been 46 percent. Utilization for the two days surveyed was 41 percent. It is not anticipated that there will be significant change in storage capacity in the next few years.

Appendix G

As part of the study, a survey of the industry indicated that the existence of the Strategic Petroleum Reserve had not affected a single company's inventory levels.

Appendix F

The study also examined the potential effects of the futures and forward markets. Despite the substantial growth of futures trading

since the last NPC study, a survey of the primary and secondary distribution systems showed only 13 percent of respondents felt that the futures market had any effect on their level of physical inventories.

Secondary and Tertiary Systems

The secondary system operates between the primary distribution system and end-users of petroleum products. The two major components are bulk plants with storage capacity of less than 50,000 barrels, and retail outlets. Approximately 15,000 companies own and/or operate bulk plants, down from 18,000 in 1983. As of March 31, 1988, there were an estimated 170,000 retail motor fuel outlets. The bulk plants had 22 million barrels of product inventory, and the retail outlets had an additional 44 million barrels on March 31, 1988.

The tertiary storage segment consists of seven sectors: Agricultural, Commercial, Electric Utilities, Industrial, Military/Government, Residential, and Transportation. Total tertiary product inventories were estimated at 247 million barrels, with total capacity at 571 million barrels.

System Flexibility

Based on experience, the study concludes that the overall system has sufficient flexibility to handle a demand surge in defined geographic areas. Several factors tend to mitigate the importance of demand surges and diminish the likelihood of disruption. First, a call for product by the secondary or tertiary sector does not reflect a consumption surge, rather a transfer of products to secondary or tertiary storage, so the product is still available. Also, demand surges would usually not apply to all products in all geographic areas at the same time.

Primary inventories above minimum are usually available in any area. As these are drawn down in one location, product would be redirected from other areas by price-driven dynamics.

Furthermore, finished products can be imported, from within a few days to a few weeks, to correct temporary imbalances in the system. Refineries continually replenish the primary system, and may be able to increase their output to meet a demand surge. Prices play a critical role in the process by providing the financial incentives and justification for shifting supplies to affected areas.

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SUMMARY OF VOLUME V -- PETROLEUM LIQUIDS TRANSPORTATION

ABSTRACT

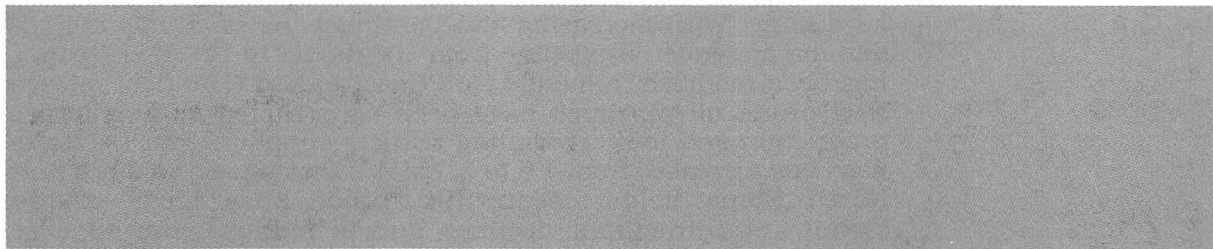
The Petroleum Liquids Transportation volume presents information on all forms of transportation of crude oil, refined petroleum products, and liquefied petroleum gases (LPGs). These include pipelines, tankers, tank barges, trucks, and rail cars.

Capacity data as of December 31, 1987 are given for common-carrier crude oil pipelines, petroleum product pipelines, and LPG pipelines, in map and tabular formats. U.S. maps of each of these pipeline systems are included, as are regional maps by Petroleum Administration for Defense District (PADD) for the crude oil and product systems. Detailed area maps for major refining and pipeline centers are also included.

In addition to capacity data, longitude and latitude data for pipeline receipt and delivery points are given, to aid in industry analysis and computer drafting. All data for pipelines were developed by an NPC survey of the major petroleum transportation companies in the United States. Some private (as opposed to common-carrier) pipelines are included in this report, but crude oil field gathering systems are excluded. Detailed profiles consisting of brief descriptions, maps, and data sheets for the individual pipeline companies that participated in the survey are available separately from the NPC.

The waterborne transportation portion of this volume updates the 1979 NPC inventory of marine petroleum transportation equipment, including U.S.-flag tankers and domestic inland waterway vessels. It also examines waterway navigational structures, and constraints on the waterborne transportation industry arising from various regulations and insufficient or outmoded facilities.

The tank cars/tank trucks transportation portion of this volume analyzes the U.S. tank truck and rail tank car fleets, and determines the number of these vehicles that might be called upon to safely haul petroleum products in the event of an emergency. Data for this portion of the study, as well as for the waterborne portion, were obtained from numerous government agencies and trade groups.



HIGHLIGHTS

VOLUME V
Chapter 1, pp. 13-14

Transportation is accomplished by a variety of land and marine modes including pipelines, rail tank cars, tank trucks, barges, and oceangoing tankers. On a volume basis, pipelines and marine carriers are predominant, but trucks and rail tank cars have essential functions.

Chapter 2, pp. 15-58

Pipeline Transportation

At year-end 1986, the nation's petroleum pipeline network, excluding gathering lines, totaled almost 204,000 miles, including 108,000 miles of crude oil lines, 72,000 miles of refined product lines, and some 23,000 miles of LPG lines transporting such commodities as propane and ethane. Over the past decade reduced product demand and shifts in supply-demand patterns have impacted the system; crude oil pipeline mileage has declined, product and LPG lines have increased, with total mileage remaining virtually unchanged. Construction over the decade totaled approximately 24,000 miles.

The study concludes that through 1992 there is ample total crude oil pipeline capacity, and no major logistical problems are envisioned. Future product pipeline activity will primarily be directed toward removing bottlenecks in certain systems. LPG lines will be modified to accommodate such developments as increased waterborne and Canadian imports of LPG.

Chapter 2, pp. 35-45
also, Appendix C

Crude Oil

From 1979 to 1983, U.S. refinery runs declined, while domestic crude oil production increased. As a result, two major crude oil pipelines -- Seaway and Texoma -- were converted to natural gas service. Built in the 1970s to move crude oil imports from the Gulf Coast to Oklahoma, these lines had become underutilized as Mid-Continent oil import usage fell. In 1981, the Louisiana Offshore Oil Port (LOOP) system came into operation to handle imported oil transported in large, deep-draft tankers. With a nominal capacity of 1 MMB/D, LOOP was underutilized until the recent rise in oil imports.

Since the mid-1980s, U.S. refinery runs have increased once again with rising demand, while domestic crude oil production has resumed its decline. With increasing Mid-Continent use of oil imports, at least one major crude oil pipeline from Oklahoma to the Texas Gulf Coast has been modified to handle Gulf Coast to Mid-Continent movements. New crude oil pipelines have been constructed to handle offshore production and to meet shifting refinery supply needs. TAPS capacity has been increased from 1.6 to 2.1 MMB/D to handle volumes from new North Slope fields. Meanwhile, other lines have experienced significant throughput declines due to falling Lower-48 crude oil production.

Successful exploration and development may require the construction of new lines, but the existing system, with minor modifications, should be adequate to meet foreseeable domestic and imported crude oil transportation needs. Figure 10 shows 1988 gross inter-PADD pipeline capacities for crude oil.

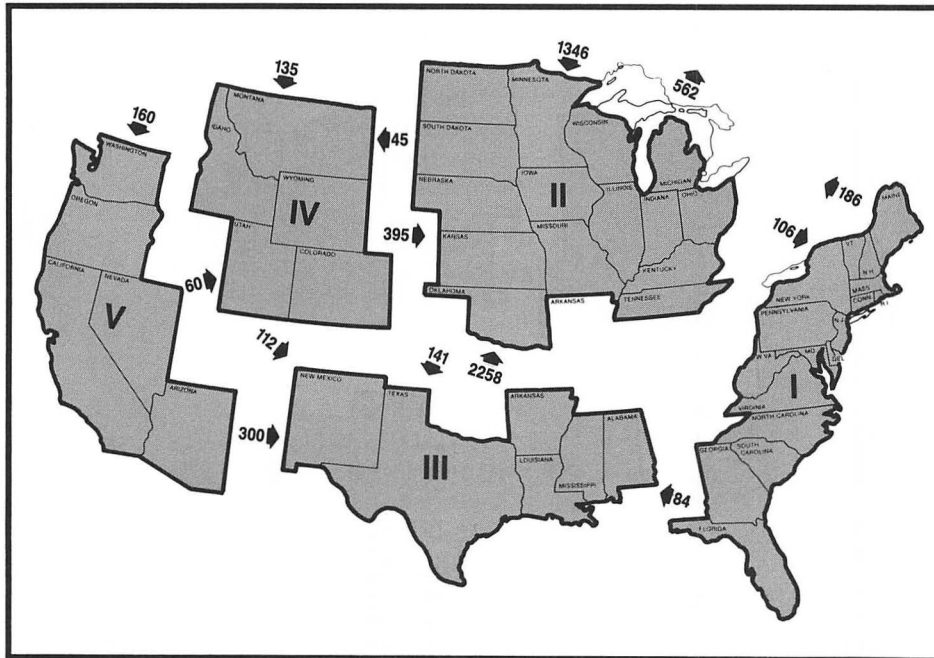


Figure 10.
Gross Inter-PADD
Capacities of Crude
Oil Pipelines -- 1988
(MB/D).

Refined Products

The nation's 72,000 miles of product pipeline accounted for 1.6 trillion barrel miles of product movements in 1987. In response to shifting supply and demand patterns, some 3,732 miles of new, looped, or converted lines were placed in product service during the past decade, with slightly over 2,000 miles taken out of service. Notable expansions during the decade include Colonial's capacity expansion in 1980, of its main line connecting the Gulf Coast and East Coast; Southern Pacific's major capacity expansion from Los Angeles to Phoenix; and Explorer's and Texas Eastern's expansion to increase capacity from the Gulf Coast to the Midwest. A line connecting the Philadelphia area and New York Harbor was expanded in 1983.

Other lines have been expanded or reversed in response to regional demand shifts. But while the trend of supply restructuring may continue in the future, no significant logistical problems are anticipated. Figure 11 shows 1988 gross inter-PADD pipeline capacities for refined products.

LPGs

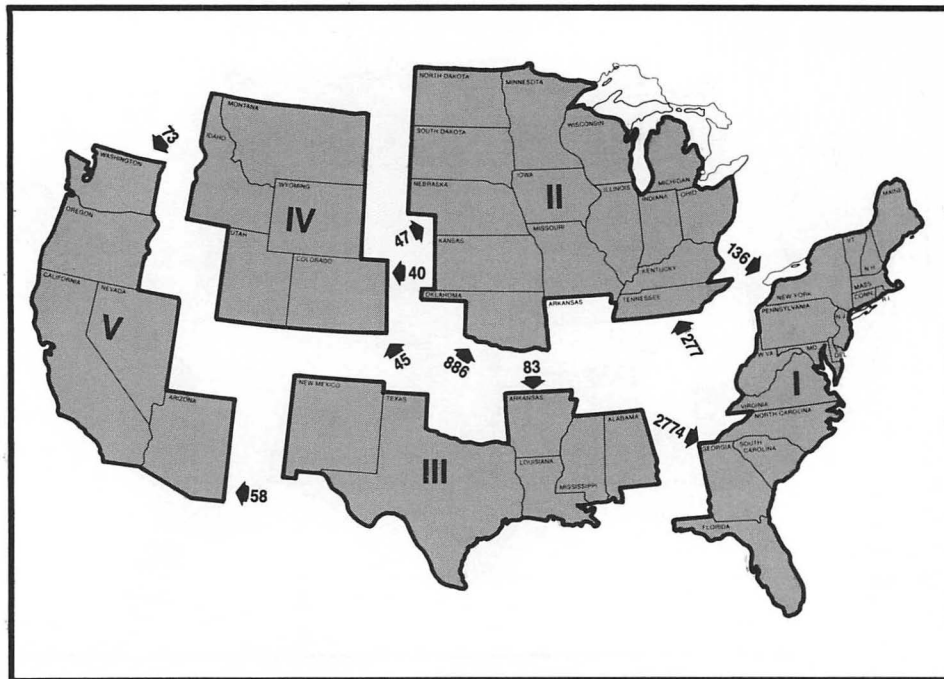
Two separate systems transport LPGs, or liquefied petroleum gas and natural gas liquids. Gathering systems collect product from gas processing plants, fractionators, and refineries and deliver it to storage hubs. Distribution systems then move the product to large consumers such as chemical plants, refineries, and wholesale distributors.

Since 1979, new lines have been constructed to move increased production from Wyoming to West Texas, and from West Texas to the Houston/Mont Belvieu area. Meeting the needs of Gulf Coast refineries has led to the need for additional lines. While no other major construction plans have been announced, a number of projects may prove feasible. Among them are potential new lines to new ethylene

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Chapter 2, pp. 51-58
also, Appendix E

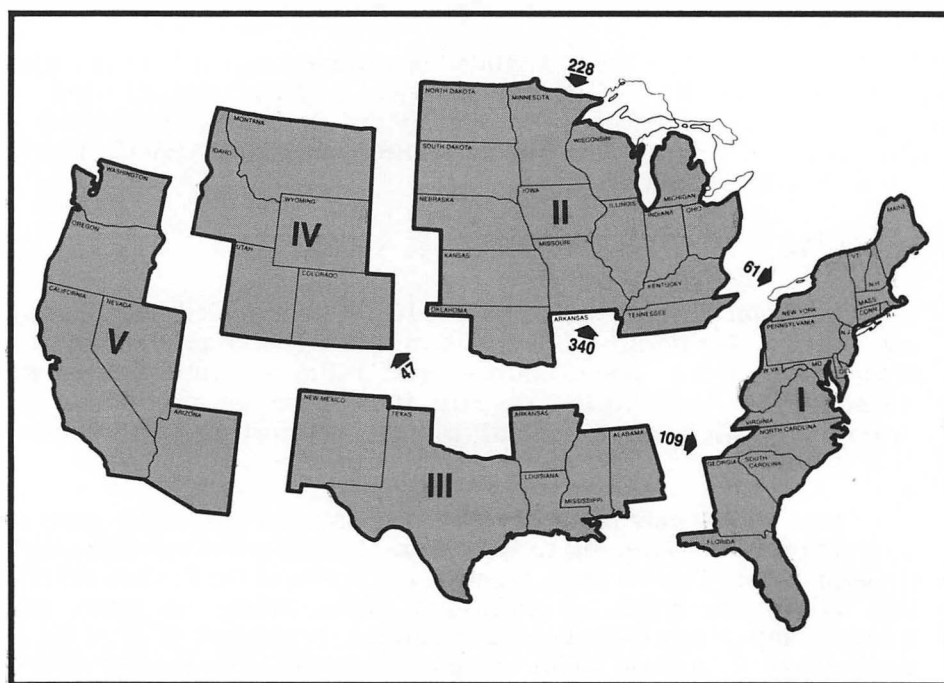
Figure 11.
Gross Inter-PADD
Capacities of
Petroleum Product
Pipelines -- 1988
(MB/D).



plants along the Gulf Coast; new connections, lines, or storage facilities to handle projected increases in Canadian and waterborne imports; a new system connecting Mont Belvieu and the chemical and refining industries in the New Orleans area; and an East Coast project to transport excess refinery butanes.

Based on projections of LPG demand, the existing system, with minor additions and modifications, will have the capacity to handle LPG volumes into the 1990s. Figure 12 shows 1988 gross inter-PADD pipeline capacities for LPGs.

Figure 12.
Gross Inter-PADD
Capacities of LPG
Pipelines -- 1988
(MB/D).



Waterborne Transportation

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Chapter 3, pp. 59-73
also, Appendix G

Marine carriers transport more petroleum than any other commodity, domestically as well as worldwide. Foreign oil traffic into the United States consists primarily of imports carried by foreign-flag tankers. Domestic traffic consists largely of petroleum product movements from refineries, inland by river tank barges and along the coast by tankers and tug-barge units. This traffic includes substantial volumes of Alaskan crude oil carried on U.S.-flag tankers.

Oceangoing Tankers

The nation's ports vary in their ability to handle oceangoing tankers. Most ports with depths of 35 to 40 feet can berth tankers in the 40,000-60,000 DWT class. West Coast ports with depths of 50 to 65 feet can handle tankers up to 190,000 DWT. The start-up of LOOP operations in 1981 gave the nation its first port facility capable of offloading Ultra Large Crude Carriers (ULCCs), which range upwards of 320,000 DWT.

Since 1979, there has been a steady decline in U.S. tanker construction. This means an inevitable decline in the relative share of U.S. tankers as transporters of petroleum.

Inland Waterways

The inland waterway system includes 25,000 miles of navigable rivers and canals, but nearly 25 percent of the system is less than 6 feet deep, and 80 percent is less than 14 feet deep. In 1986, tank barges carried almost 1.4 billion barrels of petroleum products, but tonnage has increased by only 7 percent over a 10-year period. Despite technological innovations, the system is constrained by the physical limitations of the inland waterways related to weather, waterway depths, outmoded locks, dams, and low bridges.

For the long term, substantial coastal and inland waterway movement of petroleum products will continue, with tank barges being an efficient and viable means of transportation. However, major public works investments will be required to modernize and upgrade deteriorating and outmoded inland waterways and harbor facilities.

Overland Transportation

Chapter 4
pp. 75-79

Tank trucks and rail tank cars are primarily involved in delivering finished products to redistribution terminals and ultimate consuming locations. Trucks also deliver condensate and crude oil from producing fields to pipeline origin points or refineries.

Reduced rail regulation has resulted in improved earnings, and allowed major reinvestment in equipment and facilities. This investment has, in turn, made the system safer and more efficient. Deregulation of the trucking industry has also contributed to greater efficiency and a growth in capacity. The U.S. highway system provides the industry with a high degree of flexibility, and the industry is far more adaptable in its ability to handle changing demands than it was in 1979. Both tank car and tank truck transportation will continue to play a major role in transporting crude oil and petroleum products.

Government Regulation

VOLUME V
Chapter 4, pp. 76, 78
Chapter 3, pp. 71-72

Virtually every aspect of petroleum liquid transportation is subject to some degree of current or pending government regulation. Since 1979, the substantial reduction in economic regulation of the rail and trucking industry has contributed to improved service and productivity. But the waterborne industry has faced difficulties in the form of inconsistent regulation among various local governments and governmental agencies. For example, uniform nationwide standards are preferable to a diversity of regional requirements for controlling dockside vapor emissions, which are now under consideration. The latter would require costly, redundant investment and increased time spent in loading -- raising cost and reducing effective fleet transportation capacity.

Chapter 2
pp. 28-35

The pipeline industry is particularly concerned with ongoing economic regulation and environmental issues that create uncertainties related to future pipeline investment decisions. Those decisions will be influenced both by the supply-demand equation, as well as the government's ability to clarify the regulatory uncertainties that cloud the investment process.

Appendices

APPENDIX A

**STUDY REQUEST LETTER AND
DESCRIPTION OF THE NATIONAL PETROLEUM COUNCIL**



The Secretary of Energy
Washington, DC 20585

February 20, 1987

Mr. Ralph E. Bailey
Chairman
National Petroleum Council
1625 K Street, N. W.
Washington, D. C. 20006

Dear Mr. Bailey:

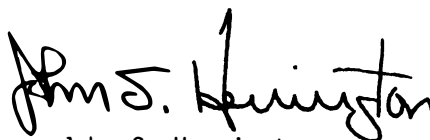
The National Petroleum Council has prepared numerous studies in the past on the nation's petroleum inventory, storage, and transportation systems. The Council's last comprehensive study on this subject was completed in 1979. The principal objectives of that study were to analyze current inventories, estimate minimum operating inventory levels, determine the total storage capacity of the primary petroleum distribution system, and provide detailed information on the nation's transportation system for oil and natural gas. In 1984, the Council issued a report updating and expanding the inventories and storage capacity portions of the 1979 study.

These studies are the most current, comprehensive treatment of petroleum storage and transportation that are available for reference, with some data being nearly a decade old and the most recent from early 1983. Since the release of these studies, there have been major changes in the production and transportation of crude oil and natural gas, refinery operations, petroleum products distribution networks, and the markets they serve.

Accordingly, I am requesting the Council to undertake a comprehensive new study on petroleum inventory, storage, and transportation capacities updating the Council's earlier studies as necessary. Emphasis should be given to the reexamination of minimum operating inventory levels, the location of storage facilities and availability of inventories in relation to local demand, and the capabilities of distribution networks to move products from refining centers to their point of consumption particularly during periods of stress.

For the purpose of this study, I designate Dr. H. A. Merklein, Administrator, Energy Information Administration, to represent me and to provide the necessary coordination between the Department of Energy and the Council.

Yours truly,


John S. Herrington

DESCRIPTION OF THE NATIONAL PETROLEUM COUNCIL

In May 1946, the President stated that he had been impressed by the contribution made through government/industry cooperation to the success of the World War II petroleum program. He felt that this close relationship should be continued and suggested that the Secretary of the Interior establish an industry organization to provide advice on oil and gas matters. Pursuant to this request, Interior Secretary J. A. Krug established the National Petroleum Council on June 18, 1946. In October 1977, the Department of Energy was established and the Council's functions were transferred to the new department.

The sole purpose of the NPC is to advise, inform, and make recommendations to the Secretary of Energy on any matter, requested by him, relating to petroleum or the petroleum industry. Matters that the Secretary would like to have considered by the Council are submitted as a request in the form of a letter outlining the nature and scope of the study. The Council reserves the right to decide whether it will consider any matter referred to it.

Examples of recent major studies undertaken by the NPC at the request of the Secretary include:

- Refinery Flexibility (1980)
- Unconventional Gas Sources (1980)
- Emergency Preparedness for Interruption of Petroleum Imports into the United States (1981)
- U.S. Arctic Oil & Gas (1981)
- Environmental Conservation -- The Oil & Gas Industries (1982)
- Third World Petroleum Development: A Statement of Principles (1982)
- Petroleum Inventories and Storage Capacity (1983, 1984)
- Enhanced Oil Recovery (1984)
- The Strategic Petroleum Reserve (1984)
- U.S. Petroleum Refining (1986)
- Factors Affecting U.S. Oil & Gas Outlook (1987)
- Integrating R&D Efforts (1988).

The NPC does not concern itself with trade practices, nor does it engage in any of the usual trade association activities. The Council is subject to the provisions of the Federal Advisory Committee Act of 1972.

Members of the National Petroleum Council are appointed by the Secretary of Energy and represent all segments of petroleum interests. The NPC is headed by a Chairman and a vice Chairman, who are elected by the Council. The Council is supported entirely by voluntary contributions from its members.

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ANDERSON, Robert O.
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ANGELO, Ernest, Jr.
Petroleum Engineer
Midland, Texas

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Chief Executive Officer
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University of Denver

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Jones Company

JONES, Jon Rex
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APPENDIX B
STUDY GROUP ROSTERS

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President and
Chief Executive Officer
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COMMITTEE ON
PETROLEUM STORAGE & TRANSPORTATION

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President
Emro Marketing Company

ASSISTANT TO THE CHAIRMAN

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Crude Oil Scheduling
Marathon Petroleum Company

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Enron Corp.

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