Environmental Conservation

The Oil and Gas Industries / Volume One

Environmental Conservation

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National Petroleum Council
in response to a request from the
Department of the Interior

NATIONAL PETROLEUM COUNCIL

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OFFICE OF OIL AND GAS

Environmental Conservation

The Oil and Gas Industries
Volume One/A Summary

June 1971

A Report of the
National Petroleum Council's Committee
on Environmental Conservation—The
Oil and Gas Industries

W. W. Keeler, *Chairman*

with the assistance of the
Coordinating Subcommittee
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Foreword

The National Petroleum Council is an officially established industry advisory body to the Secretary of the Interior and, as such, represents virtually all segments of the U.S. oil and gas industries. At the request of the Assistant Secretary of the Interior—Mineral Resources, it undertook a comprehensive study of environmental conservation problems as they relate to or have an impact on the petroleum industry. The Council was asked to assure that its study placed all pertinent facts before the government officials who are charged with making policy decisions involving pollution control regulations which may affect oil and gas operations.

Because of the scope and complexity of the assignment, the study is published in two volumes. This is Volume I, which contains the general comments and conclusions of the Council based on an analysis of the detailed data contained in Volume II. Volume I also contains a summary of Volume II. The comprehensive detail obtained and examined by the Subcommittee is included in Volume II.

In order to respond to Interior's request, the National Petroleum Council established a special Committee on Environmental Conservation—The Oil and Gas Industries, under the chairmanship of W. W. Keeler, Chairman of the Board, Phillips Petroleum Company, and the cochairmanship of Hon. Gene P. Morrell, Deputy Assistant Secretary of the Interior—Mineral Resources. The Committee was assisted by its Coordinating Subcommittee, with Leo A. McReynolds, Director, Petroleum Products and Environmental Conservation, Phillips Petroleum Company, as its chairman. The Subcommittee was cochaired by Dr. Wilson M. Laird, Director of the Office of Oil and Gas, U.S. Department of the Interior. A list of the Committee and Subcommittee memberships is included in the Appendices.

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The Cover—*The photograph on the cover, which was made during the flight of Apollo 11, shows a spacecraft-window view of the Northern Hemisphere from the Pacific at left to the Mediterranean at right. Above the thin blue film of the earth's atmosphere at the curved horizon is the darkness of space.*

(Photo courtesy of the National Aeronautics and Space Administration)

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Introduction

At certain points in time, society reaches an expressed or implied consensus as to the values it wishes to maximize or the goals it hopes to achieve. Thus the United States along with other nations today is properly concerned with problems of improving the environment in the years ahead. Environmental problems in the United States are by no means common throughout the country, just as these problems are not common among all nations. The United States, however, because of its extensive land and water area, and the great diversity of its economy, is experiencing differing degrees of pollution injury and environmental degradation.

Intensive industrialization has led to the development of urban centers with large population concentration, and thus resultant localization of pollution and environmental problems. Certainly pollution of the air has become primarily an urban problem. Although less localized, pollution of the water is also associated with a high degree of industrialization, urbanization and agricultural use.

Analysis of pollution problems can be approached in varying ways. For example, these problems are frequently divided into problems of air, water and land pollution. Another method is the analysis of the type of activity that causes pollution—such as industrial, agricultural, or general community activities. Most effectively, however, environmental conservation should be approached comprehensively by determining, on the most realistic basis, the environmental standards that need to be attained and maintained in order to provide for a satisfactory quality of life and work.

Thus environmental conservation involves the understanding and participation of all—government at every level, industry, academicians and scientists, and the public in general.

Today in the United States, one finds urban areas where pollution is seriously impairing the quality of the environment. On the other hand, there are rural areas where pollution is of little if any concern and where the natural environment shows minimum impairment.

Most peoples throughout the world, including Americans, have for some decades sought to improve the quality of life. And the manifest expectations of peoples in both developing and developed countries evidence no departure in that objective.

The United States through the operation of its free-enterprise competitive system has reached unprecedented standards of living. Not only has this system improved our own living standards, but it has also made great contributions to economic development throughout the Free World. The United States through both its private and public sectors continues to assist the Free World's developing nations to enhance economic development and standards of life.

Thus during the decades of the 1950's and 1960's, policy and effort have been largely directed to securing economic gains and it is only lately that acute concern has come to be directed increasingly to pollution control and environmental conservation. Indeed, only in recent years have information about and evidence of potentially serious pollution come to the attention of both the general public and the policy makers.

Today, society, including industries and governments, has a greater awareness that actions which are taken to raise living standards must be carried out, not only to meet adequately the needs of a rapidly expanding population, but also to maintain adequately the quality of the environment.

During the last 25 years, oil and gas have become the dominant fuels for the tremendous expansion of the U.S. economy. Oil and gas resources supply three-fourths of all U.S. energy requirements, with these resources continuing to supply the majority share of the energy market well into the decade of the 1980's. Industrial growth, upon which economic expansion is based, is directly dependent upon energy. With the world committed to economic growth there is thus an accompanying implicit commitment to increasing energy consumption. Also, economic growth is essential to provide the resources for societal objectives, including environmental conservation.

Principal sources of pollution are man and his activities, although nature also contributes. Comprehensive analysis of pollution and its causes would indicate that the operations of the U.S. oil and gas industries *per se* are responsible, relatively speaking, for a small proportion of the total, but the pollution generated by the use of petroleum products by both the public and private sectors of society is also important and the petroleum industry shares with society the responsibility to contribute to environmental improvements in these areas.

The U.S. petroleum industry has been concerned and will continue to be concerned with environmental conservation. For the future, its efforts are being strengthened to assure that its operations and products meet the requirements of our society both for energy and for environmental conservation. Of course, there will be costs associated with greater emphasis upon conservation of our environment both in the petroleum industry and in other sectors of our society. Since in the last analysis the complex American society is itself the collective source of man's pollution, these costs must be shared by all of us who will share in the benefits of an improved environment.

The National Petroleum Council has identified and addressed itself in this report to the environmental issues which it believes to be of concern to the oil and gas industries as well as to the nation. For presentation of key conclusions and recommendations, the issues have been grouped into the categories of general law and regulatory policy, the economics of environmental conservation, and specific environmental concerns for air, water and land pollution.

Part One

Comments and Conclusions

Law and Regulatory Policy

1. The role of government should be to ascertain the effects of pollutants, prescribe workable standards of air, water and land quality to be maintained and, in general, to leave to private initiative the means whereby the standards will be achieved.

To attempt to specify the particular method by which these standards are to be achieved would materially lessen the likelihood that the optimum solutions for society would be reached. By specifying the quality standards to be achieved, government will encourage individual innovation, with "marketplace regulation," and thus tend to obtain the optimum environmental quality control for each dollar of investment or other expenditure, yet avoiding governmental discriminations among competing enterprises. Such an approach will maintain the benefits of an innovative and diverse free-enterprise approach.

As a case in point, the most significant changes during the past 25 years in gasoline quality—improvements in antiknock quality, improvement in control of volatility and decrease in sulfur content—have been the free, competitive response to meet the requirements of the increasingly efficient, high-compression engines developed for automobiles. In this regard, modification of gasoline, standing alone, is generally an ineffective way to reduce automobile emissions. Gasolines, however, have been modified so as to help maintain proper operation of emissions control devices and aid in reducing and minimizing emissions.

In the field of water pollution control, also, the degree to which law or regulation is truly effective depends on the extent to which the prescribed standards are workable. For example, a definition of harmful quantities or qualities of oil discharge must necessarily be carefully drawn to permit timely yet practicable control.

2. Where a cooperative approach to the solution of an environmental problem would serve the public interest, the Executive Branch should clarify the extent of cooperation that is consistent with the intent of present antitrust laws and, if necessary, seek enactment of such further legislation as would be advisable to authorize the most effective means of dealing with such problems.

Our antitrust laws play a strong role in maintaining competition and diversity of effort that is most likely to produce the lowest cost solutions to meeting environmental standards. They properly prohibit conspiracy or collusive action by competitors in matters affecting commerce and public economic interests. However, to achieve the goal of improving the environment, in a few situations it may be that the best interests of society would be served if competitors or complementary industries were permitted to exchange information on a voluntary basis or jointly take actions regarding the modification of products or procedures in the public interest. For example, where environmental hazards exist, such cooperation may be the most feasible method to shorten the time for correction.

3. The United States should not pursue a policy of precluding or delaying exploration and development of the potential petroleum resources of its submerged continental margins.

Environmental quality control of the offshore petroleum provinces of the U.S., which are the prerogatives of the federal and concerned state governments, should be exercised effectively yet in such a way as to promote the exploration and development of these domestic reserves which are increasingly vital to the energy needs of the nation.

Several key points in this regard are:

- *Exploration and data-collection activities, which must precede drilling on the continental shelf, present no pollution hazard and should be continued without interruption in order to determine potential areas for drilling and production.*

  Adequate lead time and continuity of effort are essential to ensure efficiency and effectiveness in exploration for discovery of new reserves of oil and natural gas so that they will be available to the national economy and security when required.

- *It is a fundamental responsibility of government, after consultation with the petroleum industry, to update periodically the existing regulations for offshore drilling and production.*

  Rules and regulations under which the industry operates on the Outer Continental Shelf received considerable revision in 1969, with industry being given the opportunity to work closely, where appropriate, with the federal agencies in formulating these revisions. It is necessary that regulations keep pace with continually improving technology and procedures.

- *Undersea well completion technology is still in the early stage of development and techniques are not yet capable of being widely implemented. It would not presently be feasible and may never be desirable to require subsea completions as a matter of general policy.*

4. Conflicting jurisdiction and authority among and within governments with respect to offshore pollution hamper effective control and enforcement and should be effectively resolved.

Present laws divide jurisdiction and authority with respect to offshore spills between three federal agencies. States of the Union as well as other nations are also involved in this matter.

Economics of Environmental Conservation

5. The determination of environmental quality standards should, among other things, take into account the cost-benefit factor to society and the impact of that factor upon our economy.

Relevant inquiries in this connection are: *How clean? At what cost? With what benefit? How are these costs to be shared?* Costs and benefits to society of environmental quality control must be analyzed in the total context of losses and gains.

There are three basic costs involved in environmental conservation: (1) the cost of pollution reduction or elimination to prevent damage, (2) the cost of restoring environmental quality where damage has occurred, and (3) the societal cost associated with damage caused by pollution. The costs of restoring or preserving the quality of the environment in which we live, whether incurred by industry or government, are an expense of society and necessarily will be assumed by society in the form of increased taxes, decreased tax revenue through the extension of tax incentives, increased prices for goods and services, or in a combination of these. Abatement or restoration costs must be balanced against societal costs of damages from pollution so that the proper relationship between costs and benefits will be achieved.

The cost-benefit factor applies directly to many operations of the petroleum industry. Recognizing that its involvement in pollution control includes not only functional operations but also use of petroleum products, the petroleum industry has directed many millions of dollars toward control facilities and basic product research. These expenditures have increased from $271.4 million in 1966 to an estimated $559.5 million in 1970.

- *Severe, impractical or unnecessarily costly regulation of exploration, production and transportation reduces the incentives for proving and developing needed reserves of oil and gas and also increases the cost of petroleum products.*

- *Pollution control efforts will continue to have a major effect on capital spending and operating costs in refining operations of the industry.*

  It is difficult to determine cost alternatives in dealing with refinery waste problems, particularly because some facilities provide dual benefits in processing and pollution control. However, the ratio of capital costs for a high degree of treatment of waste waters to that of a low degree of treatment has been estimated to be almost 6 to 1. Furthermore, installing air pollution control equipment on existing refinery units is likely to cost from half again to double the amount for comparable equipment in new construction.

- *Other factors being equal, the benefits of economies of scale are just as applicable to petroleum operations as they are to other areas of the economy and ultimately result in cost savings to the consumer.*

  For example, large pipelines, huge marine tankers, and jumbo tank trucks and rail tank cars are now needed to transport crude oil, gas and other petroleum products used in the United States in order to meet the great demands. Indicative of the savings through increased size is an estimate that the transportation cost per barrel for a tanker run from the Gulf Coast to the New York City area is reduced by a factor of almost 3 for an increase in deadweight tonnage from 16,000 to 100,000.

- *Cost-effectiveness is the overriding consideration in reducing hydrocarbon emis-*

sions to atmosphere from storage and transportation of oil and gas.

Technology is available for almost any degree of control of such emissions. It is technologically possible but cost-effectively impracticable in some locations to eliminate entirely filling losses at service stations. Submerged fill pipes are a practical and economical means of reducing vapor losses from underground tanks.

6. Where environmental quality does not meet prescribed standards, the constantly moving limits of technology and economics should be taken into account in setting realistic and stable timetables for achievement of the desired quality.

Individual petroleum companies carry on intensive research programs to improve products and operations. The research effort alone of the petroleum companies relating to environmental conservation in 1970 is estimated to be almost one-third higher than the 1969 expenditures. This research effort has resulted in improved products causing less air and water pollution and improved operations minimizing all pollution.

There is an inevitable period of time involved in planning, financing and implementing measures, and in a number of instances for developing the necessary technology, to comply with prescribed environmental standards. Thus it is essential that, after standards are determined and the time period fixed for compliance, industry be able to rely upon the resulting schedule and not be subjected to continual and exceedingly costly schedule revisions.

In some instances technological advances may reach such a stage of development that they appear available for application in the very near future. If there is strong reason for confidence that such imminent technological advances will help to achieve pollution control objectives, then such technology should be awaited, provided this is in the general public interest.

These principles are applicable to several important areas of concern to the oil and gas industries today:

- *The effectiveness of control of oil discharges from offshore drilling and production operations can be continuously improved by the development of reasonable standards, together with time schedules in which to implement them, established by government with the advice of industry.*

  Oil discharges from offshore drilling and production operations have been a source of pollution. This can be controlled by proper procedures, equipment and treatment facilities, and efforts are continuing to ensure that this is done.

- *As the efforts of industry and government continue for effective offshore practices and regulations based on improved technology, every effort should be made by government to avoid the "stop-and-go" scheduling and cancellation of federal acreage sales.*

- *Technology and economics may lead to solution of the problem of sulfur dioxide emissions from petroleum fuels by the use of gas and low-sulfur fuels in small installations and residual fuels in large installations equipped with sulfur-control processes, such as stack-gas desulfurization when it becomes feasible.*

  Fuel desulfurization and lowered unit consumption in larger efficient installations are methods for reducing sulfur dioxide (SO_2) emissions with present technology; stack-gas desulfurization is not yet commercially feasible.

  The technology has not been developed for the removal of organic-type sulfur contained in coal. Low-sulfur coals, low-sulfur fuel oil and natural gas will have to be used to supply low-sulfur fuel demands until desulfurization of high-sulfur coals or removal of sulfur from stack gases becomes practicable. Currently, supplies of low-sulfur coals are limited to certain geographical areas and, as a result, fuel oil and natural gas will be used in a majority of new low-sulfur fuel markets.

7. The inevitable costs associated with environmental conservation and pollution control must be borne by society. An approach is needed which will achieve environmental objectives at the lowest net cost to society and in a fashion which will maximize current benefits so that the costs incurred may be met on as current a basis as practicable.

Costs of environmental conservation and pollution control could be met by utilization of one or a combination of methods, such as classifying environmental expenses as a normal cost of doing business, tax incentives, and/or government subsidies. Meeting environmental quality standards through market competition will provide the optimum quality for money expended.

A general tax credit for investment has been successfully used in the past as an efficient means for stimulating economic activity by encouraging the required investments. Such a tax incentive could be used to attain other objectives if there is a well-defined and practicable program at all government levels.

8. Imposition of economic penalties is not an effective means of attaining optimum environmental conservation.

As a general matter, genuine societal problems affecting the public welfare should be approached directly by the public and its government and not through indirect avenues such as governmentally-imposed economic penalties. As a practical matter, such economic penalties provide the option of meeting the imposed penalty and thus continuing the undesirable conduct without abating pollution. This approach also suffers from the virtual impossibility of selecting an equitable method of assessing charges for the vast number of potential pollutants.

This objection would be applicable to the imposition of charges on fuels as a means of controlling emissions into the atmosphere. In fact, this type of charge on fuel composition suffers from the further complication of selecting for assessment a particular aspect of the technical interrelationship between fuels on the one hand and, on the other, the vehicles or stationary plant for which they are designed. Such a charge would unnecessarily inject the government into the free-market competitive process, thus limiting the initiative of individual manufacturers to develop more effective means of emissions control. Proposals to apply charges to the sulfur content of heating fuels or to lead additives to gasoline might well, in practice, contribute nothing to environmental conservation and could even forestall progress now under way.

9. If required, regulations for the reduction of lead in gasoline should be planned realistically to provide for such reductions as are necessary to reach practical emission goals at a minimum overall cost to the public.

Regulations prescribing lead contents of gasoline are inappropriate and unnecessary. Low-lead and unleaded gasolines are now generally available and further restrictions on the use of lead will result in significant technical and economic effects on the production of gasoline. The use of lead alkyl additives in gasoline is by far the most economical method known to increase the octane quality of gasoline.

Specific Environmental Concerns

AIR

10. The most serious air pollution problem for the petroleum industry results from the use and, in some cases, the inefficient use of petroleum products to produce energy for our expanding standard of living and increasing population.

The emissions of main concern from mobile sources are hydrocarbons, carbon monoxide (CO), nitrogen oxides (NO_X) and particulate matter.

Reduction in local air quality can result from the use of petroleum products as well as any other fuel in fixed installations, such as fuel for power generation, manufacturing processes—including petroleum refineries, commercial and domestic heating, as well as from use of miscellaneous products such as solvents. Sulfur dioxide (SO_2) is primarily a result of the production of energy in various stationary sources. Small stationary energy-producing units also can produce significant quantities of unburned hydrocarbons and CO as a result of inefficient combustion and poorly maintained equipment.

11. Emissions from vehicles are a significant factor in air pollution in the United States.

The automobile has become a way of life in the United States. Almost half of the automobile travel is required for the purpose of earning a living.

The development and application of technology to reduce emissions from the internal combustion engine have been significant, and new technology will provide the essentially emission-free vehicle to conform with government goals. Hydrocarbon and carbon monoxide emissions from vehicles are trending down after having reached peaks in the 1965-68 period. Nitrogen oxides emissions will start down in 1973 and automotive particulates emissions will start down in 1976. The reciprocating engine with advanced emissions control systems will be the principal power unit for automobiles for the foreseeable future.

Natural gas and LP-gas (LPG) can be consumed in energy production with very low quantities of harmful emissions other than NO_X, but already-serious supply limitations and, in some instances, safety considerations will limit use of these fuels for vehicles.

12. Use of petroleum products is the source of only about one-fifth of the sulfur dioxide in the United States.

The petroleum industry has made substantial progress in lowering the sulfur content of its products. Since World War II, the already low sulfur content of the lighter liquid petroleum fuels—gasoline, diesel fuels and home heating oils—has been further reduced by more than 50 percent. Furthermore, progress is being made in reducing the sulfur content of residual fuel oils, although desulfurization of residual fuels significantly increases refining costs.

Stack-gas desulfurization is not expected to be a significant factor in reducing SO_2 from large electric power generating plants before late in this decade. These processes hold promise of enabling large fuel consumers to use high-sulfur fuels.

13. The amount of nitrogen oxides, carbon monoxide and hydrocarbons emitted from stationary sources is more dependent on furnace design and operating practices than on the fuel used.

All are amenable to control. New stationary installations are designed to produce low emissions. Old installations can be modified to reduce emissions.

Hydrocarbon emissions from petroleum-based solvents can be adequately controlled by incineration, adsorption or absorption if the process will allow adequate collection. However, some sources of hydrocarbon emissions, such as evaporation from newly applied paint or other architectural coatings, cannot be eliminated if a petroleum solvent is present.

14. Refinery air pollution control techniques have been developed which should permit refineries to operate in any community without constituting an area-wide environmental problem.

Progress has been made but continued efforts are required to achieve complete aesthetic and psychological acceptance by residential areas immediately adjacent to refineries. The major potential refinery emissions that may contribute to air pollution are sulfur compounds, nitrogen oxides, hydrocarbons, carbon monoxide and particulates including smoke. The methods and processes available for preventing the release of these substances in objectionable quantities are often very complex and expensive but reasonable air quality requirements can be, and generally are, met. Odors associated with even very minor amounts of certain compounds are perhaps the most perplexing problems.

15. Storage, transportation and marketing operations are essentially a closed system from source to customer; potential for air pollution exists at points of transfer and in abnormal occurrences.

16. Light and noise, although not normally categorized as forms of air pollution, are being controlled to an increasing extent at refineries.

During normal refinery operations the amount of gas burned in flares is, for conservation reasons, very small. However, at certain times, sudden increases have been the cause of complaints. It is therefore considered good policy to situate flares as well away as practicable from residential areas or other locations where they are exposed to the public, or to enclose the flares to reduce light emissions. Noise from refinery operations usually can be reduced by design changes in process equipment. Recognizing that both the public and governmental authorities have been increasingly concerned in recent years over intensified levels of noise from sources such as aircraft, highway traffic and industry, the petroleum industry will continue to be actively engaged in programs to reduce noise levels from refinery operations.

17. Petroleum industry research, on both a cooperative and an individual company basis, has led to an understanding of atmospheric chemistry and contributed to the development of technology for controlling emissions from both mobile and stationary sources.

The cooperative aspects of this research effort have been carried out in a variety of ways:

- The American Petroleum Institute has actively supported research on air pollution since 1953. This current broad research effort represents an expenditure of about $3.5 million a year in direct support of outside research efforts in addition to individual company expenditures and involves projects in both air and water conservation.

- The petroleum and automobile industries have worked cooperatively with the Federal Government through the Coordinating Research Council (CRC) and its Air Pollution Research Advisory Committee (APRAC) in developing technical information on the nature and effects of vehicle air pollution. The results of this research not only will aid industry to develop better controls for exhaust emissions but can also be an aid to the government in establishing realistic and practical air quality standards and emissions control requirements that are based on reliable technical information. The CRC program represents a research effort of $12 million over the past three years.
- Inter-industry sponsored research groups have contributed significant research results from extensive studies on the development of vehicle hardware and fuels required to meet the vehicle emissions goals and regulations. Much of the hardware now used on vehicles for emissions control was developed in these inter-industry (petroleum and automobile) research studies.

Within the framework of the antitrust laws, cooperative research by the petroleum industry will continue in the future with related industries and government. Major specific needs for such further research include:

- Health effects of emissions into the atmosphere
- Fuel-vehicle system to produce a "pollution-free car"
- Desulfurization of fuels and stack gases

18. Based on scientific studies, on a global aggregate basis air pollution is not a serious problem, although in many urban industrialized areas it has reached serious proportions. Studies involving international cooperation are needed to define any global effects of air pollution, particularly from man-made sources.

While man's contribution produces localized problems of varying degrees, depending on population density and natural ventilation, there is a question as to the effect of man's pollution on a global basis in view of nature's contribution and absorptive capability.

WATER AND LAND

19. Oil spills that occur during drilling and production operations offshore have resulted from uncontrollable natural causes or from accidents occasioned by equipment failure or human error. The potential hazard of such spills can be minimized but cannot be entirely eliminated.

The potential for pollution from such operations has been substantially reduced by sound practices, regulations and supervision.

An examination of the industry record offshore reveals that, despite the recent major oil spills during drilling and production processes, the petroleum industry has been highly successful in keeping serious pollution incidents at a low level during its history of operations in the offshore areas.

Safety and pollution control on offshore platforms are interdependent. Reasonable supervision of drilling operations, including ensuring the continual use of trained personnel and compliance with offshore drilling regulations, is imperative for safe operating practices and pollution control.

No oil spills of relative consequence have been associated with offshore pipelines. The potential hazard for accidental spillage from pipeline transportation of hydrocarbons offshore is somewhat greater than on land, but pipelines are the safest known method of transportation.

The greatest potential for water pollution from storage operations exists in offshore operations; pipeline transportation to shore reduces required storage volumes and therefore potential for large spills, but is not always economically feasible. Precautions are taken at terminals and bulk storage facilities to prevent oil pollution from surface runoff.

20. Although significant progress has been achieved by industry, even more advanced and more widely used standards, practices and facilities are needed for the prevention and control of oil spills from petroleum marine transportation and transfer operations—whether upon the high seas or upon U.S. coastal and inland waters.

The petroleum industry has taken positive steps for many years to improve technology and operational practices and to adopt the necessary standards so as to avoid oil spills from water transportation operations, but recognizes that oil on the ocean and coastal waters remains a major problem—one that is international in scope and requires the active participation of the petroleum industry for solution. At the same time, the problem encompasses all classes of ships, many of which are outside the petroleum industry's control, e.g., dry cargo vessels, government ships.

- *Where adequate facilities for disposal of oily wastes are not available, they must be provided at terminals, shipyards and marine facilities.*

  Although oil tankers are potentially a source of major oil pollution, there is no immunity from the threat of oil pollution from other types of vessels. The United States is subject to pollution to some extent from each of more than 5 million craft, including those on inland or intercoastal waters and those which call at U.S. ports in the process of carrying international commerce or for other purposes.

  Methods to ensure proper handling of all oily wastes should be established for all ships, regardless of ownership or registry. Without adherence to such methods and the availability of adequate disposal facilities, improper disposal will continue to cause pollution.

- *The prevention of major oil spills from mishap in tanker transportation of oil requires the continuing attention and cooperation of industry and government.*

  In the immediate areas affected, major oil spills from accidents with tanker transportation of oil are a serious pollution source for which the petroleum industry is developing solutions. Analysis of such mishaps during the period from 1956 to 1969 has provided relevant facts upon which to base actions to control this problem. For example, the most likely spill involved a tanker carrying crude or residual fuel oils and occurred within 25 miles of a port suitable for staging control action.

  Governments, as well as private industry, have a vital role in prevention of mishaps. Improved transportation support services, such as weather forecasting and navigational aids, and improved ship lanes would assist to minimize such accidents.

  Education and training requirements for ships' crews should be improved and geared to the size and design of the vessel. Increasingly coordinated efforts are needed between federal agencies and the shipping industry concerning marine operations and regulations. Efforts must continue through international organizations to improve international standards of vessel design and operation to prevent pollution.

21. Specific well-staffed and well-equipped oil spill control centers are needed and should be established in strategic areas of high pollution potential.

Methods of meeting this need are under study by the petroleum industry and substantial progress is being made in some geographical areas.

22. Technology is not presently available to contain major oil spills under conditions of strong currents or heavy seas. Where conditions permit, containment and mechanical recovery of spilled oil often provide the most effective method of oil spill control.

Little effective containment or recovery of spilled oil is possible today at sea where wave heights exceed 3 feet or surface currents exceed 1 knot.

However, at present, dispersing, sinking and burning offer possibilities for controlling major oil spills where their use is not prevented by other considerations.

Much research is needed on containment and recovery methods at sea and a considerable effort is under way. Current research efforts must be continued and additional funds allocated for oil spill control research efforts. This is an appropriate area for joint industry-government effort.

In addition to research efforts on containment and recovery of oil at sea, some other specific areas for research to improve control are:

- Methods of off-loading tankers at sea in an emergency situation.
- Methods of identifying oils, both in producing areas and in transportation, for proper identification of pollution sources.
- Definition and classification of oil-spill treating agents for both offshore and onshore, to provide guidance and safeguards in their use.
- Advanced techniques for rapid and efficient beach and shoreline cleanup, restoration of these areas, and methods of disposal of cleaned-up oil.

- Development of improved material specifications, testing procedures and instrumentation.
- The fate and behavior of oil on water and its true effect on the marine environment.

23. The preponderance of evidence does not support the thesis that permanent damage has been done to marine life and the environment by oil spills.

Oil spills are unsightly to the area where they occur and regrettably cause some mortality of certain marine invertebrates and birds. These disruptions of the ecology appear to be temporary, however, and the environments are restored in time. Further studies are being carried out in this important area.

24. The petroleum industry recognizes that refinery operations are a potential source of pollution and has taken positive steps for many years to reduce such pollution.

A petroleum refinery consists of a complex series of processes designed and operated to maximize the product yield from the crude oil utilized while minimizing the escape of hydrocarbons and other petroleum components.

Control is exercised over both water and airborne effluents, and precautions are taken to dispose of solid wastes in a manner acceptable to regulatory agencies. Nevertheless, more advanced and sophisticated environmental control equipment must be developed and placed in operation to keep ahead of societal demands.

The industry has, through its trade association, the American Petroleum Institute, made a comprehensive assessment of refinery effluent characteristics and waste-water quality control practices. Results of this survey are available to concerned government agencies for planning purposes.

Major aspects of the control problem are:

- *The nation's 281 refineries all have waste-water treating systems designed to handle various types of liquid and solid wastes.*

  Broadly speaking, most systems include in-plant control equipment, sewer systems and ancillary equipment for the collection and segregation of wastes, and gravity-type separators for the removal of oil and suspended solids. Many systems also include additional units for oil removal and/or some form of biological treatment. Facilities for the disposal of solid wastes and treatment of recovered oil are also important system features generally employed. Particular attention is usually given to reducing the oil content, suspended solids, oxygen demand, ammonia and phenolics content, and the taste and odor of refinery effluents.

- *Refineries require relatively large amounts of water for cooling, processing, steam generation, sanitation, and potable use, but much of it is furnished by recycling.*

  The freshwater intake of the refining industry has been reported to be only about 0.7 percent of total U.S. withdrawals and its consumption is only about 0.25 percent of total U.S. consumptive use. Ninety-seven percent of the total water requirement is for cooling. As water reuse, particularly for cooling purposes, continues to expand, raw water requirements per barrel of crude will, on the average, continue to decrease.

- *Advanced waste-water treatment processes are being developed and placed in operation at some refineries.*

  Various of these methods will be used more extensively as the degree of treatment needed to maintain proper quality of the receiving body of water increases. Chemical and physical monitoring of both refinery effluents and receiving water is commonly practiced.

25. Considering the volume of materials handled, land pipeline transportation of hydrocarbons is a minimal source of pollution.

It has been estimated that only six thousandths of one percent of liquids moved by pipeline per year was spilled, with the causes of most unrelated to daily oil industry operations.

26. Improper disposal of used lubricating oils and other wastes from marketing operations is a potential source of pollution, although not a major one at present because of industry efforts to assure proper disposal procedures.

As long as good housekeeping practices are followed, marketing operations pose little potential for pollution of land and water.

Summary Conclusion

It is the conclusion of the National Petroleum Council, an industry advisory body to the Secretary of the Interior representing virtually the entire American oil and gas industries, that these industries are conscious of their significant responsibilities for environmental conservation and are sincerely dedicated to a continuing and effective approach to the solutions to those environmental problems which lie within their purview.

The oil and gas industries are well aware of the environmental problems resulting from the conduct of their various operations of production, refining, storage, transportation and marketing of products, and also outside these industries, from the use of their products. Real progress has been made in defining these problems and developing solutions to them, but, nevertheless, problems remain. Continuing progress will be required to improve standards and to develop more advanced technology and better operating practices and equipment to achieve improved environmental quality.

The oil and gas industries face a requirement to provide to the society of which they are a part vital energy in a manner consistent with environmental conservation, recognizing that the costs involved are those of society. We are confident that these industries will continue to do their part, including full cooperation with government and with the general public which they serve, so that the requisite environmental standards can be developed and met, consistent with providing the nation with its necessary energy.

Part Two
Summary of Volume II

General Considerations

Chapter One:

The Requirements for Environmental Conservation

The United States finds itself today with unparalleled affluence but with social problems, some of them environmental in nature, so significant that they have become of national concern.

Analysis of pollution problems can be approached in various ways. For example, these problems are frequently divided into problems of air, water and land pollution. Another is the analysis of the type of activity that causes pollution—such as industrial, agricultural, or general community activities. Most effectively, however, environmental conservation should be approached comprehensively by determining, on the most realistic basis, the environmental standards that need to be attained and maintained in order to provide for a satisfactory quality of life and work.

Lawmakers and regulators at every level of government, industrialists—large and small—trade associations, professional societies, engineers, scientists, ecologists, professional writers, students and, indeed, citizens of all ages and from varying types of communities are addressing themselves to practical and timely solutions of environmental problems. This sharpened focus on problems of environmental quality indicates a growing realization that material well-being and a high standard of living based on continuous economic expansion cannot continue to be the overriding goal of society if severe abuse of the environment that sustains life is an inevitable result of pursuing such a goal.

Surely, however, economic growth and a satisfactory environment are reconcilable. It is necessary, then, to achieve a proper balance between the human need and desire for the products of science and technology provided by an industrialized society and the need for a wholesome environment. Society must continue to use the resources of the environment because they are the only such resources it has. Through wise management of the environment we must continue to accelerate the resolution of conflicting interests and achieve a balance that is in the best interest of all.

To some extent, air, water and land can be permitted to absorb the wastes of civilization and nature without harm. Such absorption reduces the cost to society of disposing of wastes in other ways. However, if the waste load imposed is such as to endanger health or the environment, then further pollution control becomes essential. Control also becomes desirable when the penalties to society from pollution are greater than the cost of correction. The problem lies in measuring values.

All members of the petroleum industry are becoming aware that economic solutions are no longer, in themselves, meeting the value standards of society. While continuing to fulfill their primary mission of supplying energy to the nation, the oil and gas industries are increasing their commitment to environmental conservation substantially wherever pollution control is needed.

SECTION 1.
POLLUTION—NATURAL AND MAN-MADE

Both nature and man contaminate the environment. For example, natural forest fires or simple organic decay may cause large additions of solids or gases to the atmosphere. Man's contributions to air pollution may be aerosols or gaseous compounds from power generation, industrial operations or from automobile exhausts. Nature, in turn, contributes such widely diverse contamination to water and land as uncontrolled animal wastes, or debris and suspended particulates swept into streams by storms. Man litters the landscape with discarded trash, pours inadequately treated human wastes into receiving waters, and releases industrial materials in undesirable quantities.

With these dual and, in the case of nature, often uncontrollable sources of contaminants, there is a need to define acceptable quality of air, water and land, so as to meet society's concerns by providing realistically achievable base points for industry and community action.

In assessing the role of the oil and gas industries in the problems of environmental quality, it appears to be appropriate to list the major pollutants which may occur as the result of the industries' operations and the use of their products in mobile or stationary sources (see Table 1).

Some of these pollutants are most likely to be found in higher concentrations in urban areas where man's activities are concentrated. Others are localized industrial wastes which may be found either in urban areas or the countryside. Many are substances found normally in nature—products of oxidation and natural liquids. Thus the type of source, its location, and the mechanisms of nature are all important factors in judging the need and manner of control.

A. The Urban Environment

Pollution by man becomes significant usually in urbanized areas, with each area differing because of such varying factors as climate, geography, industrial development, utilization of fuels for transportation and energy and refuse disposal procedures. Further factors compounding the environmental difficulties of today's cities are the lack of open spaces and parks, faltering transportation systems, substandard housing, poor sanitation, periodic power shortages and, in general, the crush of too many people and inadequate services.

Our knowledge of the effects of pollutants is not complete, but we do know that those effects are not uniform in all urban areas. Acute toxicological effects of some air contaminants on humans are well known, but the effects of exposure to low concentrations of the individual pollutants and mixtures thereof are still not conclusive even after years of investigation. The soiling effects of smoke on buildings and laundry, the effects of acid mist on fabrics, and the corrosion of metal and carbonate stone by acid pollutants are well known, but vegetation damage shown in the laboratory has been difficult to correlate positively with field data. Actual psychological effects on urban residents from offensive odors or haze formation point

TABLE 1: Major Pollutants of U.S. Oil and Gas Industries

substance	*sources: use of products*	*sources: industry operations*
AIR		
Sulfur oxides	stationary combustion sources	refining
Hydrogen sulfide		production, transportation and storage, drilling, refining
Carbon monoxide	vehicles, stationary combustion sources	refining
Nitrogen oxides	vehicles, stationary combustion sources	refining
Particulate matter	vehicles, stationary combustion sources	refining
Hydrocarbons	vehicles, stationary combustion sources	petroleum transportation and storage, marketing, drilling, production, gas treating, refining
WATER		
Oil	petroleum handling	drilling, production, transportation and storage, refining, marketing
Drilling mud and treating fluids		drilling and completion
Brine		production
Organic compounds (amines, phenolics, sulfides, mercaptans)		refining
Suspended particulate matter		refining
Spent caustics		refining
Nutrients		refining
Used or waste oil	vehicles, industrial use	
LAND		
Oil	industrial use	drilling, production, transportation and storage, refining, marketing
Brine		production
Waste water		production
Sludges		refining, production, marketing
Trash and litter	all	all

to the need for better understanding of aerosol formation and photochemistry of the atmosphere so that problems may be properly overcome.

Like air pollution, water and land pollution are generally most acute in densely settled sections. Spillage of crude oil or petroleum products in or adjacent to these densely populated areas is understandably high on the list of the public's pollution concerns.

Overcoming the pollution ailments of our urban environment requires recognition of the interrelationships among the many problems of the urban community and the cooperation of every segment of society, including government and industry, as well as each individual. Governments have the responsibility of developing effective policy and standards and the means for their administration. Industry must get on with its task of adjusting its operations and developing its products to meet urban environmental needs as well as to accomplish their primary purposes. Every urban dweller must be made aware of the environmental consequences of his actions.

In the long run, our cities may require many fundamental changes. For example, a major cause of urban environmental problems—too many people in too little space—may have to be solved by decentralization of population and industry to make better use of available land and air space. In the shorter run, however, serious pollutants must be brought under control, utilizing available technology.

The petroleum industry has long recognized its role in this effort and has made significant steps forward, both in improving its own operations in heavily populated areas and in improving its products to meet the requirements of consumers for energy and of environmental conservation. The major pollutants concerned have previously been listed. A brief elaboration of those most significant in the urban environment provides a useful perspective.

1. Air Pollutants

a) Sulfur Dioxide

The petroleum industry has demonstrated its ability to reduce the sulfur content of its fuels. For those areas dependent primarily on liquid fuels for energy, confidence is justified that SO_2 from petroleum products will continue to decrease as required to achieve acceptable ambient SO_2 levels. For large combustion processes using those fossil fuels which are not amenable to desulfurization, confidence seems justified that flue-gas desulfurization technology being developed will bring these sources under control.

b) Carbon Monoxide

Carbon monoxide is another pollutant for which there is considerable concern. The major combustion source is the gasoline engine, although lesser amounts of carbon monoxide are produced by other combustion sources.

Recent improvements in carbon monoxide control on automobile exhausts and the confidence being evidenced by automobile makers that they can make further substantial reductions indicate that within the next decade this pollutant will be brought under control.

c) Nitrogen Oxides

Nitrogen oxides are of concern in certain urban situations where photochemical smog develops. High-temperature combustion processes contribute to their formation by fixation of nitrogen and oxygen atoms. About half the man-made nitrogen oxides emitted in the U.S. are from stationary combustion sources and about half from the automobile internal-combustion engine.

There seems to be justification for concluding that technology will bring emissions of nitrogen oxides from the automotive engine under control to the point where this source will no longer be a problem. The development of technology to control emissions from stationary sources is, however, only in its early stages.

d) Gaseous Hydrocarbons

Gaseous hydrocarbons may enter the urban atmosphere either as evaporatives from liquid hydrocarbons or as escaping gases in their normal state. The most important emissions take place during use of the products as a fuel, either because of incomplete combustion or from evaporation in the combustion system. Some emissions may also occur as a result of use of industrial organic solvents.

The amount of hydrocarbon emissions from automobiles has already been reduced substantially. Reduction is particularly important because of the role played by hydrocarbons in the complex photochemical smog reaction.

Since hydrocarbons are products of the petroleum industry, control measures to prevent their loss during normal industry operations are customarily accepted as good practice for economic reasons as well as to ensure the proper atmospheric quality.

e) Particulates

Smoke and particulate matter are basically urban problems. However, control techniques are now available for 90- to 99-percent control of most particulate emissions. The problem does not lie with the development of technology, but only in the reasonable setting and application of standards by governments so as to bring particulate emissions under control at a rate that can be met by the economy.

2. Water Pollutants

Spillage of liquid hydrocarbons may occur from several types of operations of the petroleum industry. Marketing is done in all urban areas, while transportation activities, refining and even production may be accomplished in or near urban areas, depending on the locale. In each case, the magnitude, the nature of the problem, and the solutions vary widely. Over the years, pollution from the normal operations of production, refining, and transportation has been drastically reduced and work is continuing to accomplish further improvements. Marketing problems of spillage of hydrocarbon and disposal of waste oils require and are receiving the attention of the industry, although these are also problems requiring personal care by each user individually.

Technology is generally available for reducing water pollution to an acceptable level. Most research is aimed at improving the cost-effectiveness of waste-water treatment methods and related processes.

B. Global Source and Fate

Perhaps the greatest motivating force behind society's concern for the condition of the environment is an awareness of predictions that the future will be much worse. Data exist which counter such views, and accomplished technological advances and progress in the control of air and water quality presage improvements rather than further degradation. Furthermore, on a global basis, man's contributions of a given class of air pollutants may be overshadowed by nature's, and the mechanisms of nature are quite capable of rendering harmless the cumulative contributions from both of them.

Studies involving international cooperation are needed to define any global effects of air and water pollution, particularly from man-made sources.

1. Air Pollution

The global source and fate of atmospheric trace gases which are the same as those produced from operations of the petroleum industry and use of its products, have been studied carefully by eminent scientists. The basic concept developed from studies by Junge,[1] Robinson and Robbins,[2] and others is that for every pollutant entering the atmosphere, there is some mechanism in nature for its removal. On a long-term global basis, it may be concluded from these studies that for the more reactive pollutants such as sulfur oxide, nitrogen oxide, nitrogen dioxide, hydrogen sulfide and even carbon monoxide, concentration increases appear unlikely.

a) Sulfur Dioxide

Estimates of global production of sulfur dioxide range from 80* to 146† million tons a year. While responsible estimates are that sulfur dioxide will last an average of 43 days and probably less and the American Association for the Advancement of Science (AAAS) has stated that sulfur oxides may be of little global concern from a long-range point of view, it is apparent that local concentrations of some consequence do exist. All the other sulfur compounds which might be considered as pollutants (such as hydrogen sulfide and mercaptans) are converted by direct and photochemical oxidation to sulfate and are washed from the air. Therefore it appears that, as far as sulfur compounds are concerned, if man can control their peak occurrence in crowded urban centers so that they do not cause unwanted effects before they are diffused in the atmosphere, then we should have no present need for action concerning their global effects, other than continued study.

b) Carbon Monoxide

As in the case of sulfur compounds, the problem with carbon monoxide is control of emission souces to prevent its reaching health-damaging concentrations in urban atmospheres. Studies now under way show that there has been no increase globally, and it is not expected to be a problem on a global scale.[3]

* American Association for the Advancement of Science, *Air Conservation* (Washington, D.C., American Association for the Advancement of Science, 1965).

† Robinson and Robbins.

c) Nitrogen Oxides

Even if natural reactions did not remove nitrogen oxides from the air, the potential for global buildup of this pollutant would appear to be insignificant. Man's contribution to the global atmospheric loading of nitrogen compounds is minor as compared with that by nature, and all are washed from the air as nitrates. Control is needed only to keep nitrogen oxides below health-damaging and visibility-diminishing levels in urban atmospheres.

d) Particulates

Indications are that additions of particulates to the atmosphere at the present rate do not threaten to overload nature's cleansing mechanisms on a global scale.

e) Carbon Dioxide

Carbon dioxide from the combustion of fossil fuels is not normally considered an air pollutant and therefore has not been discussed as such in this report. The hypothesis has been advanced that increases in global levels of carbon dioxide, by increasing the greenhouse effect, could cause increases in the earth's temperature. However, responsible investigators believe it will be the turn of the century before trends in the earth's temperature can be established. It should be noted that others hypothesize that the shielding effect of today's levels of particulates will cause a cooling trend in the earth's atmosphere.

2. Water Pollution

There has also developed a growing interest that local pollution incidents may affect the ecological balances of the marine environment. Investigations of this possibility are proceeding and the global problem of oil on public waters is a matter of immediate concern to the U.S. petroleum industry.

A recent comprehensive review[4] indicates that, with very few exceptions, adequate observation of the environmental conditions prior to an oil-spill incident is lacking, so that an accurate assessment of the impact of a spill is extremely difficult. Even so, on the basis of those situations for which data are available, recovery was generally rapid and complete where damage occurred.

The effects of an oil spill on the environment appear to be most significant with regard to seabirds and their habitats. Also affected at times are shellfish beds, inshore spawning areas and high-use coastal property. However, in most instances, the ecological effects appear to be temporary. Damage to the environment from oil-spill control or cleanup operations appears to be limited to marine life in the intertidal zone and to be linked primarily to the possible detrimental effects of improper use of chemicals.

Mature finfish generally appear to be unaffected by either the presence of spilled oil or the dispersed mixture of oil and chemical treatment materials. Similarly, spilled oil is generally considered to result in minimal harm to marine mammals.

The effects of oil spillage on the marine food chain or food web (which consists of plants, bacteria and small marine organisms) are not well understood because of the wide fluctuations and cycles that occur naturally and are totally independent of the effects of oil. In general, oil spillage and cleanup methods do not appear to have lasting effects on the food elements of the marine environment. The petroleum industry, government agencies and others[5] have been and are continuing to conduct studies in this area, as well as taking actions to improve methods of oil-spill prevention and control. Some research has been conducted by several distinguished scientists, including those at eminent oceanographic institutions.

SECTION 2.
BALANCING BASIC NEEDS

Having achieved impressive economic gains in recent decades, the United States along with other nations is reexamining the priority of values. Greater emphasis is being placed on the conservation of the natural environment in which we live. At the same time we must continue to grow economically in order to achieve all of our nation's needs, including the adequacy of the environment.

Therefore, in the current process of harmonizing values, all must recognize the interrelationships between the basic need for conservation of our environment and the requirement for energy and the inevitable cost to be paid. The cause-effect relationship in national energy and environmental conservation matters must be anticipated by government policy-makers. Government should carefully take into account cost-benefit factors and their impact on the economy.

A. The Need for Energy

The tremendous economic expansion that has taken place in the United States during the last quarter-century has depended on energy supplied increasingly by petroleum. Today, of the total U.S. energy requirement which is satisfied by fossil fuels, nuclear power, water power or other direct sources, about three-fourths is met by oil and gas.

1. United States Energy Requirements

U.S. energy requirements are projected to continue to increase, responding to the needs of a complex, industrial-based society and a steadily expanding population.

In the more distant future—1980 to the year 2000—forecasters tend to differ more widely in their estimates of both population and economic growth. Since U.S. energy requirements are closely correlated with both population and economic trends, as well as with society's changing characteristics, the range of energy demand forecasts for the closing years of this century similarly tends to widen. Energy demand growth usually is underestimated, and, even in the earlier years, each succeeding forecast, public and private, tends to be higher than its predecessor. Present (1970) estimates by oil companies and others reflect the continuation of this phenomenon, as evidenced by Table 2, although each forecast is analyzed carefully by its maker in the light of existing conditions and expected change before release.

TABLE 2: Selected Energy Demand Projections to 1980
(In Quadrillion BTu's)

Source	Date of Preparation of Estimate	
	1966-69	1970
Oil and Gas Journal (1969)	101.7	......
Arthur D. Little (1969)	99.3	......
Stanford Research Institute (1969)	100.0	......
Bureau of Mines (1968)*		
Medium	88.1	......
Range	73.9-104.7	......
Chase Manhattan Bank (1968)	97.6	108.5
Department of the Interior (1966)	88.1	......
Shell Oil Company (1969)	103.0	......
Texas Eastern (1968)	97.8	......
Marathon Oil Company (1968)	92.2	101.7
Humble Oil Company	......	105.7
Standard Oil Company (Ind.)	......	107.6
Gulf Oil Corporation	......	100.0
Mobil Oil Corporation	......	98.9
Continental Oil Company	......	102.4
Average	96.4	103.6

* Source: Warren E. Morrison and Charles L. Readling, *An Energy Model for the United States, Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000,* U.S. Department of the Interior IC 8384 (July 1968).

Currently, most forecasters expect U.S. energy demand to total at least 100 quadrillion BTu's* in 1980 following an average annual growth of at least 4 percent above the 69 quadrillion BTu's recorded in 1970.[6]

The U.S. industrial sector† comprised the largest market for primary energy resources in 1970, followed by (in descending order) electric utilities, transportation, residential/commercial and non-fuel raw materials. By 1980 each is projected to consume more energy. Electric utilities are projected to exhibit the most rapid growth and become the largest market. In addition, marked future gains are anticipated for petrochemical feedstocks and other non-fuel uses of petroleum, which are included within the broad category of "energy requirements."

Interfuel competition for the foreseeable future is expected to be profoundly influenced by the degree to which society emphasizes environmental quality. No real interfuel competition exists in today's transportation market, and a major displacement of petroleum seems unlikely for at least the period to 1980. However, interfuel competition is highly intense in residential, commercial and industrial markets, with oil and gas encountering strong competition from electricity. Electric utilities themselves represent a highly competitive arena, with the fossil fuels competing with each other and increasingly with nuclear fuels.

Looking in general terms toward the year 2000, many experts expect one or more advanced energy conversion systems to acquire dominance where energy is needed for a fixed (i.e., immobile) installation. However, the purpose of this report is to provide a perspective as to the relationship of growing energy demand and supply to environmental conservation, rather than to examine the energy outlook for the balance of this century.[7]

a) Demand for Oil

The 1968 Bureau of Mines "medium" projection of liquid hydrocarbons demand in 1980 was 18.2 million barrels daily, and their highest estimate was 21.6 million barrels dai-

* 1 quadrillion (10^{15}) British thermal units equals about 470,000 barrels daily crude-oil equivalent.

† For purposes of analysis, markets for energy resources are usually divided into:

- Industrial (e.g., manufacturing, industrial processes, etc.)
- Transportation
- Electric Utilities
- Residential/Commercial
- Raw Material and Other (essentially non-energy use of energy resource)

ly. Currently, oil industry observers would agree that even the "high" projection appears low, after an expected average growth rate of about 4.0 percent annually over the 14.7 million barrels daily recorded in 1970.[8]

The major transportation fuels (primarily gasoline, jet fuel and diesel) will exhibit rapid growth through the 1970's. Demand for light and heavy fuel oils is now expected to show renewed competitive vigor through the 1970's due to rising supply costs for coal and natural gas, limited availability of natural gas, and severe sulfur restrictions—factors of particular importance to the large utility and industrial customer. In this period, low-sulfur fuel oils are expected to gain a significant portion of the electric utility market from coal, while non-breeder nuclear fission may not attain formerly expected prominence during this time.

b) Demand for Natural Gas

Projected natural gas requirements now indicate the potential for greater expansion than previously estimated. In a 1969 report by the Future Requirements Agency,[9] natural gas demand was forecasted to increase from 21.5 trillion cubic feet in 1968 to 46.7 trillion cubic feet in 1990, a 3.6 percent compounded annual growth over that period. However, the FRA projection assumes an adequate supply of gas and continuation of present interfuel relationships. More likely, potential demand growth will be curtailed to some extent by a lack of gas, depending largely on the economics of gas supply.

2. United States Energy Supplies

The long-term stability of petroleum supplies to meet the nation's diverse needs appears to be a policy objective of the Federal Government. To achieve this desirable goal it then becomes imperative that the Government adopt wise, firm, predictable, long-range policies for environmental quality that are consistent with this objective.

The United States produces about 90 percent of its overall energy requirements, importing the balance in the form of oil, natural gas and LNG. Rapid depletion of proved domestic reserves of oil and gas—unless countered by policies that provide a favorable climate in which the industry can increase domestic exploration and production —will lead to increasing dependence on imports. In this regard, it should be noted that the number of exploratory wells drilled in 1970 was the lowest in 22 years. A myriad of political, social, technological and economic factors will interact in shaping the future energy supply environment, with security of supply increasingly becoming a paramount issue.

In recent years, new reserves of oil and gas have not been added to the U.S. energy inventory in volumes sufficient to offset production (see Table 3).

Both newly discovered Alaskan oil and gas reserves and the reserve potential offshore of our nation are apparently large. Furthermore, a recent report of the National Petroleum Council indicates a major untapped potential within the contiguous states of the United States.[10] However, it has become evident that considerably more extensive exploration and development will be required to assure a reasonable degree of domestic self-sufficiency, and that a continuing large financial commitment must be made. Further, normal operations to explore for reserves of oil and gas do not contribute a pollution hazard and, although a threat of pollution from spilled petroleum does exist in development and production operations, the probability of such pollution is extremely small and has been continually reduced through improved technology (see Industry Operations, Chapters Three through Seven of this report).

Regulation of gas prices at the well has tended to discourage exploration for natural gas supplies. Higher natural gas prices would undoubtedly help the reserve picture for this relatively pollution-free energy resource.

For the future, oil shale and coal appear to provide an enormous domestic resource for energy and both should become major elements in the future supply picture for liquid and gaseous hydrocarbons. However, because of their economics, they will probably not provide an appreciable source of these hydrocarbons before 1980.

B. The Benefits and Costs of Degrees of Environmental Quality

1. Benefits

The various forms of pollution constitute more or less serious hazards to the physical health of man, animals and plants. Similarly, often inseparable from health hazards, physical and mental irritants can downgrade the general well-being of living organisms. Finally, there are a variety of direct and indirect economic benefits that would result from reduction of pollution.

Broadly, then, some short- and long-run benefits from control of environmental pollution could be classified as follows:

- *Improvements in Physical Health* (I)

  a) Reduced incidence of human disease.
    1) Major—emphysema, typhoid.
    2) Minor—common cold, dysentery.

  b) Fewer diseases in animals/plants destined for human consumption.

  c) Reduced effects on non-food animals/plants.

- *Improvements in the Quality of Life* (II)

  a) Reduction in physical irritants—unpleasant odors, particulate matter, high noise levels.

  b) Reduction in mental irritants—discolored foliage and art works, unsightly dumps.

  c) Improved recreational facilities—beaches, parks.

  d) Improved aesthetic qualities—tree-lined streets, clear skies.

- *Economic*

  a) Benefits from I and II above—absenteeism, productivity, agriculture, recreation.
  b) Reduced corrosion.
  c) Waste recycling—human waste, garbage, industrial.

Some of the above could be broadly quantified, but most—being intangible—can not. Moreover, the degree of air, water or land "purity" required to achieve various benefit "levels" must be balanced against the impact of their attainment on the other requirements of society.

Improvements will not be achieved quickly nor uniformly around the nation. A series of economic trade-offs must be made at local, state and national levels among these basic questions: *How clean? How soon? What benefit? What cost? Who pays what share of the costs?*

TABLE 3: U.S. Proved Reserves of Oil and Gas*

	Reserves at 12/31	Average Annual Additions	Average Annual Production	R/P † at 12/31
A. Crude Oil (In Billions of Barrels)				
1950	25.3			13.0
		3.0	2.4	
1960	31.6			12.8
		2.5	2.6	
1965	31.4			11.7
		4.6	3.1	
1970 ‡	39.0			11.7
B. Natural Gas Liquids (In Billions of Barrels)				
1950	4.3			18.8
		0.6	0.3	
1960	6.8			15.8
		0.7	0.5	
1965	8.0			14.4
		0.6	0.7	
1970	7.7			10.3
C. Natural Gas (In Trillion Cubic Feet)				
1950	184.6			26.9
		18.0	10.4	
1960	262.3			20.1
		19.3	14.6	
1965	286.5			17.6
		20.3	19.6	
1970 ‡	290.7			13.2

* Sources: (a) *Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the U.S. and Canada and U.S. Productive Capacity as of December 31, 1969,* Vol. XXIV (May 1970), published jointly by the American Petroleum Institute, American Gas Association and Canadian Petroleum Association; (b) American Petroleum Institute and American Gas Association, News Releases (March 31, 1971).

† The "Reserves-to-Production Ratio," i.e., year-end reserves divided by that year's production.

‡ 1970 year-end figures show an increase because they include reserves in the Prudhoe Bay Permo-Triassic reservoir on the North Slope of Alaska. These resources were discovered in 1968 but reported by the API and AGA for the first time on March 31, 1971, as proved reserves of 9.6 billion barrels of crude oil and 26.0 trillion cubic feet of natural gas, as of December 31, 1970.

For example, if there is strong reason for confidence that imminent technological advances will help to achieve pollution control objectives at lower cost, then such technology should be awaited, provided this is in the general public interest.

2. Costs

There are three basic costs involved in environmental conservation: (1) the cost of reducing or eliminating pollution before damage is done, (2) the cost of restoring environmental quality where damage has occurred and (3) the societal cost associated with damage caused by pollution. Abatement or restoration costs must be balanced against societal costs of damages from pollution so that a proper relationship between costs and benefits will be achieved.

The costs of restoring or preserving the quality of the environment in which we live, whether incurred by industry or government, are costs of society in the final analysis and necessarily will be assumed by society in the form of higher taxes, inconvenience, higher prices for goods and services, or a combination of these.

a) Responsibility for Costs

The determination of environmental quality standards should, among other things, take into account the cost-benefit factor to society and the impact of that factor upon our economy. For example, severe, impractical or unnecessary costly regulation of exploration, production and transportation operations of the petroleum industry reduces the incentives for proving and developing needed reserves of oil and gas and also increases the cost of petroleum products. The effectiveness of environmental controls can be continuously improved by the development of reasonable standards together with time schedules in which to implement them, established by government with the advice of industry.

Assigning responsibility for pollution damage or control costs is, of course, often a formidable task. In situations where the oil and gas industries have assumed sole or joint responsibility, costs can be related to mobile and stationary sources (automobiles, electric utilities) and to various operations (production, refining, transportation). Costs could be further classified as to where they are incurred in the stream from raw materials to point of final consumption.

- *Cleanup/Repair Costs of Pollution Damage*
    - a) Tangible
    - b) Intangible
- *Costs of Pollution Control*
    - a) Mobile Sources
        - 1) Responsibility of consumer
        - 2) Responsibility of vehicle manufacturer
        - 3) Responsibility of fuel producer
    - b) Stationary Sources
        - 1) Responsibility of fuel user
        - 2) Responsibility of fuel producer
    - c) Oil and Gas Operations
        - 1) Drilling and production
        - 2) Refining
        - 3) Storage and transportation
        - 4) Marketing

b) Magnitude of Costs

The total past and future costs of reducing or eliminating various types of air, water and land pollution are also unknown. However, major efforts have been undertaken by industry and government to evaluate required control costs at differing standards or levels.

The Department of Health, Education and Welfare (HEW), for example, identified three basic costs associated with air pollution control: (1) the cost to consumers of reducing two types of polluting emissions from automobiles, (2) the cost to various industries of reducing sulfur oxides and particulate emissions from stationary sources, and (3) the cost to governments of eliminating stationary source emissions, plus research and development expenditures by the National Air Pollution Control Administration.[11] These three alone will require a total estimated annual expenditure of \$1.7 to \$1.9 billion by 1974, depending on the degree of air pollutant reduction required. They do not include such related costs as the automobile industry expenditure to develop and produce emissions control devices, or oil company costs directed towards making fuels of lower sulfur or lead content available.

Such cost figures can be misleading as they fail to account for offsetting revenue which may result or for alternative possibilities. For example, elimination of sulfur oxides would bring some offsetting revenue from the sale of sulfur. An example of a major tradeoff or compromise would be accepting lower performance in automobiles in return for a combination of engine design and fuel composition that would eliminate or greatly reduce polluting emissions.

No satisfactory answer exists as to total tangible costs of pollution damage borne by the oil, gas or other industries, or by property owners. Obviously, the intangible costs, such as long-run health damage and physical irritants, are even less amenable to compilation.

Published tangible costs of major oil spills are illustrative. For example: The Santa Barbara oil leak cost the companies involved about $5 million in cleanup expense; the Torrey Canyon accident cost several insurance companies about $7.3 million in claims by countries and individuals. No one knows, however, the derived costs even from these incidents (such as higher insurance premiums, etc.).

c) Petroleum Industry Conservation Actions

The U.S. oil and gas industries, recognizing that their involvement in conservation includes not only functional operations but also the various aspects of consumer use of petroleum products, have directed many millions of dollars toward control facilities and basic product research. A recent American Petroleum Institute (API) survey indicates that the petroleum industry's expenditures for air and water conservation have increased 106 percent since 1966 (see Figure 1).

In addition, it should be noted that the expenditure data cover only what the oil companies spent within the United States. Heavy investments, for example, made in the Caribbean and elsewhere to provide low-sulfur fuel oils—most of which are consumed in the Northeastern states—are not included.

The petroleum industry also recognizes that with about 4,000 tankers and 30,000 other large ships plying the world's oceans, some accidents will happen. The industry has therefore taken steps to be sure that means are available to handle the costs of cleanup of oil spills and the costs to persons sustaining pollution damage. For example, voluntary plans have been instituted for handling the costs of cleaning up oil discharges from tankers operating in any part of the world's oceans.

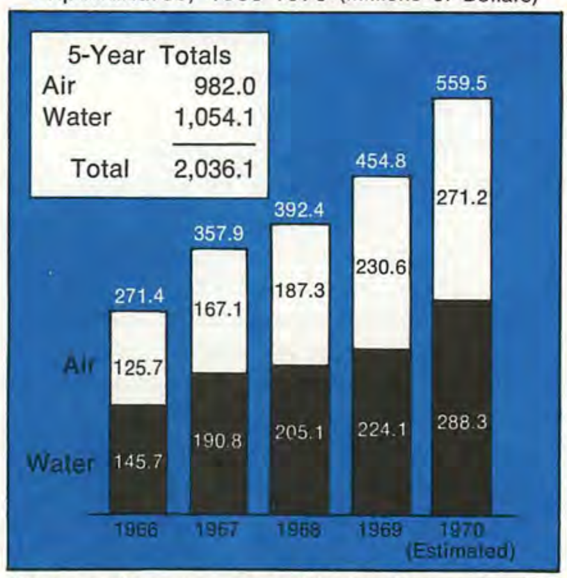
One such plan, known as TOVALOP (Tanker Owner Voluntary Agreement Concerning Liability for Oil Pollution), was put into effect in 1969 by seven international oil companies and is available to all tanker owners who wish to become participants. To date, most of the Free World's tanker tonnage, exclusive of government-owned vessels, is now covered by TOVALOP. TOVALOP provides for reimbursement by participating ship owners to national governments at the rate of $100 per gross ton of tanker capacity up to $10 million, for expenses reasonably incurred by them to prevent or clean up pollution of coastlines as a result of the negligent discharge of oil from a participating tanker.

Effective April 1, 1971, a new plan provides extended coverage up to $30 million per incident in protection. Administered under the new Oil Companies Institute for Marine Pollution Compensation Limited, it incorporates 38 major oil companies shipping over 80 percent of the crude and fuel oil shipped throughout the Free World.

d) Meeting Environmental Costs

The inevitable costs associated with environmental conservation and pollution control must be borne by society. An approach is

Figure 1 *
Air and Water Conservation
Expenditures, 1966-1970 (Millions of Dollars)



* *Source:* "Report on Air and Water Conservation Expenditures of the Petroleum Industry of the United States, 1966-1970," API Publication No. 4075 (February 1971).

needed which will achieve environmental objectives at the lowest net cost to society and in a fashion which will maximize current benefits so that the costs incurred may be met on as current a basis as practicable.

Costs of environmental conservation and pollution control could be met by utilization of one or a combination of methods, such as classifying environmental expenses as a normal cost of doing business, tax incentives, and/or government subsidies. Meeting environmental quality standards through market competition will provide the optimum quality for money expended.

Many economists and conservationists feel that there is little direct incentive in our competitive system for a manufacturer to invest substantial sums of money in pollution abatement facilities and equipment. The claim is that, absent some compulsion or economic encouragement, unilateral expenditures would seriously impair the manufacturer's ability to compete.

A number of proposals to create economic incentives have been advanced and debated. The incentives usually take the form of tax deductions or exemptions.

The federal investment tax credit, while it was in effect, was an example of the tax-incentive form of encouragement to stimulate economic activity by spending capital funds.[12] Such a tax incentive could be used to attain other objectives, such as investment in pollution abatement facilities, if there is a well-defined and practicable program at all government levels.

e) Economic Penalties

A number of proposals to create economic deterrents to pollution have also been advanced and debated. These deterrents are expressed in terms of charges or levies against polluters based on the quantities of potential pollutants in materials such as fuels, which are utilized in a combustion or other process.

Dr. Gardner Ackley, when chairman of the President's Council of Economic Advisers, challenged the use of economic incentives. He proposed penalties related to the amount of each firm's contribution to pollution, i.e., a tax or a charge levied on companies according to the wastes or pollutants they discharge.

Dr. Ackley's deterrent proposal came again under consideration as a result of a General Accounting Office (GAO) report strongly criticizing the Federal Water Pollution Control Administration for its program of waste-treatment plant construction grants to municipalities. Because of this report a bill (S.3181) was introduced in the 91st Congress providing for a system of effluent charges against industrial polluters based on the quantities discharged and their relative strength and toxicity. The GAO report and S.3181 illustrate the extremes in the swing of the abatement pendulum.

In any event, to use government practices in its grant program to municipalities as justification for financial reprisals against industry in the form of an effluent tax is a non sequitur of serious proportions. A major argument against a tax system of this sort, already pointed out in the Senate, is that such fees or charges are a potential license to pollute rather than an incentive to find alternative methods of waste discharge.[13] Practical arguments involve the cost of administration. Arbitrary formulas would have to be devised for determining the amount of each discharger's tax and a massive administrative effort would have to be mounted to enforce collection and to police the entire waterway involved.

A similar assignment with respect to airspace would seem almost superhuman. For example, in cities like New York or Chicago, any corps of inspectors, no matter how large, would find it impracticable to allocate, among the thousands of pollutant sources, each one's pro rata share of the total. Obviously, arbitrary assessments would have to be made with provisions for hearings and appeals, leading to administrative problems and acrimonious disputes.

As a general matter, genuine societal problems affecting the public welfare should be approached directly by the public and its government and not through indirect avenues such as governmentally-imposed economic penalties. As a practical matter, such economic penalties provide the option of meeting the imposed penalty and thus continuing the undesirable conduct without abating pollution. This approach also suffers from the virtual impossibility of selecting an equitable method of assessing charges for the vast number of potential pollutants.

This objection would be applicable to the imposition of charges on fuels as a means of controlling emissions into the atmosphere. In fact, this type of charge on fuel composition suffers from the further complication of selecting for assessment a particular aspect of the technical interrelationship between fuels on the one hand and, on the other, the vehicles or stationary plant for which they are designed. Such a charge would unnecessarily inject the government into the free-market competitive process, thus limiting the initiative of individual manufacturers to develop more effective means of emissions control. Proposals to apply charges to the sulfur content of heating fuels or to lead additives to gasoline might well, in practice, contribute nothing to environmental conservation and could even forestall progress now under way.

SECTION 3.
COOPERATION FOR EFFECTIVENESS

To attain environmental conservation on the most effective and economical basis, cooperation among government, industry and private citizen groups, as is sanctioned by applicable law, must be continued and expanded.

A. General Measures

Cooperation may take many forms, but one of the most fundamentally useful is the basic one of continual and open dialogue between industry and government so that government may have the facts at hand of the effects of possible decisions before their implementation. This knowledge is of vital importance in assessing the practical limits of technology and economics. Also, it is essential that, after environmental standards are determined and the time period fixed for compliance, industry be able to rely on the resulting schedule and not be subjected to continual and exceedingly costly schedule revisions.

There is also a basic need for cooperation in developing a common understanding of the realities of environmental quality and ways of safeguarding it. People should, through all means of communications, including public education programs, be made aware of all of the causes of pollution and the measures which the individual can take to reduce and control pollution. The oil and gas industries are expanding appropriate education programs in order to contribute to a wider understanding of these environmental conservation matters.

Many forms of cooperation exist to obtain the maximum use from available manpower and facilities, thus reducing societal costs of maintaining environmental quality. Industry and municipalities should and do share, equitably, both the use and cost of their respective waste treatment facilities. The petroleum industry actively supports increased attention to harbor cooperatives, to cleanup of oil spills, and to broader arrangements with concerned local and federal groups for such purposes as providing waste disposal facilities and minimizing the effects of oil spills in coastal and inland waterways.

B. Research

Individual petroleum companies carry on intensive research programs to improve products and operations. The research effort alone of the petroleum companies relating to environmental conservation in 1970 is estimated to have been about $36 million, an increase of 32 percent over the 1969 expenditures.

In addition, cooperative research into problems associated with air and water conservation has been conducted or financed—or both—by the petroleum industry over the years, both in cooperation with government and wholly within the industry. Cooperative efforts toward water pollution abatement from refinery operations were initiated through the American Petroleum Institute in 1929 and pioneering air pollution research in 1953. This current broad research effort represents an expenditure of about $3.5 million a year in direct support of outside research efforts in addition to individual company expenditures and involves projects in both air and water conservation.

Current research efforts in which the petroleum industry plays a significant part involve a wide range of subjects. Multicompany research programs are proceeding with the aim of developing an internal-combustion engine and fuel combination that will emit virtually no harmful pollutants. These research efforts have provided new basic knowledge of pertinent chemistry and contributed to the development of effective emissions control systems.

Related research of somewhat broader scope is being conducted by the Coordinating Research Council (CRC), a joint industry-government group supported by the Automobile Manufacturers Association, the American Petroleum Institute, and the Environmental Protection Agency (EPA). Its projects range from such engineering aspects of vehicle air pollution as driver habits and traffic patterns to studies of atmospheric chemistry and the medical aspects of air pollution.

In addition to sponsoring research related to vehicular fuels, the American Petroleum Institute has also sponsored extensive industry research since 1966 into the engineering, scientific and environmental health aspects of the sulfur content of heavy fuels used by industry.

In the field of water pollution control, the American Petroleum Institute and the EPA have been working as a government-industry team on research studies in biological treatment processes for municipal and industrial wastes. The petroleum industry has also moved, through the API, to investigate the problems of oil spills at sea and to develop effective means of control.

Individual companies of the petroleum industry have recognized the need for more precise understanding of the nature of pollution and means to control it. As a result, both separately and cooperatively, they have developed and published substantial amounts of related technical information. This information has been used by them in the training of their own personnel, by other industries, by government bodies and by the general public.

Much indeed has been accomplished by research efforts. Yet most of the information and understanding needed to set ultimate objectives, criteria and standards necessary to solve all of our pollution problems is not available. Consequently, the cooperative resources of society can well be turned to substantial and continuous support of broad programs of basic research to evaluate more conclusively the effects of contaminants on human health and on the general ecology over the short and long terms.

Chapter Two:

Law and Regulatory Policy

The legal aspects of pollution control cover a broad spectrum, ranging from local ordinances and regulations at one end to international treaties and conventions at the other. Individually and collectively they act to control the manner in which the elements of society carry their responsibilities for maintaining acceptable environmental quality and providing other fundamental needs.

The role of government should be to ascertain the effects of pollutants, prescribe workable standards of air, water and land quality to be maintained, and, in general, to leave to private initiative the means whereby the standards will be achieved. Best results can often be achieved where industry is asked to participate, in an advisory capacity, beginning at an early stage in the development of policy, laws and regulations. Such participation can assist to ensure that the time required to implement legislation and its economic feasibility receive adequate consideration in the formative stages.

SECTION 1. FEDERAL LAWS AND REGULATORY POLICY

A. Definitions

The federal water and air laws contain no definition of pollution. This omission was probably intentional because of the basic federal philosophy of leaving to the states the primary responsibility of preventing and controlling pollution, including the perimeters of the concept of pollution itself. There is, however, a federally recommended definition of water pollution which appears in the Federal Water Pollution Control Administration's Suggested State Water Pollution Control Act [14] and this Act has been adopted in whole or in part by a majority of the states. The Council of State Governments in its Suggested State Air Pollution Control Act defines air pollution.[15]

The words "health" and "welfare" appear in both of these suggested state laws and also in those portions of the federal water and air enactments authorizing abatement proceedings with respect to pollution "which endangers the health or welfare of any persons." [16] Although neither of these words is defined in any of these acts, the Federal Government takes the position that the endangerment of health or welfare does not require evidence of the existence of actual harm or injury. "The true inquiry," it is said, "in the light of the policy of the statute, is whether there is a reasonable apprehension of such danger. If this exists, the requirement is met." [17]

B. Water Pollution

Until 1948 the role of the Federal Government with respect to the quality of the nation's water resources was very limited. Problems in that area were left largely to the individual states. However, there were some areas of overriding national importance which led the Federal Government to establish legislation concerning pollution of navigable waters as far back as 1890 when the forerunner [18] of the River and Harbor Act of 1899 [19] was enacted.

Although the River and Harbor Act was aimed at impediments to navigation, its confusing arrangement has produced results having no relationship to navigation. Thus, refuse dumping is unlawful regardless of its effect on navigation, and refuse has been held to include materials not commonly thought of as waste, such as aviation gasoline accidentally discharged into a navigable river. Violation of the antidumping provisions of the River and Harbor Act is a criminal offense, and freedom from fault or negligence and absence of knowledge or scienter appears to be no defense.[20]

In 1948 a more comprehensive federal approach to the problems of water quality was initiated, leading to the Federal Water Pollution Control Act [21] which, with its subsequent amendments,[22] is the basic federal framework for water pollution control today.

In putting together the federal legislative package, three fundamental questions were faced. A basic one was whether water quality standards should be adopted by the Federal Government or the states. Ultimately this issue was resolved by giving the states the initial opportunity to establish water quality standards with authority to the Federal Government to act only if the states failed to do so. A second fundamental question concerned the type of standards to be established. Should they relate to the quality of the receiving water or to the quality of the effluent discharged, or both? As finally enacted in 1965, the Act omitted any reference to effluent standards and provided only that water quality standards adopted by each state were to be "applicable to interstate waters or portions thereof within such State." A third fundamental question concerned the adoption of uniform national standards as opposed to flexible standards geared to local conditions. This issue was related to the one of federal versus state standards, and the decision to leave the establishment of standards to the states in the first instance dictated the elimination from the Act of any reference to uniform national controls. Administration of the Act is now the responsibility of the Environmental Protection Agency (EPA).

Controversies arose over requirements of an earlier administrative agency for secondary treatment or its equivalent for all water discharges and the announcement of a so-called "nondegradation standard" requiring that waters whose existing quality is better than that called for by established standards must be maintained at that higher quality level.

The secondary treatment controversy raises the issue of whether controls can, under the law, be placed on the quality of discharges rather than on the quality of the receiving water. In testing this issue, Iowa did not incorporate any secondary treatment requirements in its standards for those portions of the Mississippi and Missouri Rivers within its jurisdiction, on the ground that such requirements were not necessary in order to maintain proper water quality standards for those rivers.

The nondegradation standard raised concerns not only that it was at variance with the Act's authorization to the states to take water use and value for various purposes, including industrial, into consideration in establishing standards,[23] but also that, if strictly applied, it would preclude the development of remote, untouched areas. It remains to be seen what course will be taken by the new Environmental Protection Agency.

A stringent approach to oil spills was taken by Congress when it enacted the Water Quality Improvement Act of 1970,[24] which broadly prohibits the discharge of oil into or upon (1) the navigable waters of the United States (which end at the 3-mile limit), (2) the adjoining shorelines, or (3) the contiguous zone (which extends for another 9 miles beyond the 3-mile limit). Sources covered by these prohibitions are:

- vessels other than government vessels;
- onshore facilities, which would include refineries, terminals, manufacturing plants, motor vehicles and rolling stock; and
- offshore facilities within the 3-mile limit, which would include drilling rigs, drilling platforms, storage facilities and pipelines.[25]

Any such deep-water facilities beyond the 3-mile limit would not be covered by this law.[26] They were exempted because the Secretary of the Interior had already covered spills from offshore wells beyond the 3-mile limit by regulations[27] issued under the Outer Continental Shelf Lands Act.[28]

The Act directed the issuance of regulations which would specify the quantities, occasions, circumstances and conditions to be utilized in characterizing an oil discharge as harmful and therefore prohibited, and those to be characterized as not harmful and therefore permissible. On September 11, 1970, the Department of the Interior issued regulations which defined "harmful quantities" of oil as discharges of oil which (1) violated applicable water quality standards, or (2) created a visible film or sheen upon, or discoloration of, the water. However, industry has contended that under the "sheen" standard virtually any discharge containing oil, no matter how minute in quantity, can be construed as harmful since discharges of water containing *de minimis* quantities of oil can, under some conditions, cause a sheen, although normally they would not do so. Moreover, even though the "sheen" standard does not seem to be technologically feasible at this time, the regulations became effective immediately.

The affirmative, positive cleanup thrust of this law is directed to the President to remove spills. Among the affirmative obligations placed on oil dischargers is a requirement to reimburse the Federal Government for the costs of cleanup unless the discharger can prove that the spill was caused under specified exculpatory circumstances. In the absence of such circumstances, one who discharges oil in violation of the statute will be liable to the Government for the costs of cleanup, subject to separate cost limitations for vessels, offshore facilities and onshore facilities, if the discharge is not willful.

In spite of this new statute, the old River and Harbor Act of 1899 still remains in effect,[29] thus portending what may well be serious and inequitable consequences for oil operators because of the mutually inconsistent provisions of these two laws.

On December 23, 1970, the President issued Executive Order 11574 requiring the implementation of a permit program under the Act of 1899 "to regulate the discharge of pollutants and other refuse matter into the navigable waters of the United States or their tributaries and the placing of such matter upon their banks." [30] The Secretary of the Army (acting through the Corps of Engineers) has subsequently issued implementing rules and regulations.[31]

In addition to the statutory provisions on oil spills, the Department of the Interior issued specific regulations in 1969 covering operations on the Outer Continental Shelf under federal oil and gas leases.[32] Although the Secretary of the Interior stated that it was his intention to impose unlimited and absolute liability on companies holding Outer Continental Shelf leases for cleaning up oil spills regardless of fault or negligence,[33] there is some question whether the language of the regulation goes that far. Furthermore, the Department has issued some orders which indicate that discharges containing *de minimis* quantities of oil are to be permitted.

Another question with respect to these regulations is whether they are legally applicable to existing leases, as claimed by the Government.

C. *Air Pollution*

In 1955 Congress established a role for the Federal Government in air pollution by the passage of the Air Pollution Control Act.[34] The states' rights principle was recognized by the provision that "the prevention and control of air pollution at its source is the primary responsibility of states and local governments." [35]

Successive acts leading to the Air Quality Act of 1967 provided, among other things, for the development of air quality criteria by the Federal Government (now the responsibility of the EPA) to guide local control agencies, for abatement proceedings, and for the establishment of national standards for emissions from new motor vehicles.[36]

The Air Quality Act of 1967, enacted in November of that year, makes applicable to air much of the philosophy and procedural arrangements previously written into the water program, including the issuance of criteria by the Federal Government and authority to promulgate federal standards in cases of inadequate state action.[37] In addition, immediate federal action for an injunction to stop pollution is authorized when there is an emergency endangering public health.[38]

One jurisdictional difference, however, is the concept of control regions in the Air Quality Act, some of which encompass areas in more than one state. Another dissimilarity is that the implementation plans to be formulated by each state in support of its ambient air standards should contain emissions controls applicable to the sources or classes of sources of various discharges.[39]

Because the ambient air must be fit to breathe in all places of human habitation, whereas the quality of water may be permitted to vary depending on primary water needs, it follows that the achievement of these different objectives requires the establishment of both ambient air and emissions standards on the one hand while utilizing only receiving water standards on the other. In addition, with potential air polluters literally scattered and moving everywhere and with ambient air essentially having no fixed boundaries, control by ambient air standards alone without emissions controls would probably impose impossible administrative and enforcement burdens.

However, air emissions controls should be framed in terms of limitations on types and amounts of discharges from particular sources or classes of sources, as distinguished from requirements specifying kinds or types of emissions control equipment. To do otherwise, by making mandatory specified control techniques or equipment, would discourage the development of new technological improvements.

Title II of the 1967 Act also makes clear that the basic philosophy of leaving standard-setting to the states would not be applicable to new automobiles.[40] In spite of logical arguments for uniform national emissions standards for new motor vehicles, however, California was given an exemption permitting it to enforce its own stricter standards. Also a government agency (now EPA) is authorized to require specified reports from fuel and additive manufacturers so that the Government can, by its own test, determine the effect of the use of such additives on human health.

The 1967 Act was the subject of major revisions and modifications by the Clean Air Amendments of 1970. The main thrust of the

1970 law is to further increase the power and authority of the Federal Government to cope with air pollution, while at the same time maintaining the basic premise of the earlier underlying legislation that "each State shall have the primary responsibility for assuring air quality within the entire geographic area comprising such State."

Under the 1970 law, the Environmental Protection Agency is to issue criteria for major pollutants from mobile and stationary sources which have an adverse effect on public health; to promulgate regulations prescribing a national primary ambient air quality standard to protect public health and a national secondary standard to protect public welfare for each pollutant; and, if state implementation is unacceptable, to promulgate an implementation plan.

The Administrator of the Agency is further directed to publish a list of categories of stationary sources and to establish federal standards of performance for new stationary sources. He is also to publish a list of hazardous air pollutants (to which no ambient air quality standard is applicable) and to prescribe emissions standards for each such pollutant.

The 1970 law also requires the Administrator to prescribe standards applicable to the emission of any pollutant from any new motor vehicle or engine which causes pollution or endangers health. The manufacturers of motor vehicles have until January 1, 1975 (for 1975 model cars), to attain a 90-percent reduction in emissions of carbon monoxide and hydrocarbons allowed for 1970 models. During and after the 1976 model year, emissions of oxides of nitrogen from new vehicles or engines must be reduced by 90 percent from the average emissions actually measured during the 1971 model year. Automobile makers can seek a one-year extension of these deadlines. For carbon monoxide and hydrocarbons, the earliest date manufacturers may apply for such an extension is January 1, 1972, and for oxides of nitrogen, January 1, 1973.

As in the Air Quality Act of 1967, the Administrator may designate any fuel (including, but not limited to, motor fuels) or fuel additive, and after such dates as he may prescribe, it becomes unlawful to sell, offer for sale or introduce into commerce such fuel or additive unless the Administrator has registered it. Under the 1967 Act, registration was automatic when the Government was supplied requisite information concerning the composition and purpose-in-use of fuel additives. Under the new law, however, the Administrator may also require the fuel or additive manufacturer to (1) conduct tests with the results not to be considered confidential, (2) furnish the description of analytical technique, (3) specify the recommended range of concentration and purpose-in-use of the additive, and (4) provide such other information as is reasonable and necessary to determine the emissions resulting from the use of the fuel or additive, its effect on the emissions control performance of any vehicle or engine, and the extent to which the emissions affect the public health or welfare.

The Administrator may control or prohibit manufacture or sale of any motor vehicle fuel or fuel additive (1) if the emissions therefrom will endanger the public health or welfare or (2) if their combustion products will interfere with the performance of any emissions control device in general use, or sufficiently developed that it could be in general use in a reasonable time if the fuel or additive were regulated. Prior to controlling or prohibiting the manufacture or sale of any fuel or additive, the Administrator is required to "consider" all relevant medical and scientific information available to him, as well as other technologically or economically feasible means of achieving emissions standards. After the Administrator has taken any action controlling or prohibiting the manufacture or sale of any fuel or fuel additive, no state other than California may prescribe regulations for such fuels or additives unless they are identical to those prescribed by the Federal Government or unless they are approved by the Administrator as being necessary to achieve national air quality standards.

Provision is made under the 1970 law for federal aircraft emissions standards and for the creation of an office of noise abatement.

The Federal Aviation Act of 1958 is amended by adding a new provision for federal regulation of the composition or chemical or physical properties of any aircraft fuel or fuel additive to control or eliminate emissions which the Administrator (of EPA) determines "endanger the public health or welfare."

With certain procedural limitations, any person may bring a suit against any person, including the United States (where permitted by the Constitution), who is allegedly in violation of an emissions standard or an order issued by the Administrator or a state.

D. *Land Pollution*

The Solid Waste Disposal Act, enacted in 1965, authorizes federal agencies to undertake research and to make grants to state and local agencies for solid waste disposal programs.[41]

In this vein, the Secretary of the Interior recently announced the start of a research program on deep-well disposal of wastes.[42] This is a primary area of concern because of the possibility of the effect of such waste disposal on the underground environment, particularly ground-water supplies. The petroleum industry has been particularly proud of its waste-water disposal program through injection wells which return brine to the producing formation.

This favorable experience of the oil industry should not lead to a general conclusion that deep-well injection is a convenient and safe method of disposing of industrial liquid wastes. The Interior program may well lead to legislative proposals for some form of federal control over this method of disposal. Today, where there is any control at all, it is entirely in the hands of the states.

E. *Interstate Compacts*

Both the Federal Water Pollution Control Act and the Air Quality Act authorize two or more states to enter into compacts for cooperative pollution control programs.[43] However, few states have taken advantage of the authorizations. The interjection of the Federal Government on a broad scale in pollution abatement probably removed some of the impetus to solve these problems through interstate agencies.

F. *National Environmental Policy*

The National Environmental Policy Act of 1969 established for the first time an overall policy of the Federal Government with respect to the environment and created a Council on Environmental Quality in the Executive Office of the President. Title I of the law sets forth a policy of federal action in cooperation with state and local governments and other concerned public and private organizations, and provides that it shall be the responsibility of the Federal Government to improve and coordinate its own actions with respect to the environment. Specific applications of these general principles are discussed throughout this report.

Where a cooperative approach to the solution of an environmental problem would serve the public interest, the Executive Branch should clarify the extent of cooperation that is consistent with the intent of present antitrust laws and, if necessary, seek enactment of such further legislation as would be advisable to authorize the most effective means of dealing with such problems.

Our antitrust laws play a strong role in maintaining competition and diversity of effort that is most likely to produce the lowest cost solutions to meeting environmental standards. They properly prohibit conspiracy or collusive action by competitors in matters affecting commerce and public economic interests. However, to achieve the goal of improving the environment, in a few situations it may be that the best interests of society would be served if competitors or complementary industries were permitted to exchange information on a voluntary basis or jointly take actions regarding the modification of products or procedures in the public interest. For example, where environmental hazards exist, such cooperation may be the most feasible method to shorten the time for correction.

SECTION 2.
STATE AND LOCAL LAWS AND REGULATORY POLICY

A. *Water Pollution*

1. Common Law

Common law has been applied in various instances to the general subject of water pollution, through the doctrines of riparian rights,[44] appropriative rights[45] and nuisance.[46] But, all in all, the common law was not a satisfactory vehicle for solving water pollution problems. The result was a turning to legislatures for solutions.

2. Statutory Law

By 1930 most states had vested regulation in one or more state agencies, usually in the Department of Health. In the ensuing years many programs suffered as the result of lack of statutory authority to act, lack of forceful administration, inappropriateness of public health jurisdiction, and lack of centralized control. This last defect has been lessened considerably, although problems of overlapping jurisdictions and differing powers and policies of different agencies of a single state government still exist.

As the powers of the boards or commissions vary, so does their effectiveness. The most effective boards will normally make policy. They are severely hampered where their jurisdiction is shared with other agencies or where they do not have direct access to relevant information and expertise.

In some areas where industry representatives are local board or commission members, questions of conflict of interest have been raised. It should be noted, though, that the interests of society can generally best be served if the responsible boards or commissions have the advantage of knowing the technical and economic feasibility of their policies at the earliest stages of policy development.

Under state procedure, most states can issue cease-and-desist orders, and failure to comply can result in criminal penalties.[47] Actually, the states have been reluctant to invoke these penalties, understandably so in the light of the strictness of the burden of proof under common-law criteria.

With respect to the specific problem of oil pollution, several states (such as Florida, Massachusetts and Maine) recently have enacted legislation which unnecessarily duplicates or creates obligations inconsistent with those obligations created under the Federal Water Quality Improvement Act of 1970.

3. Effect of Federal Legislation

The Water Quality Act of 1965, as discussed in Section 2, has had a profound effect on state regulation. If the states failed to act, the Federal Government would set standards.[48]

The states, following the passage of this Act, began to formulate standards in compliance with the Act. However, in attempting to enforce their pollution laws against other agencies of the state, such as municipalities, state governments face difficult problems, the primary one being the need for money.

B. Air Pollution

1. Common Law

Application of the doctrine of nuisance is difficult in the field of air pollution because air knows no boundaries.

In a specific case of air pollution, the Supreme Court of the United States held in 1916 that municipal ordinances controlling smoke were constitutional even if it meant the closing of a business.[49] The Court considered the problem at that time severe enough to warrant such harsh relief. However, in several recent cases, while the courts have not had trouble in finding a legal basis for closing down a business, they have been reluctant to do so.

2. Statutory Law

While smoke ordinances have been with us for many years, the advent of comprehensive control statutes and enabling acts on the part of the states is of fairly recent origin. The pattern of the state statutes is a familiar one. The Council of State Governments promulgated a model state air pollution control statute in 1966.[50] This model has been adopted in whole or in part in many states.

The statutes are for the most part very broad in nature, leaving the passing of regulations to the appropriate administrative agency. Since the advent of these statutes and development of the "state of the art" is so new, most of these states are just now in the process of developing regulations.

Typically the State Department of Health is the administrative and enforcement agency in charge of pollution abatement. There is usually a board or commission which operates as a regulatory and policy board, but the responsibility for enforcement remains with the Department of Health.

At the local level, ordinances were enacted against smoke at an early date.[51] More sophisticated ordinances have followed.[52] In the past three years, there has been a proliferation of local ordinances.[53] Two tendencies appear most prevalent: (1) a trend toward regulation of fuel characteristics and (2) more stringent enforcement tools, such as direct court action bypassing an administrative procedure. A major problem has been the repeated failure to develop regulations that can be effectively enforced.

C. Other Problems

Another area of state and local regulation in the pollution field that has aroused interest in recent years is the control of ground water.[54] Control of deep-well disposal of oil-field brines has been exercised for some years with appreciable success. Other types of disposal have not met with such definitive resolution.

Of overriding concern in all areas is the coordination of efforts in the control of our environment. Different areas of the country are subject to differing priorities. In one area, the main problem may be water. In another, the main problem may be air. The common problem is, as always, money and manpower. Several states have moved toward the creation of agencies with authority for overall supervision or control of environmental problems, and the National League of Cities has recommended coordination.

SECTION 3.
INTERNATIONAL CONSIDERATION OF ENVIRONMENTAL CONSERVATION

Increasingly the maintenance of a satisfactory overall environment is being viewed as a matter of concern to the international community and to international organizations of nations. International concern with specific evironmental problems is not new. For example, the Inter-Governmental Maritime Consultative Organization, a specialized agency of the United Nations, has long been an avenue for international community consideration of prevention of pollution of the high seas as well as the territorial waters of nations. Broadening interest is also evidenced by the plans of the United Nations for a Preparatory Conference on the Human Environment in 1972. Similarly, such regional international organizations as the North Atlantic Treaty Organization (NATO), the Organization of Economic Cooperation and Development (OECD) and the Economic Commission for Europe (ECE) are becoming increasingly involved with environmental matters. A promising element is that these bodies welcome cooperation of private organizations in their work.

At the same time, however, some nations which are greatly concerned with air and water conservation have initiated unilateral action which raises serious questions of jurisdiction under international law. Some nations have initiated programs to deal with environmental problems on a domestic basis. There are also international conventions dealing with pollution of the seas by oil and with pollution of some of the great international rivers. Yet it is fair to say that neither nations nor international organizations have truly begun to approach the conservation of our earthly environment on a comprehensive basis.

A. International Aspects of Environmental Conservation

There are certain conservation problems that are global in nature and to be feasibly dealt with require concert among nations. And the converse—unilateral action by many nations to cope with global environmental problems—can lead to myriad and difficult questions of conflict of laws and conflicts of jurisdiction. Other environmental problems which may be essentially domestic in effect will nevertheless demand a regional, if not global, approach if they are to be effectively resolved.

The threshold task of meeting the concern for development of proper international law in the field of environmental conservation would be to determine the problems of environmental conservation which lend themselves appropriately to an international solution. Illustratively, the following types of problems appear appropriate for international consideration.

Nations have an interest in promoting a satisfactory quality of international waters both of the high seas and of international drainage basin systems. Pollution of the high seas endangers the quality and resources of the territorial waters of coastal nations and of course the shores as well.

The point here is that comprehensive examination should be made, for legal purposes, of the conservation of the quality of high seas and the pollution of those waters from whatever cause, including radioactive wastes, excessive nutrients and the discharge of waste water of extremely high temperature.

Connected with conservation of the quality of the high seas is the interesting question of a coastal nation's jurisdiction to prescribe and enforce its laws outside its territory and territorial waters in order to prevent pollution damage to its territory and to punish those causing such damage.

In other words, does international law limit a nation's capacity to act unilaterally outside its territory to protect its territory from potential pollution damage? Unquestionably, such issues of jurisdiction should be carefully examined.

The exploration for and production of mineral resources from the subsoil under the high seas is estimated to be increasingly significant in the decades ahead. Here questions arise as to coastal nation jurisdiction over these minerals and the nature of the international regime to be established in the deep-ocean area seaward of such jurisdiction. Surely these resources should and must be produced for the benefit of the expanding world economy. This production, however, should be harmonized with the maintenance of a satisfactory quality of the surrounding marine environment.

It goes almost without saying that the earth's airspace or atmosphere is a matter of international concern, and for effective action an international approach will be required. The *Trail Smelter Arbitration* between Canada and the United States (discussed in Volume II) is an illustration of the general principle of nation-to-nation obligation under international laws in matters of atmospheric environmental conservation.

This report only attempts to indicate in brief the need for an international rather than a purely domestic approach to earth-space environmental problems. This is not to say that the earth-space environment could not be improved upon, perhaps adequately, through domestic action. However, concerted action among nations would provide a more effective approach.

Accordingly, over the months ahead, governments and international organizations, with the assistance of experts in environmental sciences, will be examining categories of problems that lend themselves to international or regional consideration. In these efforts, the experience of industry and its role must be taken fully into account if the resulting agreements are to have balanced and optimum effectiveness.

B. General Principles of International Law

The basic principle of international law is that a nation is generally limited in taking action that would cause injury within the territory of another nation. From judgments of specific cases, it can be concluded that there is a general international obligation among nations to refrain from conduct that would result in pollution to or within the territory of other nations.

C. Treaties and Conventions

Several international agreements that have been concluded, dealing with oil and gas operations and environmental conservation, are directed toward prevention of pollution of the seas.

Article 24 of the Geneva Convention on the High Seas, which is in force and ratified by the United States, obligates nations party to the Convention to prescribe laws or regulations to prevent pollution of the seas from petroleum operations, including exploration and production and transport by pipeline or ship.

The International Convention for the Prevention of Pollution of the Sea by Oil, 1954 and 1962, applies to specific sizes and types of sea-going ships, including oil tankers. Party nations are obligated to exercise restrictions on discharging oil or oily mixtures in certain zones of the oceans and to enforce various standards and practices designed to prevent pollution. The Congress of the United States enacted implementing legislation in 1961.

In November of 1969, the Assembly of the Inter-Governmental Maritime Consultative Organization convened a conference of nations in Brussels to consider the adoption of a convention or conventions on questions relating to marine pollution damage.

The Conference prepared and opened for signature and accession the following:

- The International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties.
- The International Convention on Civil Liability for Oil Pollution Damage.

The former would provide that party nations "may take such measures on the high seas as may be necessary to prevent, mitigate or eliminate grave and imminent danger to their coastline or related interests from pollution or threat of pollution of the sea by oil, following upon a maritime casualty or acts related to such a casualty, which may reasonably be expected to result in major harmful consequences."

The second of the 1969 Brussels Conventions, focusing on Civil Liability for Oil Pollution Damage, would, if it enters into force, "apply exclusively to pollution damage caused on the territory including the territorial sea of a Contracting State and to preventive measures taken to prevent or minimize such damage." Thus, applicability of the Convention is based upon the place of damage, i.e., the territory of a nation. With certain exceptions, the owner of a ship would be liable within specified limits for any pollution damage caused by the escape or discharge of oil from the ship as a result of an occurrence causing such damage.

Both of these draft conventions were signed on behalf of 16 nations, including the United States. The ratification and effectuation process will undoubtedly require considerable time for basic concepts of liability as between cargo owner and ship owner, as well as the basis and extent of liability are involved.

D. International Resolutions and Executive Agreements

In an effort to move toward treaties or conventions or develop international agreements of a less formal nature, nations often initiate resolutions by an existing intergovernmental group. The United Nations or its specialized agencies provide a normal forum for such activities. The planned 1972 U.N. Preparatory Conference on the Human Environment is an example.

Another more recently developed forum, through which the United States is making several far-reaching proposals concerning pollution by oil, is the Committee on Challenges to Modern Society, which is associated with the North Atlantic Treaty Organization.

A point of importance in international consideration of environmental problems is to ensure that resolutions and more formal actions are developed and implemented by the body most qualified to do so from the point of view of applicable expertise. Technical problems are best solved by groups constituted specifically to deal with such problems. The same is true for legal, scientific or economic problems. Although international action is ultimately taken by the participating governments, they should do so with the full cooperation of those elements of the private sector having relevant experience and expertise.

Regarding problems of environmental conservation and pollution control that are clearly of international concern, thereby involving the interests of many nations, the desirable approach should be to reach broadly based agreement among nations so that conflicting unilateral regulation by many nations would be avoided.

Industry Operations

Chapter Three:

The Fundamentals of Industry Operations

The purpose of this and subsequent chapters concerned with oil industry operations is to provide (1) a basic description of these operations and (2) an assessment of the problems faced by management in its efforts to meet public needs for both energy and environmental quality.

SECTION 1. OPERATIONS: THEIR NATURE, SCOPE AND EVOLUTION

The U.S. petroleum industry is comprised of more than 40,000 companies engaged in finding, producing, transporting, processing and marketing oil and gas and the products made from them. Collectively these companies employ about 1.5 million people and, with assets of $71 billion, constitute the nation's third largest industry.[55]

Some of these companies are engaged exclusively in one facet of industry operations (e.g., production, refining, marketing, transportation). These companies, whatever their size, are known as "nonintegrated" companies. Others, called "integrated" companies, engage in all phases of the business, while in between are those "semi-integrated" companies with two or more types of operation.

A. Exploration and Production

An extensive drilling effort is required to find and develop adequate oil and gas resources, and a large portion of that effort results in dry holes (Table 4).

While oil and gas are produced in 32 of the 50 states, only about 1.4 percent of the total land area of the country (31,309,585 acres) has proved so far to be productive.[56] At the end of 1970, there were 642,607 producing wells in the United States, of which 517,177 were oil wells and 125,430 were gas wells.[57]

Total U.S. production of crude oil for 1970 was 9,176,775 barrels per day (Table 5).[58] It has been estimated that domestic crude oil production needed in 1975 will be 10,080,000 barrels per day, and in 1980 will be 11,370,000 barrels per day.[59]

The marketed quantity of domestic natural gas produced in 1970 was 22.0 trillion cubic feet.[60]

A 1969 survey indicated that there were 840 gas-processing plants (normally considered a part of the production phase of the industry), with a total production of 70,061,-030 gallons of products per day.[61]

The industry's ability to maintain and expand its producing capacity depends on both a continuing program of exploring for new reserves and a developing technology for reservoir performance and production operations. In this report, special emphasis will be given to the discovery of new reserves through offshore operations, because of their increasing importance and because of the inherent possibilities for pollution.

Offshore areas now account for about 17 percent of the nation's total domestic crude

TABLE 4: Review of Drilling Operations For 1969 & 1970*

Type of Well	Number of Wells Drilled 1969 Exploratory	1969 Total	1970 Exploratory	1970 Total
Oil	1,084	14,368	850	13,750
Gas	616	4,083	550	4,050
Dry	8,001	13,736	7,000	11,650
Total	9,701	32,187	8,400	29,450
Total Footage Drilled		157,107,859		145,160,000

* Source: American Petroleum Institute, News Release (January 10, 1971).

TABLE 5: Review of Production for 1969 & 1970 Petroleum Liquids *

Type of Product	Daily Average Number of Barrels 1969	1970
Domestic Crude	8,778,071	9,176,775
Domestic Lease Condensate	459,603	454,822
Domestic NGL	1,589,701	1,680,085
Other Hydrocarbon	11,543	17,090
Total U.S. Production	10,838,918	11,328,772

* Source: U.S. Bureau of Mines, "Crude Petroleum, Petroleum Products, and Natural Gas Liquids, December, 1970," *Mineral Industry Surveys* (Monthly Petroleum Statement, published March 23, 1971).

Modern offshore oil-drilling platform in Alaska's Cook Inlet. Photo courtesy of Sinclair Oil Corporation

oil supply, even though practical methods for drilling and producing in offshore waters have been developed entirely since the end of World War II and the proportion of U.S. domestic crude demand supplied from offshore operations will continue to grow. The historic trend in offshore activity is shown in Figure 2.

Several technical improvements have helped increase productive capacity in recent years, offshore and onshore. These include hydraulic fracturing and the accelerated application of fluid injection. Other important factors include extensive use of unitized operations. Unitized operations and wider spacing have permitted the production of oil reservoirs with fewer wells, with consequent major savings in costs and the development and continued production of otherwise uneconomic fields. These and other technological advances have materially reduced the possibility of accidental pollution of land and water.

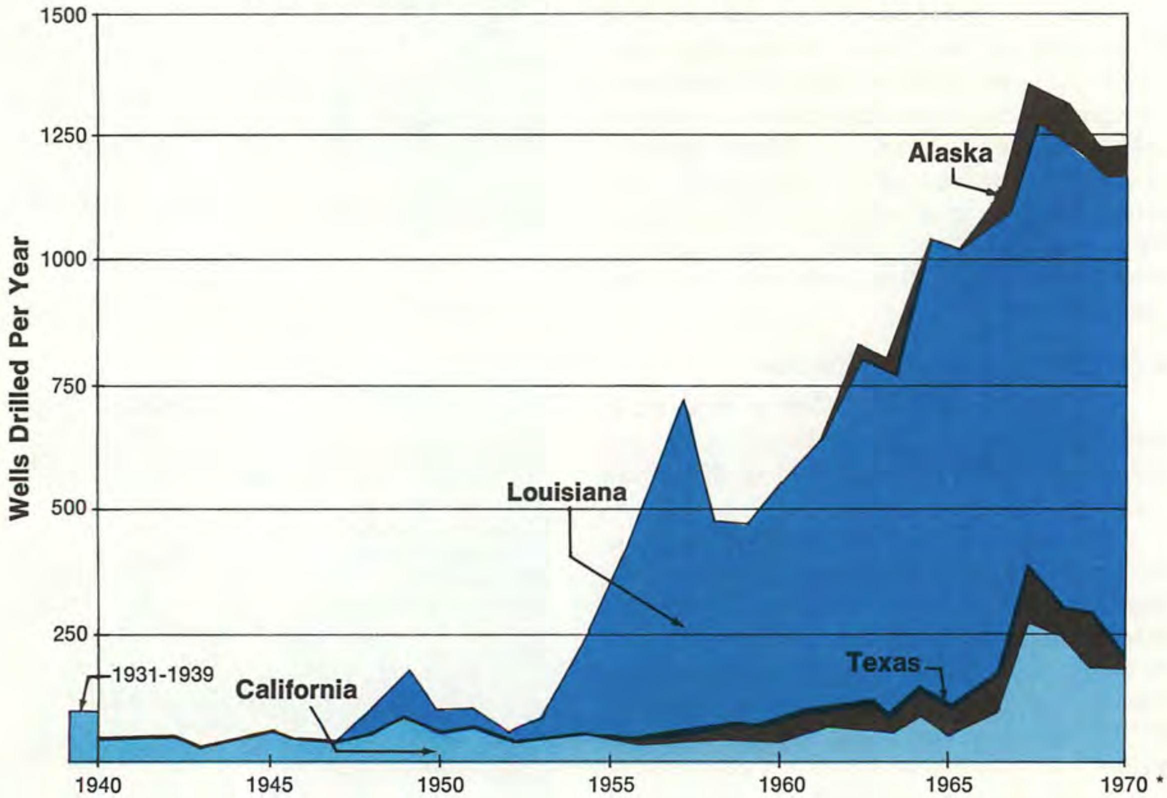
B. Refining

As of the end of 1970, the United States had 281 petroleum refineries, with a total processing capacity of 12.75 million barrels of crude oil a day.[62] Individual capacities range from less than 1,000 to 434,000 barrels

Figure 2

Annual Offshore Drilling on U.S. Continental Shelves

More than 14,000 Offshore Wells Drilled through 1970



* Estimate.

a day[63] and all have waste-water treating systems to handle various types of liquid and solid wastes. The geographic concentration of most U.S. refining capacity in a few states (as shown in Table 6) is an important consideration in evaluating the impact of refining on the nation's total pollution problem.

It is also significant that while U.S. crude processing capacity has increased by about 32 percent since 1960, the number of refineries in operation has decreased by 8 percent. Many of the smaller and older plants—generally the ones with less effective waste control systems—have been shut down, and the trend toward larger installations is expected to continue.

The mix of products from industrial refineries varies considerably because of differences in market requirements, type of crude and type of processing, but, on a national basis, the major products and their approximate percentage of total refinery yields are as follows:

Product	% Yield
Gasoline	44.8
Kerosine	2.8
Jet fuel	7.6
Gas oil and distillates	22.2
Residual fuel oil	7.6
Other products and plant fuels	15.0
	100.0

C. *Storage, Transportation and Marketing*

A large and efficient distribution system is the key to supplying the nation with adequate amounts of petroleum. Storage, transportation and marketing facilities and technology have improved in the interests of greater efficiency, safety and convenience; these improvements have often resulted in more effective conservation of the environment.

Terminal bulk storage facilities, New Haven, Conn.
Photo courtesy of Mobil Oil Corporation

1. Storage

The petroleum industry requires storage facilities for tremendous volumes of raw materials and products: tanks for crude and refined oils, pressure vessels for natural gas products, and underground storage or cryogenic storage for liquefied gases.

U.S. stocks of crude oil and products at the end of 1970 were estimated at more than 1,017 million barrels,[64] but that represents only part of the total volume of tankage required during production, processing, transportation and marketing.

Underground storage capacity for liquefied petroleum gas (LPG) in the United States in late 1968 was 152 million barrels. At

TABLE 6: Concentration of U.S. Refining Capacity*

State	Number Plants	Crude Capacity MB/CD	Crude Capacity % of U.S. Capacity	Cumulative % of U.S. Capacity
Texas	47	3,118	27.1	27.1
California	32	1,529	13.3	40.4
Louisiana	16	1,191	10.3	50.7
Illinois	11	704	6.1	56.8
Pennsylvania	13	629	5.5	62.3
Indiana	10	566	4.9	67.2
New Jersey	6	524	4.5	71.7
Total	135	8,261	71.7	

* Source: *Oil and Gas Journal* (March 24, 1969).

the same time there were 315 underground reservoirs for natural gas, with a capacity of 4.8 trillion cubic feet,[65] and as of June 1, 1969, ten storage facilities for liquefied natural gas (LNG) were operating with a total capacity of 4.6 billion cubic feet. Eight more LNG facilities had been proposed, with additional capacity of 12.4 billion cubic feet.[66]

Technological advances in the design and construction of steel tanks, particularly since World War II, have greatly accelerated a trend toward product conservation. Evaporative losses (with consequent vapor emissions) have been reduced by the introduction of vapor conservation systems, including floating-roof tanks.

2. Transportation

Crude oil, gas and other petroleum products used in the United States move by pipeline, barge, railroad tank car, tank truck and marine tanker, with economics the main factor in determining which mode is used.

Other factors being equal, the benefits of economies of scale are as applicable to petroleum operations as they are to other areas of the economy and ultimately result in cost savings to the consumer. For example, large pipelines, huge marine tankers, and jumbo tank trucks and rail tank cars are now needed. Indicative of the savings through increased size is an estimate that the transportation cost per barrel for a tanker run from the Gulf Coast to the New York City area is reduced by a factor of almost 3 for an increase in deadweight tonnage from 16,000 to 100,000.

a) Pipelines

Pipelines are the most widely used method of transporting crude oil, refined products, natural gas and LPG (see Table 7).

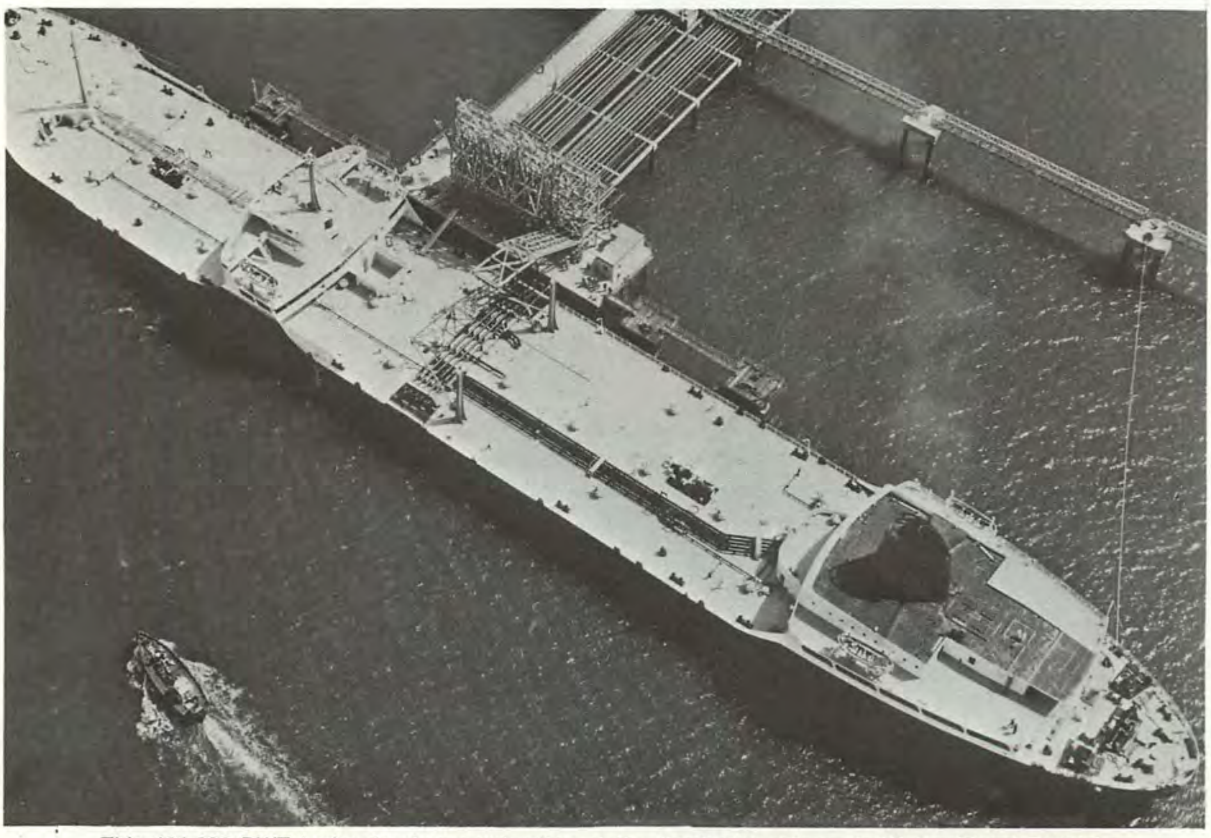
Total pipeline mileage in the United

TABLE 7: Petroleum Products Transported in United States

Mode of Transportation	Percentage of Product: Domestic Crude *	Percentage of Product: Refined Products †
Pipelines	82.33	30.92
Tankers and Barges	16.25	26.14
Rail Tank Cars	1.42 (Rail Tank Cars and Trucks combined)	2.46
Trucks		40.48

* Based on 1969 refinery receipts. Source: U.S. Bureau of Mines, "Crude Petroleum, Petroleum Products, and Natural Gas Liquids, 1969," *Mineral Industry Surveys* (Annual Petroleum Statement, December 15, 1970).

† Source: Association of Oil Pipe Lines, "Shifts in Petroleum Transportation, Table 3," Press Release (April 8, 1971).



This 101,000 DWT tanker is shown unloading at the Pembroke refinery in Wales (Great Britain).
Photo courtesy of Texaco Inc.

States at the beginning of 1969 was more than 1 million miles, as shown in Table 8.

TABLE 8: Pipeline Mileage for Crude Oil, Products and Natural Gas

Crude Oil *	
Gathering	74,124
Trunklines	70,825
Total Oil (as of Jan. 1, 1968)	144,949
Products Total* (as of Jan. 1, 1968)	64,529
Natural Gas†	
Field and Gathering	64,440
Transmission	233,940
Distribution	554,030
Total Gas (as of Jan. 1, 1969)	852,410
Total (all pipelines)	1,061,888

* Source: U.S. Bureau of Mines, "Crude-Oil and Product Pipelines, Triennial," *Mineral Industry Surveys* (December 23, 1968). Note: Recent informal estimates indicate no significant change in total oil pipeline mileage as of January 1, 1971, although the distribution is now essentially equal among the three types of pipelines.

† Source: American Gas Association, *1969 Gas Facts* (New York, American Gas Association, Inc., 1969).

New technology in the manufacture and laying of pipe has made possible the use of larger-diameter lines. At the same time, the industry has developed new welding techniques to match with safety the economic gains of high-strength, thin-wall steel pipe. The industry has continued to improve pipe coatings and cathodic protection to minimize the dangers of corrosion.

b) Tankers

Marine tankers not only are the sole means of transporting petroleum and LNG from overseas to the United States but also are the second most widely used means of moving domestic crude and products. The extent of the U.S. and world tanker fleets is shown in Table 9.

Currently the average tanker, worldwide, is approaching the 40,000 deadweight-ton class. However, the trend is toward much larger vessels, with tankers of 326,000 DWT already in service. Because of a number of restricting factors, plans to increase tanker size above 326,000 DWT appear to be limited.

Current port facilities in the United States are generally restricted to the relatively smaller tankers, with vessels in the 100,000-ton class being the largest that can presently be accommodated. On the other hand, technology exists for constructing offshore loading berths almost anywhere off the East or West Coasts of the United States to accommodate tankers of unlimited size. On this basis it is reasonable to assume that such facilities will be constructed in the foreseeable future.

TABLE 9: Size and Tonnage of Marine Tanker Fleets*

(Oceangoing Vessels of 2,000 Gross Tons and Over)

	Number of Ships	Total DWT	Average DWT
U.S. Fleet			
Present	365	8,797,900	24,100
Ordered †	22	1,458,000	66,300
World Fleet			
Present	3,893	146,029,100	37,500
Ordered †	570	59,328,000	104,100

* *Analysis of World Tank Ship Fleet, December 31, 1969* (Philadelphia, Sun Oil Company, Corporate Development Group, August 1970).

† On order or under construction as of December 31, 1969.

c) Barges, Rail Tank Cars, Trucks

Where the nation's approximately 25,000 miles of inland waterways are located, barging is the most economical means of transporting crude oil and petroleum products. Railroad tank cars, no longer widely used for crude oil movement, are often ideally suited for carrying special, limited-volume products. Tank trucks and trailers, now with capacities as large as 10,000 gallons, are important links in the petroleum distribution system. Table 10 shows the relative number of units and capacities of these three modes of inland and shallow-water transportation.

TABLE 10: U.S. Oil Transportation Capacities*

Mode of Transportation	Number of Units	Total Capacity (In 1,000 Bbls.)
Barges (Petroleum)	2,925	35,509
Tank Trucks & Trailers	81,300	11,840
Rail Tank Cars	185,228	50,631

* NPC, *U.S. Petroleum and Gas Transportation Capacities* (1967).

3. Marketing

While marketing systems exist for all petroleum products, the system for automotive gasoline is used here to illustrate the scope of the industry's marketing operations for two reasons: It is by far the most extensive, and it provides outlets for the industry's principal product.

Automotive gasoline is generally directed from a refinery or terminal to (1) service stations, (2) individual, large-volume "consumer" accounts, and (3) small bulk plants which in turn normally direct it to service stations or consumer accounts. A 1962 Los Angeles study indicated that 95 percent of automotive gasoline was marketed through service stations and 5 percent through consumer accounts.[67] Statistical information is not available on the total number of gasoline terminals and bulk plants in the United States. A rough estimate would be 20,000. There were 219,000 service stations in the United States in 1968. While the total consumption of automotive gasoline is expected to increase, recent industry trends indicate that the number of service stations will decrease. Thus the average station will handle a larger volume of sales.

SECTION 2.
THE MANAGEMENT OF CHANGE— A BALANCING OF PRIORITIES

The remainder of this chapter will review some of the major factors which must be taken into consideration by management—in government or the oil industry—before it decides on any course of action involving environmental conservation.

A. Control of Water and Land Pollution

Regard for the protection of both land and water from harmful spillages of petroleum liquids is essential in all oil industry operations. However, the circumstances that dictate the cost-effectiveness of preventive measures may vary considerably from one operation to another.

In exploring, refining, pipelining and marketing, the major problems are preventing small spills and containing them when they occur. Only in drilling and production and in the transportation of petroleum liquids by tanker or barge does the problem of large spills arise. Here the problems are to keep the number of such spills to a minimum and to be prepared to prevent damaging pollution when they do happen.

In any case, the proper control measures must be chosen to satisfy society's needs for safety, environmental conservation and an uninterrupted supply of energy fuels.

1. Production

Determining cost-effectiveness in production operations requires balancing requirements for low-cost basic energy against the increasingly difficult conditions under which petroleum must be found and produced.

The problem is compounded because it is almost impossible to determine the true cost of finding and developing a barrel of crude oil at any given time. Much depends on the amount of oil in the reservoir. Estimates of total recoverable oil made soon after discovery may not be accurate.

It has been established, however, that new technology in drilling and production has resulted in substantial cost savings. So has wider well spacing. It has been estimated that without developments in these two areas from 1950 to 1965, the cost of crude oil would be at least $1.00 higher per barrel produced.[68]

At the same time, the search for oil and gas has extended more and more into offshore regions, where expenses are substantially higher than for comparable onshore operations. Total exploration and development costs are expected to increase still more as water depths increase, with costs in 1,000 feet of water from three to five times those in 100 feet.[69]

A petroleum manager, then, must balance the effects of cost savings through technological improvements, the projections of increasingly difficult operating conditions, and the costs and benefits of environmental conservation.

2. Refinery Operations

It is also difficult to determine cost alternatives in dealing with refinery waste problems, partly because some facilities provide dual benefits in processing and pollution control.

The Environmental Protection Agency (EPA) has developed data on which it bases an estimate of the capital and annual operating costs of waste-water facilities for a hypothetical 100,000-barrel-per-stream-day refinery using typical technology at three different levels of treatment. The results are shown on page 57.

It should be emphasized, however, that many industry experts believe these costs to be too low. The ratios between costs may, on the other hand, be more realistic.

In any event, there can be no doubt that pollution control efforts will continue to have a major effect on capital spending and operating costs in the refining section of the industry.

	Degree of Treatment *		
	Low	Intermediate	High
Capital Cost	$219,000	$445,000	$1,126,000
Annual Operating and Maintenance Cost	33,000	72,500	187,000

* Low — Includes API separator plus slop-oil treatment.
Intermediate — Includes API separator, slop-oil treatment, aerated lagoon and foul-water stripper.
High — Includes API separator, slop-oil treatment, foul-water stripper, activated sludge, thickening, vacuum filtration and incineration.

Source: U.S. Department of the Interior, Federal Water Pollution Control Administration, *The Cost of Clean Water*, Vol. III, Industrial Waste Profile No. 5, Petroleum Refining (Washington, D.C., November 1967), Table 18.

3. Marketing

The disposal of used crankcase oil and used industrial cutting oils and lubricants is a lesser known but important factor which marketing managers must recognize in determining the cost-effectiveness of environmental control activities.

Re-refining operations, which formerly handled many waste oils, are becoming economically marginal. Consequently, disposal becomes a cost problem for service stations and auto repair shops as well as for larger industries.

Municipal sewage treatment facilities, if up-to-date and properly operated, can handle some oil, but this disposal problem needs further study. Burning appears to be one effective disposal method.

4. Oil-Spill Recovery and Containment

In determining cost-effectiveness, the containment and cleanup of spilled oil is perhaps the most difficult to assess of all environmental conservation activities. Operational costs can usually be measured in terms of expenditures for containment and cleanup action, but the benefits to society from such action are much more difficult to weigh.

The risk of spills is inevitable when society depends so heavily on large volumes of petroleum for its energy. The goal of the industry—already attained to a substantial degree in many operations—is to reduce that risk to its practicable minimum.

Top priority is currently being given to the development of equipment and techniques for containing and recovering large-volume spills in the open sea.

B. *Control of Atmospheric Pollution*

Control of atmospheric pollution is more a problem of the use of petroleum products than of the industry's operations. A detailed discussion on use of products follows in a later section of this report. However, some operational phases—notably refining—do have emissions control problems for which the cost-effectiveness of control measures is a significant management problem.

1. Refineries

The cost of adequate air-pollution control facilities in a refinery depends on many factors, including the complexity of facilities, types of crude processed, location and local regulations. Most refiners now consider that air-pollution control facilities will add at least 5 percent* to the overall cost of building a new refinery. This is about triple the percentage considered adequate in the early 1950's.[70] It is also equivalent to a cost of about $85 for each barrel-per-day of capacity of a new plant, which gives some indication of the magnitude of the costs involved.

Furthermore, installing air-pollution control equipment on existing refinery units is likely to cost from 150 to 200 percent of the amount for comparable equipment in new construction.

Not all such expenditures, of course, are without some economic return. A few years ago, an industry-wide survey showed that 37 percent of the expenditures for control equipment in 1960-65 had a good economic payout compared with normal investment practices. Another 31 percent had a fair payout, and 32 percent had a poor payout or none at all.[71]

2. Other Operations

Evaporative losses from storage tanks have not been shown to contribute significantly to air pollution. Control measures taken by the industry have generally been motivated by the desire to reduce product losses.

C. *Control of Noise and Light*

Noise and light, while more in the nature of annoyances than pollutants, can become problems, especially when refineries near urban areas are involved.

As in most other industry operations, complexity makes it difficult to determine the cost of noise abatement. From the limited information available, it appears that such a program at a typical refinery of 100,000-

* Five percent is estimated from the total cost of pollution control of 10 to 15 percent of overall cost.

barrels-a-day capacity could range from $100,000 to $250,000.

Light from refinery flares is negligible under normal conditions, while the cost of facilities to conceal such flares may occasionally reach $150,000 to $250,000.

Chapter Four:

Exploration and Production

The importance which the oil industry attaches to pollution control in drilling and producing operations is aptly indicated by the large investment required and provided, particularly offshore, to prevent mishap and to control our valuable petroleum resources.

This investment is made for sound business reasons as well as for meeting regulatory requirements and societal needs, for the destruction of an offshore platform or premature depletion of a reservoir by reason of ineffective safety or other control procedures would result in major financial losses to the companies concerned.

SECTION 1.
BASIC OPERATIONS FACTORS

In general, pollution engendered by drilling, completion, producing and pipelining operations is not a significant problem when properly controlled and, with the exception of a few spectacular accidental situations, has been handled to the satisfaction of all parties concerned.

Extensive operational experience in pollution control on land has equipped the oil and gas industries for handling similar problems in the newer province of offshore operations. The pollution control procedures involved in offshore operations are similar to land operations, although the control problem generally is more difficult because of the hostile environment in which the equipment must operate.

The principal difference between offshore and land operations is the possibility of catastrophic failure of the offshore well due to damage or destruction by shipping or storms. Therefore, highly sophisticated, remotely controlled, or automatically actuated safety devices are employed in offshore operations. Basically, these systems are designed to be fail-safe; that is, to be normally closed and to be opened only if any of a number of programmed all-clear conditions exist. Even the most sophisticated equipment requires man to exercise judgment to ensure control in any given situation.

Improvements in preventive actions have reduced spills or uncontrolled flows from wells to rare occurrences. Where such events have occurred, the petroleum industry has acted vigorously to devise means of preventing future pollution. Prevention and control of oil field pollution requires a never-ending effort involving research, planning, personnel training, equipment, safety features, automation and supervision.

SECTION 2.
WATER-COVERED AREAS

The primary activities involved in offshore exploration are geophysical surveys, bottom sampling and core drilling, of which core drilling is the only possible source of significant pollution from oil. In the past ten years, however, thousands of core holes have been drilled by the petroleum industry (under U.S. and Canadian government permits) on the shelves and slopes of all U.S. and Canadian coasts and no pollution has resulted. Additionally, the JOIDES (Joint Oceanographic Institute Deep Earth Sampling) deep-water coring program has, through December 1970, resulted in no pollution.

Pollution from offshore oil development and production operations can result from blowouts during drilling, from rupture of well casing due to storm or ship collision, from spillage of oil in storage at the surface and from pipeline leaks. Here again, however, the record of the industry is extremely good, insofar as incidents with a pollution potential are concerned.

It is estimated that over 14,000 offshore wells in U.S. federal and state waters had been drilled through 1970, if multiple completions are counted as one well. Approximately 9,000 wells have been drilled on the Outer Continental Shelf (OCS).[72] Yet in only 25 of these wells were blowouts experienced. Furthermore, only three oil-spill incidents (one off Santa Barbara in 1969 and two in the Gulf of Mexico in 1970) have been of a magnitude to cause any serious pollution threat.

Petroleum companies recognize the seriousness of such incidents and not only seek to improve ways of preventing them but also to control such spills when they do occur (see Chapter Seven).

The Federal Government establishes and enforces rules by which the petroleum industry must operate on the Outer Continental Shelf. Within state waters, inland bays and rivers, detailed rules are developed and enforced primarily by local governments—state, county and city. These rules are, in general, consistent with the rules which apply to areas of the OCS. That these regulations, procedures and practices have been effective in preventing serious acts of pollution is shown by their very low incidence of occurrence in offshore operations over the years. However, regulations must advance parallel to technology. As technology is improved, regulations must be revised and updated. To accomplish this, government and industry representatives must continue to work together.

A. Drilling

Offshore petroleum drilling operations are essentially the same as those for onshore drilling except that the rig is supported by a structure that rests on the bottom of the sea or on a floating vessel rather than on land.

Pollution of offshore waters during normal drilling operations is prevented by collecting mud and oil used in the operations and either separating the oil on-site for later disposal or disposing of the mixed waste ashore.

Normal well control is maintained through proper use of blowout preventors, riser pipe assembly, coupling devices, casing, drilling mud and well-trained drilling staffs.

Blowout preventors and related control equipment are tested as often as prudent operations dictate, but no less than that required by existing procedures issued by the regulatory agencies, and in each instance, the equipment is approved by the appropriate agency prior to receiving a permit to drill. The normal riser pipe completes the tie-in from the wellhead to the rig, while coupling devices permit the operator to disconnect from the well during storms and to leave the well shut in with the blowout preventors closed.

The casing program is approved by the regulatory agencies prior to receiving a permit to drill a well. A quantity of cement sufficient to cover and isolate all hydrocarbon zones and freshwater sands and to isolate normally pressured intervals from abnormally pressured intervals is used.

The drilling fluid, normally called "mud," must perform several primary functions, one of which is to keep the well under hydrostatic pressure control. Mud-testing equipment is maintained at the drilling site at all times and mud tests are performed at least daily or more frequently if conditions warrant. Here again, the drilling mud program is approved by the appropriate regulatory agencies prior to the granting of a permit to drill.

In some instances a light oil, such as diesel fuel, is used in place of some of the water in drilling fluids. The use of oil in this manner could be a possible source of minor pollution. However, self-contained systems are generally used to prevent pollution and all drill cuttings are treated for oil removal before their disposal, or are hauled to shore for disposal. Oil substitutes for use in drilling muds have been developed to further minimize the risk of pollution.

In normal circumstances, loss of drilling fluid to subsurface zones or encountering abnormally high pressured zones does not lead to a blowout. However, accidents can happen wherein control of pressures in subsurface zones is lost. It is these circumstances that allow a well to get out of control and permit situations to develop wherein pollution could occur.

Proper drilling systems equipment design and effective drilling staff training programs are all used to prevent loss of well control and/or a blowout. Since proper mud weight is the principal control of pressure in formations being drilled and those previously drilled but not cased off, elaborate mud system monitoring equipment is installed with strategically located indicators to monitor drilling operations that are taking place.

B. Well Completion

After a well has been drilled to the desired total depth, it must then be completed as an oil- and/or gas-producing well, or plugged with cement as a dry hole and abandoned. Exploratory wells require geological evaluation of the formations penetrated and extensive testing to determine their potential commercial value prior to completion. Additional wells are drilled to develop the reservoirs discovered by the exploratory wells.

The most accurate diagnostic method of evaluation prior to completion of a well is a "drill stem test" which involves the production of formation fluid to the surface through the pipe used for drilling the well. To prevent pollution of the ocean, the fluids that are produced during a drill stem test are collected in tanks at the surface. The drilling mud is returned to storage tankage, the oil not used for laboratory analysis is placed in a waste-oil tank for storage and subsequent disposal, and the gas, other than that collected for analysis, is burned by an appropriate flare arrangement.

After testing is concluded and it has been determined that the drilled well is to be completed as a producing or fluid injection well, the final string of casing is placed in the well and sealed to the penetrated formations with cement. Blowout preventors attached to a casing string installed during drilling operations guarantee control of the well during the completion operation. Regulations specify that cement around the production casing should extend up a sufficient distance to protect all potentially productive zones.

To ensure adequate control of well production and to permit future maintenance of the system, well fluids are normally produced through a relatively small-diameter tubing installed inside the production casing. Surface control valves (in a configuration known as a "Christmas tree") are normally installed at the surface, although a limited number of completions have been attempted using a "Christmas tree" installed on the ocean floor.

Surface control valves in a "Christmas tree" configuration, used on land or on a fixed platform over water.

Photo courtesy of Standard Oil Company (New Jersey)

Subsea completions will probably increase in the future, but they still represent experimental steps taken by the industry to improve and advance completion techniques. The history of subsea completions is too short to compare the pollution risks with those utilizing facilities installed at the surface.

A storm choke, or subsurface tubing safety valve, designed to automatically or manually shut in a well below the surface when production volume or pressure differential is excessive or when hazardous conditions are encountered at the surface, is generally installed in the tubing through which oil or gas is produced. Any failure of surface equipment, such as a line break which results in excessive flow, will close the safety valve. Most of these safety devices are required by federal and/or state regulations unless exceptions are obtained from the regulatory agencies for specific circumstances listed in the regulations. The conditions which merit exceptions are those which otherwise would make well operation impractical. Regulations provide for the installation of such valves in all wells not so equipped when storms threaten.

It is sometimes necessary to suspend operations on a well pending additional drilling. Where operations are to be suspended, cement plugs are set to confine fluids and prevent flow to the surface. If the reserves are found to be noncommercial, however, the well is abandoned by cutting off the casing beneath the mud line and above the top cement plug. Regulations specify the minimum length and location of plugs to be set, and approval of the abandonment procedure for each well must be obtained from the regulatory agency. During plugging operations, the danger of blowout is no greater than during drilling, since all control equipment remains in use.

C. *Production*

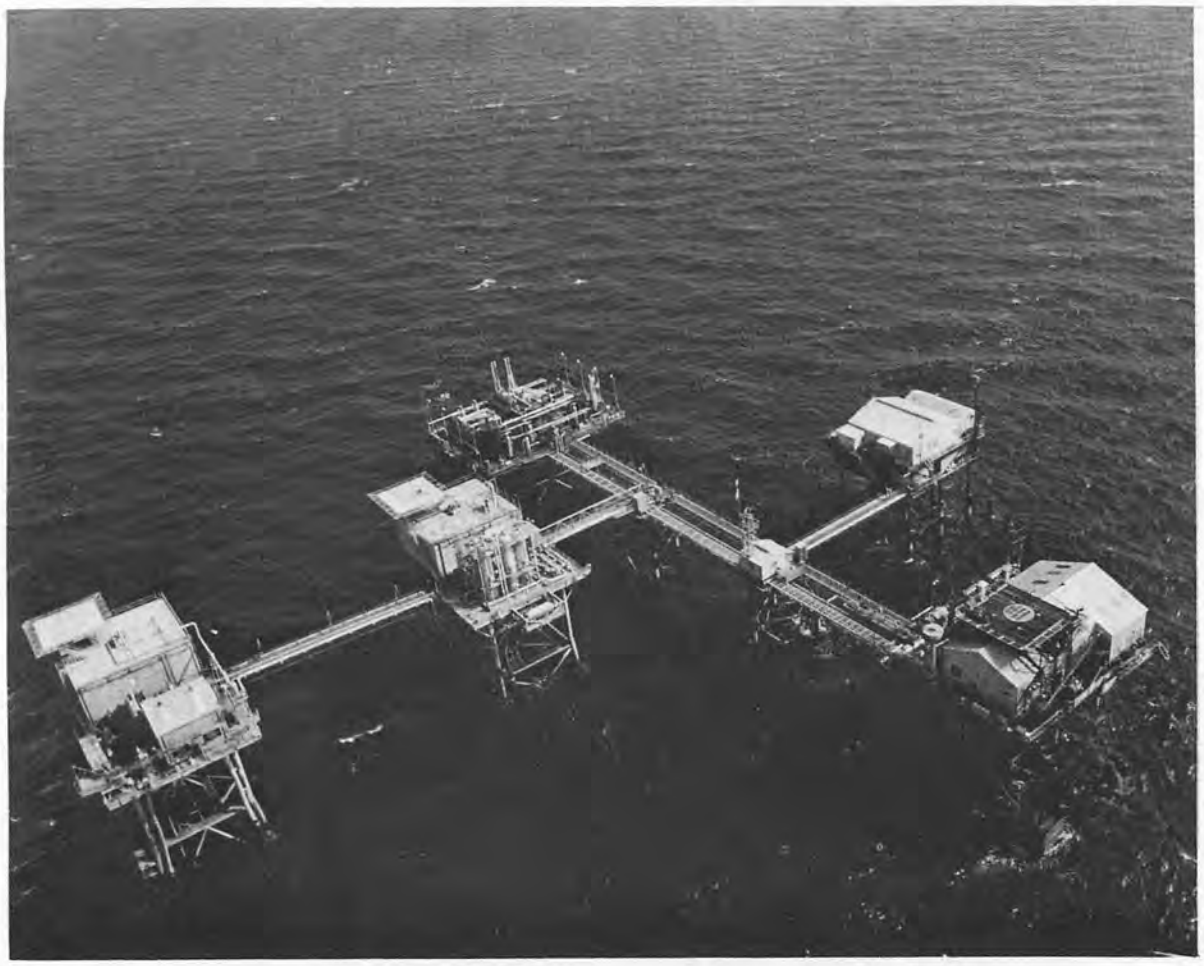
Petroleum liquid is almost universally associated with hydrocarbon gas which is in solution in the oil at reservoir pressure, but the gas becomes a separate phase as it migrates or moves through tubing and flow lines and as pressure is reduced. Formation water is often produced in association with the oil and gas. Offshore separation of gas, oil and water is the general practice, although the practice in some cases is delivery to shore for separation.

Safety features incorporated in the production and test equipment facilities normally provide automatic shut-in of the wells for a number of functions such as high and low pressure on the flow line or high liquid level in one of the separators. Shut-in controls may be actuated manually from a central control station or may be actuated automatically by such occurrences as a fire or other disaster.

After the produced fluids have been separated into the three basic components—gas, oil and water—they may be handled separately on the offshore structure. The gas usually constitutes the greatest hazard to safety, although it is less of a pollution problem than oil or produced water. Most production separators permit liquid particles to be carried over into the gas stream, and special scrubbers designed to remove this liquid must be installed before the gas can be sold or vented. When venting is necessary, the pollution potential is minimized by burning.

The water from a conventional production separator normally contains minute particles of oil which preclude its release to offshore waters without further cleaning to comply with regulatory standards. It has been common practice to clean the produced water at nearby onshore facilities so that it will meet environmental standards before release into the ocean or a disposal system. Recently, special filter media or other processing techniques have been developed so that produced water may be cleaned at the offshore facility and released directly into the ocean.

Periodic inspection and maintenance of all production equipment are essential if reliable operation is to be expected. Inspection, maintenance and repair of subsurface safety valves are required by regulations at 6- to 12-month intervals. Safety drills and operational checks are desirable to verify that all safety devices are functioning properly. All personnel must be trained to remedy any situation that may cause or contribute to pollution, and to report immediately to the next higher authority any situation which cannot be corrected immediately. Regulations also require immediate reporting of any significant oil spill to appropriate government agencies.



Air view of a modern oil and gas producing platform in the Gulf of Mexico.

Photo courtesy of Mobil Oil Corporation

Corrosiveness of the produced well fluids does not generally present a serious pollution problem in the destruction or failure of well tubing, flow lines or pressure vessels, and there is little direct danger of pollution resulting from corrosion of water-handling facilities. However, since any loss of control endangers the entire facility, corrosion protection of the structure in its entirety must be properly engineered and carefully supervised.

After an offshore well has been on production for a period of time, it is frequently necessary to conduct remedial work. In general, pollution hazards during workover operations are comparable to those experienced during drilling, and careful planning is necessary to ensure that a well is maintained under control at all times. In common use today as a control fluid is a treated salt water which can be weighted, will not reduce the productivity of the well, and, in addition, is relatively safe from a pollution standpoint.

Pumping acid into producing formations is a widely used stimulation technique in offshore wells. After treatment, the well is placed back on production and the spent acid, which has mixed with formation fluids, is separated from the produced crude oil and disposed of in the same manner as the salt water produced from the well. All oil and oil-contaminated salt water are placed in tanks for onshore disposal.

In some areas, the influx of formation sand into the wellbore presents a major obstacle to maintaining production. Most methods of controlling sand influx require that all of the sand be cleaned from the wellbore after the well "sands up" and goes off production. This sand normally is oil saturated and must be cleaned or transported ashore for disposal to avoid the danger of pollution.

Improved recovery techniques are applied to petroleum reservoirs to increase the amount of oil recovered above that which might be obtained by natural expulsive forces of the formation fluids. The most common improved-recovery devices are the injection of water or natural gas at high pressure. For a typical offshore waterflood, the water source may be (1) the surrounding body of surface water or (2) a freshwater or saltwater formation from which water is produced through a well in the same manner as it is obtained from wells for domestic use. If there should be a pollution problem in returning produced water to the sea, it can be reinjected into the subsurface formations. The use of high-pressure gas is more of a safety hazard than the use of high-pressure water in improved recovery techniques. If gas produced along with oil is not marketable, its use for reinjection may be a conservation measure, since later beneficial use may be preferred to waste by flaring.

SECTION 3.
LAND POLLUTION

On land, as in water areas, operating companies in the oil industry have given a great deal of attention to prevention of blowouts during drilling. As a result, in the eleven years, 1960 through 1970, only 106 blowouts occurred in the drilling of over 273,000 wells in eight major oil-producing states. Most blowouts are from high-pressure gas wells rather than oil wells. With gas, any ground pollution would be from drilling mud blown out of the hole or salt water produced with the gas.

In order to further reduce such occurrences, the producing industry and some service companies have developed training programs to give drilling superintendents, drilling engineers and operating personnel the necessary understanding, skill and practice in well control.[73]

During the extraction process, large amounts of salt water are produced as oil and gas fields age. Such water can create pollution problems from producing wells on land or freshwater-covered areas. Its proper disposal in these areas has been and continues to be of major concern to operators.

A study by the Interstate Oil Compact Commission (IOCC) shows that 72 percent of the produced water coincident with hydrocarbon production is being reinjected into the ground either for supplemental recovery of oil or into nonproductive saltwater-bearing zones. Prior to returning such salt water to underground formations, extensive geologic and engineering studies are made to ensure that no damage is done to freshwater horizons. Where proper natural conditions exist, this disposal method is desirable, both from commercial and ecological standpoints.

The IOCC study also indicates that 12 percent of the salt water extracted during production is put into nonpotable water bodies or approved disposal sites, or if suitable, used for irrigation or livestock. Government authorities do not permit disposal of salt water into freshwater streams, although it may be disposed of in saline bays and estuaries and offshore.

Another 12 percent is disposed of in pits where it evaporates into the atmosphere. Unlined pits are not allowed in some areas (e.g., Texas). However, where unlined pits are used, studies are being conducted to ensure that seeping water does not migrate into nearby freshwater supplies.

Good housekeeping practices are being increasingly followed during drilling and production operations, particularly in areas with problems of unusually fragile ecological balance, such as the North Slope of Alaska. Waste liquids are treated and neutralized in disposal pits, which are then refilled, after usage, with native soil to original grade. Efforts are being made to collect all trash and debris. Erosion is being guarded against in Alaska by the planting of new cold-climate grasses.

The industry has also been careful to control the abandonment of wells. In addition to action by regulatory bodies, most modern lease agreements spell out specific proper abandonment procedures.

SECTION 4.
AIR POLLUTION

A. Drilling and Completion

Of the relatively few blowouts which have occurred during the drilling of many thousands of wells, a majority have been from gas wells. In gas-well blowouts hydrocarbon vapors, mixed in some cases with hydrogen sulfide vapors, are the principal air contaminants. However, the contamination is principally airborne and is usually localized and temporary in nature. Because of the areas in which drilling operations are generally conducted, such contamination normally does not have a significantly deleterious effect.

Natural gas is sometimes used instead of mud as a controlling and circulating medium during drilling operations. Because it is impractical to reuse this gas, it is usually flared.

Well testing is normally of short duration and gas produced is also usually flared. The oil produced during well testing is often dumped into waste pits and burned. Such well-testing programs are only infrequent occurrences.

Conventional well-stimulation methods do not contribute to air pollution, but the use of nuclear devices for stimulation of gas wells could possibly allow radioactive substances to escape if proper control procedures were not followed. To date, only two nuclear devices have been fired, and preliminary results from both of these experiments indicate apparent success, with little or no pollution in the atmosphere.

B. Production and Processing

The production of oil and the production and processing of natural gas have a relatively low potential for air pollution.

Most of the air contaminants associated with the production of oil or gas are emitted as a result of the venting or burning of vapors and liquid waste materials. In isolated areas, where production facilities are widely scattered, control of air contaminants is difficult to monitor. However, the continuing development of new control devices, such as a smokeless or nonluminous flare for individual well settings, may be the answer.

If a use or market is available for the gases obtained with oil production, or in areas that have "no-flare" regulations which require that some use be made of the gases, the gases are separated, then gathered and transferred to a processing plant.

Following processing and treatment, the oil is usually moved into stock tanks. Normally the oil at this time has a higher than atmospheric vapor pressure, and the vapors are flashed off because of the reduced pressure in the tanks. These vapors are often rich in hydrocarbons, and are usually recovered and processed.

In the production of natural gas fields, the gas is processed at the lease for the removal of free liquids in a manner similar to the oil and gas separation that takes place in oil fields. Following the processing at the lease, the natural gas is gathered and moved to a central processing plant. Closed gas-gathering systems and storage vessels ensure control of possibly contaminating losses to the atmosphere.

Waste materials which cannot be recovered within a process plant are disposed of by means designed to minimize pollution. For example, vapors unsuitable for use in fuel systems are usually disposed of by flaring rather than by venting them directly into the atmosphere. Liquid waste materials are transported for recovery or disposed of in some other manner. Burning of liquid wastes is allowed by most state air pollution control boards when no other practical method of disposal exists.

Chapter Five:

Refining

SECTION 1.
BASIC REFINING OPERATIONS

A. Refining Crude Oil

Refining of crude oil into finished products is accomplished in four major steps—separation, conversion, treating and blending.

The crude oil is first separated into selected fractions. Some of the less useful are converted to products having a greater demand (e.g., heavy naphtha to gasoline) by splitting, uniting or rearranging the original molecules.

1. Separation

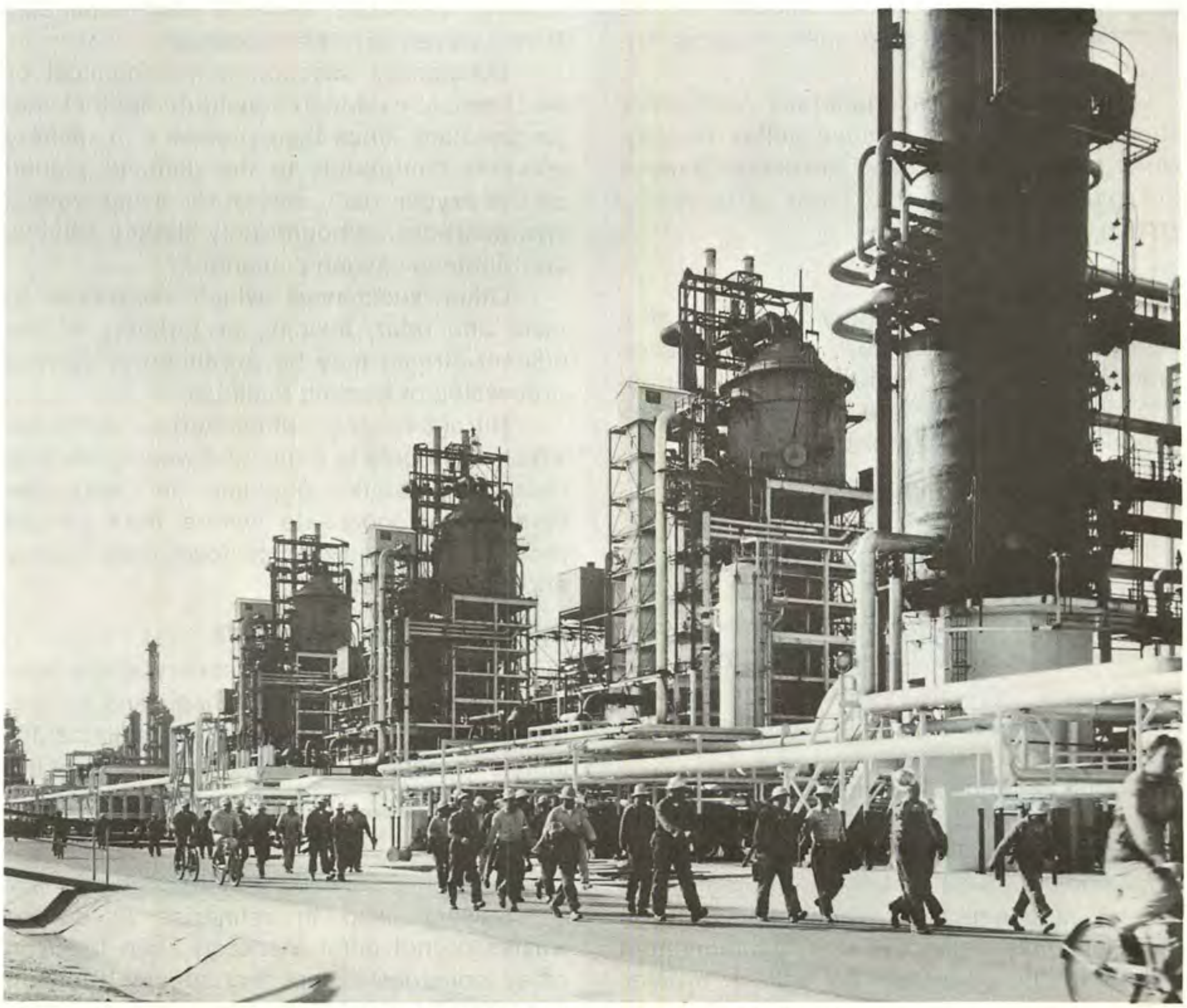
The most important separation process is fractional distillation, which depends entirely on the relative volatilities of various hydrocarbons.

In the distillation of crude oil, the feed is heated and partially vaporized in a furnace, then fed to a fractionating column in which it is separated into various fractions of various boiling ranges. The products of crude distillation range from noncondensable gas through gasoline, kerosine, naphthas and gas oils to a heavy residuum. Some of these fractions can be treated and blended into finished products, while others are used as feed to conversion or other processes.

2. Conversion

Conversion processes involve a change in size or structure of the hydrocarbon molecules.

In a cracking operation, large molecules are decomposed by heat into smaller, lower-boiling molecules. At the same time, some of the molecules combine (polymerize) to form larger molecules. The usual products of cracking are gaseous hydrocarbons, gaso-



Catalytic-cracking units at a modern oil refinery.

Photo courtesy of Cities Service Company line, gas oil, fuel oil and coke. Modern cracking practice is to apply heat to the petroleum fraction in the presence of a catalyst to increase gasoline yield and improve quality.

Hydrocracking is carried out in a hydrogen atmosphere at very high pressures. This produces only gasoline and jet fuel without coke formation.

Alkylation is a process for converting light, gaseous olefins into high-octane gasoline.

Catalytic reforming uses low-octane gasoline as a feedstock and, by molecular rearrangement, produces a gasoline of higher quality and octane number, along with quantities of hydrogen.

3. Treating

Sulfur removal from both product and intermediate feedstocks is important, not only for product quality, but because of the sensitivity of certain catalysts to sulfur poisoning.

The platinum catalyst used in catalytic reforming, for example, is extremely sensitive to sulfur poisoning. Sulfur is removed from the low-octane gasoline feedstocks for this process by catalytic hydrogen treating (hydrotreating).

Hydrotreating has generally supplanted chemical treating to remove sulfur directly. Other processes are used to remove various corrosive compounds from processing streams.

4. Blending

The last major refinery operation step involved in the manufacture of most finished products is blending. Motor gasoline, lubricating oils and asphalt are blended or "compounded" from base stocks.

B. Water Use in Refineries

Refineries are relatively small consumers of water even though they are large water users.

Freshwater intake of the refining industry is only about 0.7 percent of total U.S. withdrawals and its consumption is only about 0.25 percent of total U.S. consumptive use.

Cooling and condensing account for most of a refinery's total water needs. Ninety-seven percent of the total water requirement is for cooling. Such waters are generally not subject to chemical contamination, but on occasion they may become contaminated with oil from exchanger tube leaks or breaks. Although much smaller quantities of water are required for process purposes, the possibility of contamination is high. Water for steam generation is normally reused.

The water quality required for these uses varies, but only in steam generation is high quality especially important. Water quality is seldom the determining factor in locating a new refinery.

Water reuse is becoming an increasingly important factor in the design of refining water supply and waste-water control systems. It is particularly helpful in improving the quality of receiving waters by minimizing effluent volumes, while at the same time reducing the capital and operating costs of high levels of waste treatment. As water reuse, particularly for cooling purposes, continues to expand, raw water requirements per barrel of crude will, on the average, continue to decrease.

SECTION 2.
WATER AND LAND POLLUTION CONTROL

A. Sources of Refinery Contaminants

Oil is the most obvious pollutant from refining operations, and one which emanates from a variety of in-plant sources.

Substances susceptible to chemical or biochemical oxidation constitute another major pollutant, since their presence in refinery effluents contributes to the demand placed on the oxygen resources of receiving waters. Hydrocarbons, although only slightly soluble, contribute to oxygen demand.

Other substances which contribute to taste and odor, toxicity, or turbidity of the effluent stream may be produced in various processing or treating facilities.

Nitrogen and phosphorus nutrients, which contribute to algae and weed growth in receiving waters, originate in ammonia-containing condensate waters from certain process units and in blowdown from boilers and cooling towers.

B. Waste Control Methods

Broadly speaking, a refinery waste system usually includes a drainage and collection system; oil-water separation facilities; facilities to control pollutants causing toxicity, taste and odor; and—when required—some form of secondary treatment.

1. Collection and Segregation

Sewers used in refineries to collect wastes do not differ markedly from those in other industries except that special attention must be given to safety because volatile hydrocarbons are involved. The collection or drainage system is laid out to prevent drainage of surface waters subject to oil contamination directly onto adjoining properties or into adjacent surface waters.

2. Loss Prevention and Reuse

Normal small losses of products occur during most processing and handling of hydrocarbons. Included are such activities as loading and unloading (see Chapter Six).

In some refineries, piping is installed above ground on sleepers or on overhead racks to permit easy detection of leaks. Other loss-prevention practices include providing a) special equipment to pump out the contents of the towers, lines and vessels of process units when they must be shut down; b) special sewers and sumps to collect spills and losses of solvents or chemical treating agents; and c) substitution of surface condensers for barometrics where water and hydrocarbons come in direct contact.

3. Oil Removal

Since oil is the pollutant most closely related to refining, its removal is a main objective of refinery waste control. The basic unit for recovering oil is the gravity-type oil-water separator, the operation of which depends on the difference in specific gravity of oil and water.

Oil and suspended solids can also be reduced by flocculation, i.e., the addition of chemical coagulants to produce finely divided precipitates which are then agglomerated into larger clumps that can be removed by sedimentation.

Dissolved air flotation is another process for reducing oil and suspended solids to low levels. Its success depends on the use of very fine bubbles to increase the rate of rise of suspended oil or solid particles so they can be floated to the surface for removal.

4. Recovered Oil Treatment

Oil skimmed from API oil-water separators is not clean oil, but contains solids and water in emulsion form and is returned for further processing. Emulsions can be broken up by heating, distillation or centrifuging. Some emulsions can be broken under the influence of a strong electrical field, some by chemicals, some by a combination of the two.

5. Ballast-Water Treatment

Many refineries located on navigable waters have installed facilities for the disposing of ballast water from tankers and barges. The minimum treatment applied to ballast water involves simple settling in ballast-water tanks equipped with an oil-skimming device. Such a simple installation is not always adequate, and more complex and efficient facilities may be required to meet local objectives.

6. Disposal of Spent Chemicals

Some of the chemicals used in refining are employed in closed systems and do not present a disposal problem. Sale is frequently the most attractive method of disposal for other types. Caustics, for example, can be used in pulp and paper making and as a source of cresylic products.

Coastal refineries have disposed of spent caustics, acid sludges and chlorinated hydrocarbons far at sea, and such disposal is considered to cause minimal ecological damage.

Other disposal methods include regeneration, air oxidation and neutralization. Incineration is seldom used because refinery waste chemicals are usually either too low in fuel value or too high in constituents that would cause polluting stack emissions.

Deep-well disposal has not been used extensively for refinery wastes but its application for this purpose is receiving careful attention.

7. Process-Condensate Treatment

Various refinery processing operations produce waste water containing dissolved contaminants. These waters may have a high-oxygen demand and strong odor, and they may be toxic to aquatic life. Before discharge to the waste-water system they are commonly treated by stripping or oxidation.

8. Biological Treatment

Treatment by biological oxidation is a well-established procedure for removal of organic components in waste waters. Biological treatment depends on the use of bacteria and other organisms to metabolize waste. Selection of a particular type of biological treatment for a particular refinery can involve both the economics of construction and the quality of effluent.

The activated-sludge process is an aerobic biological treatment process in which organic impurities are removed by microorganisms suspended within an aeration tank into which oxygen is introduced.

A trickling filter employs a gelatinous film of slime, composed of aerobic organisms, over which waste water trickles. Both dissolved and suspended matter are removed by adsorption and then metabolized by the organism.

Trickling filters have the advantage of

producing less excess sludge for disposal than the activated-sludge process, although they are generally not capable of as high a degree of treatment.

Oxidation and stabilization ponds constitute another popular type of biological treatment system where land is plentiful. They depend on bacteria to stabilize organic wastes aerobically.

An interesting innovation in biological waste treatment by at least one refinery involves the use of cooling towers as oxidation towers. The process has been compared with both the activated-sludge and trickling-filter processes and has certain similarities to each.

9. Solid Waste Disposal

The principal sources of solid wastes in refineries are: coke fines, clays, catalysts, tank bottoms, basic sediment in crude oil, waste organic sludges from the various types of biological treatment processes, water-treatment sludges, and solids from surface drainage.

Solids entering the refinery waste system add to the problem of sludge disposal from waste-water treating units, but, perhaps more importantly, they tend to reduce treatment efficiency by stabilizing emulsions and by becoming coated with oil to the point that they do not settle because of reduced specific gravity.

The sludge from raw-water treatment is best handled at its source to avoid contact with oil in the drainage system. If space is available, such sludges may be settled in ponds. Centrifugation and vacuum filtration are effective dewatering methods. Sanitary land fill is commonly used for disposal of the solid waste from refinery operations.

Sludges containing oil, water and solids present the most difficult disposal problems.

Refineries are now employing more efficient methods for separating and disposing of oil sludge from water systems. The use of centrifuges for refinery oily wastes is relatively recent but increasing. Oily sludges and emulsions can be effectively handled by pressure or vacuum filtration. Ponding has long been an economical method of disposal. However, sludge ponds take up valuable space and may be odor sources. It is also becoming increasingly difficult to find satisfactory places to haul settled sludge from ponds.

According to recent tests, an effective, nuisance-free method of ultimate disposal of oily solids is to spread them on land where soil bacteria consume the hydrocarbons.

Excess biological solids are produced to some degree by most biological processes. Anaerobic digestion of waste sludge as practiced in municipal plants is not generally applicable in refineries. Aerobic sludge digestion followed by dewatering by conventional means may be required.

10. Other Treatment Processes

Consideration is being given to the application of a variety of so-called "advanced waste treatment" techniques that can be applied either to special waste streams or to the refinery effluent. Considerable research has been conducted on the use of activated carbon as a tertiary method of treatment to reduce oxygen demand and threshold odor numbers of refinery wastes to values below those obtainable with methods now in use. There are other examples of treatment methods which may be utilized as the degree of treatment needed to maintain proper receiving-stream quality increases.

11. Effluent Monitoring

Effluent monitoring is used to assess the pollution potential of the plant effluent, determine waste treatment performance, determine the effects of wastes on receiving waters, and comply with control agency requirements.

Although monitoring ordinarily is applied to the plant effluent, it may also be conducted in receiving waters.

Chemical and physical monitoring of effluent involves analysis of representative effluent samples. Because protection of aquatic life in waters is a major goal of effluent treatment, some form of biological monitoring in which living organisms are exposed, such as fish aquariums, has very dramatic and directly apparent results.

Stream monitoring may take several forms, including complete biological surveys of receiving waters, chemical analyses, and studies of animals living on or in bottom mud, as well as fish, plankton and other organisms.

12. Diffusion of Effluents

A growing number of refineries are finding it advantageous or necessary to use some type of diffusion mechanism for mixing and distributing or dissipating effluents in receiving waters. The use of such mechanisms —the last phase of the waste control system —can often reduce or eliminate undesirable localized areas of effluent concentration by speeding up the dilution process.

C. Waste Loads

The most comprehensive survey of refinery effluent characteristics ever conducted was carried out by the American Petroleum Institute in 1967.[74] The study assessed the industry waste loads and current waste control practice.

Data show that average values in terms of pounds of a particular contaminant per thousand barrels of crude for most contaminants increase with increasing refinery complexity. Similarly, within a given complexity category, intermediate and biological waste treatment procedures yield improved effluents as would be expected. Points of significance disclosed by the survey data are the seemingly superior performance of intermediate treatments over biological treatments for the removal of oil and suspended solids.

SECTION 3.
ATMOSPHERIC POLLUTION CONTROL

The major potential refinery emissions which may contribute to air pollution are sulfur compounds, hydrocarbons, particulates including smoke, nitrogen oxides and carbon monoxide.

A. Sulfur Compounds

Sulfur compounds constitute major refinery emissions unless available control techniques are employed.

Nearly all refinery processes generate some gases which contain hydrogen sulfide or other low-molecular-weight sulfur compounds. Fortunately, economical techniques are available for the removal of all but a trace of hydrogen sulfide in the gases utilized as fuel.

Combuston of residual fuel oils in process heaters and boilers can be a significant source of sulfur oxide. In this regard the refining industry is confronted with the same difficulties as other industries burning sulfur-containing fuels. Processes for removing sulfur oxides from stack gases, while known, are not currently generally employed commercially.[75] Processes are now being developed which can convert all residuals to distillates and lighter products, with procedures that permit removal of essentially all of the sulfur compounds.

Regeneration of catalytic-cracking catalyst by controlled combustion produces small amounts of sulfur oxides. Procedure for the removal of sulfur dioxide from catalytic-cracking flue gases has not been developed, but sulfur oxide emissions are greatly reduced (by 75 to 80 percent) when the cracking unit feed is desulfurized by hydrogenation.

Aqueous solutions from refinery processes will normally be contaminated by hydrogen sulfide. The most common procedure is to strip the hydrogen sulfide with steam. The stripped hydrogen sulfide can be processed in a sulfur-recovery system.

A two-stage sulfur plant is ordinarily capable of recovering 90 percent of the hydrogen sulfide as elemental sulfur; the remaining 10 percent is emitted from the incinerator stack as sulfur dioxide. A three-stage unit will normally recover 95 to 96 percent of the sulfur.

Although these units are major air conservation devices, their operation occasionally creates locally unsatisfactory ground-level concentrations of sulfur dioxide. New processes are being developed to remove sulfur dioxide from these stack gases.

B. Hydrocarbons

Hydrocarbon emissions in amounts normally released by refinery operations are invisible and nontoxic. Detailed surveys in Los Angeles by regulatory agencies show that only 10 percent of these emissions have high reactivity.*

Refinery storage tanks are a potential source of hydrocarbon emissions. Control techniques are described in Chapter Six (Storage, Transportation and Marketing). Another source is catalytic-cracking regenerators. Hydrocarbons are almost completely consumed, however, when the cracking units are equipped with waste-heat boilers or heaters.

Waste-water separators may be equipped with covers to prevent loss of hydrocarbon vapors. Hydrocarbon leaks to the atmosphere from pumps and compressors can usually be controlled with proper packing and sealing, while periodic inspection and maintenance of all units provide adequate emissions control from miscellaneous minor sources.

C. Other Emissions

The major potential sources of particulate matter emissions in modern refineries are catalytic-cracking regenerators.

Normally, two-stage conventional cy-

* A hydrocarbon with high reactivity is one which reacts readily with nitrogen oxides to form photochemical smog.

clones are located within the regenerator vessel for catalyst recovery and recirculation. The catalyst content of the flue gas is generally reduced by use of an additional cyclone or an electrostatic precipitator which treats the gas before discharge to the atmosphere.

Smoke is another potential pollutant from refinery operations. However, approximately 80 percent of the fuel utilized in the petroleum industry is natural gas, or refinery gas, which is easily utilized without production of smoke. Whenever liquid fuels such as residual fuel oils are burned, adequate and relatively inexpensive equipment is available to prevent all but a minimal amount of smoke.

Waste-gas vent flares can be a major source of smoke, which results from an inadequate supply of air in the combustion zone. Smoke can be virtually eliminated by the induction of additional air into the combustion zone through injection of high-velocity steam with flare tips.

New methods of disposing of oily wastes and sludges make it possible for most refineries to avoid burning them or to burn these materials in a smokeless manner.

The major source of oxides of nitrogen in a refinery is from combustion of fuel in process heaters and boilers. The amount of refinery emissions in an urban community, however, is relatively minor compared with other sources.[76]

The only significant source of carbon monoxide emissions in petroleum refineries is the catalytic-cracking regenerator. These emissions can be eliminated by incinerating the gases in waste-heat carbon monoxide boilers or heaters.

D. *Odors and Miscellaneous*

Odors associated with minor releases of unusual compounds are probably the most perplexing problems associated with refinery operations. Extremely small concentrations well below toxic or harmful levels cause complaints from nearby residents. However, these odorous compounds are usually destroyed by oxidation after a short time in the atmosphere.

The increased usage of hydrogen treating in place of chemical treating is simplifying the nuisance problem of malodorous compounds.

Good maintenance and operating practices must be employed to control odors that can be emitted from leaking equipment.

SECTION 4.
LIGHT AND NOISE

A. *Light*

On the basis of complaints by the general public, it does not appear that the average citizen finds the light provided for general illumination of refineries to be very objectionable. Light produced by refinery flares, however, is quite unlike that associated with general illumination.

During normal refinery operations, the flame is so small in size that the effect on overall illumination is negligible. However, when starting up or shutting down plants, or when process upsets occur, the venting rate to the flare will increase suddenly, with a pronounced increase in size of the flame and accompanying light. Annoyance can be minimized by placing the flares well away from residential areas or other locations where they are exposed to the public.

B. *Noise*

The major noise sources in oil refineries can be classified into four general categories: (1) noise produced by moving fluids confined within the process system, (2) noise produced by high-velocity jets of gas or vapor discharging to atmosphere, (3) noise produced by mechanical equipment, and (4) noise produced by combustion processes.

The noise associated with fluid movement originates from severe turbulence or vibratory impulses. In many cases, problems can be avoided by careful attention to design of piping system and selection of specialized equipment.

Noise from atmospheric vents can be controlled by limiting velocity and providing silencers.

With the exception of air coolers, most of the noise generated by mechanical equipment is usually only a problem within the refinery and seldom disturbs the community.

Reduction of noise from combustion processes has posed a difficult problem for the industry, but progress in its solution is being made as a result of cooperative efforts between refineries and suppliers.

On new plants, noise abatement begins with the selection of quiet equipment. In addition, there is usually sufficient flexibility in the layout and arrangement of facilities to allow higher noise sources to be located remote from the community, or to take advantage of shielding provided by other facilities.

Noise abatement on existing facilities is more difficult and apt to be quite costly.

Chapter Six:

Storage, Transportation and Marketing

SECTION 1. BASIC OPERATIONS

A. Normal Operations

Fortunately, from a pollution standpoint, liquid petroleum is handled almost exclusively in what, except for points of transfer, is essentially a closed system from source to customer. This is also true of natural gas.

B. Abnormal Operations

Petroleum systems are designed to hold the number of abnormal occurrences or upsets to a minimum, and emergency systems are available to accommodate the unexpected.

SECTION 2. WATER AND LAND POLLUTION CONTROL

A. Storage of Petroleum and Its Products

1. General Causes of Spillage

In petroleum storage, liquid spills are the only significant contribution to pollution, and their sources and causes are much the same wherever the storage tank is located. They include human error during transfer operations, leakage because of corrosion or other deterioration, and rupture by accidents.

Keys to prevention include highly trained and responsible operating people, inhibition of corrosion, frequent inspection, and—in the case of offshore facilities—adequate warning systems for major storms and ocean shipping.

2. Offshore Storage Methods and Problems

While most current U.S. offshore production is best delivered to shore by pipeline, the trend toward exploring in deeper waters may make offshore storage economical.

Overseas, such facilities are now being operated in water depths up to 200 feet. Types include above-surface, floating, semi-submerged, submerged-moored, and bottom-supported. An example is a 500,000-barrel bottomless conical tank in the Persian Gulf off Dubai.

Damage to offshore storage—and consequent loss of oil—could occur because of hurricanes, collision by seagoing vessels, blowouts at adjacent wells or fire. Certain structures could also be undermined by wave action.

Fire control systems are generally automatic, while adequate structural strength and stability must be engineered into the facility.

B. Transportation of Liquids by Pipeline

1. On Land

Considering the extent of the U.S. petroleum pipeline system and the volumes of crude and products moved, losses from spillage are remarkably low: approximately 6/thousandths of 1 percent of the volume moved annually, according to recent reports of the Department of Transportation.

Principal causes of pipeline accidents in 1970, again according to the Department of Transportation, were external corrosion (42.8 percent), outside sources such as earth-moving equipment (20.2 percent), and operating error (3.8 percent).

Properly applied coating and adequate cathodic protection are the keys to preventing corrosion leaks, along with periodic inspection and testing of the line.

Block valves, line-pressure sensors and automatic shutdown equipment are among the safety factors that reduce the loss of oil and consequent threat of pollution when leaks do occur.

2. Offshore

Offshore pipelines are laid on the sea bottom, sometimes in trenches to protect them from the current. Structural strength of the pipe is important because of such outside forces as current and waves, and particular care must be taken to be sure the pipe is not damaged by faulty construction practices that make it susceptible to failure while in use.

Pipeline terminals offshore must be protected against damage from storms or ship collision. Mechanical damage to the pipeline itself can occur from such causes as dragging anchors of ships.

C. Transportation of Liquids by Tankers and Barges

1. Sources and Causes of Spillage

While tankers present the potential for large-scale spills, studies indicate that more total sea pollution may result from the daily, permissible, discharges from other vessels. The following statistics indicate the size and complexity of the problem:

- *Vessels Over 1,000 Gross Tons—International*

13,832	Naval Vessels—all types
10,974	Dry Cargo Freighters
3,967	Tankers
2,676	Bulk Carriers
832	Refrigerated Vessels
966	Passenger-Freighter Combinations
33,247	Total

- *Vessels 1,000 Gross Tons or Under—U.S. Registry*
  42,242
- *Pleasure Craft—Non-certificated—U.S. Registry*
  5,000,000 +

Tank washing and dirty ballast discharges by ocean tankers engaged in international trade are a major cause of oil pollution at sea. Others are the pumping overboard of bilges and the discharge of raw sewage and food waste from literally millions of craft, large and small, on both ocean and inland waterways.

2. Methods of Improvement

The U.S. petroleum industry is among the sponsors of research to improve equipment reliability, including better ship designs and navigation systems, which in turn minimize pollution.

To combat pollution from oily tank washings or ballast, the industry has instituted "load-on-top" procedures and, in some instances, installed on-board oil-water separators.

Control of bilge pumpings from all vessels may be accomplished by the development of an on-board separator or the installation of holding tanks. The latter would be more comprehensive, but it would also require construction of adequate disposal facilities at terminals, shipyards and marine facilities.

Most new mammoth tankers are equipped with loading control facilities that minimize the chance of a spill attributable to human error during transfer of cargo.

Good maintenance practices on shipboard and the sound basic design of the vessel are other important factors in preventing spills.

Improved education and training of officers and crew—geared to the size and design of the vessel—plus more stringent navigation and traffic controls in crowded waters, will help reduce the possibility of spills caused by collision or grounding. Improved transportation support services, such as weather forecasting and navigational aids, would assist to minimize such accidents.

Increasingly coordinated efforts are needed between federal agencies and the shipping industry concerning marine operations and regulations. Efforts must continue through international organizations to improve international standards of vessel design and operation to prevent pollution.

D. Marketing of Products

1. Sources and Causes of Spillage and Wastes

In loading and unloading light petroleum products at terminals, bulk plants and service stations, spillage and resultant pollution can occur.

Improper disposal of used lubricating oils and other wastes from marketing operations is a potential source for pollution, although not a major one at present because of industry efforts to assure proper disposal procedures.

2. Methods of Prevention

An estimated 10 percent of the nation's 3,000 petroleum terminals have already installed some type of automated system designed to close down operations unless valving and safety devices are operating properly.[77]

Much has been done to reduce corrosion of underground steel tanks at service stations,[78] and fiber glass tanks not subject to corrosion are being used increasingly—as are underground leak-detectors.

Service station operators generally collect used lubrication oils in underground storage tanks.[79] The services of sludge, solid and liquid waste-disposal contractors are generally available to remove these products from the storage tanks.

The most promising method for ultimately disposing of waste oil is blending it with fuel oil as a boiler feedstock.

SECTION 3.
AIR POLLUTION CONTROL

A. Storage of Oil and Gas

1. Sources of Vapors

Hydrocarbon vapor is the principal contaminant involved in petroleum storage. In addition, objectionable odors may be caused by emissions of sulfur or nitrogen compounds. Emissions from storage vessels are generally caused by evaporation of liquids or boil-offs of liquefied gases.

2. Types of Storage Facilities

The type of storage facility required depends primarily on the volatility of the liquid to be stored. Lower volatility products, such as crude oil, can be stored in fixed-roof tanks. Floating-roof tanks are used for storing gasoline and other highly volatile substances. Conservation tanks include those with lifter-roof and internal, flexible diaphragms or internal plastic floating-blankets.

Products still more volatile than gasoline, such as propane and butane, must be stored in closed pressure vessels. Underground storage has also been developed for liquefied petroleum gases (LPG), while liquefied natural gas (LNG) requires refrigerated storage.

3. Methods of Control

The control of emissions from oil and gas storage facilities not only reduces air pollution but reduces fire hazards and helps recover valuable products. Studies generally show that pollution by reactive hydrocarbons from petroleum storage tanks is so small that controls for pollution-control reasons alone can seldom be justified.

Several methods of controlling emissions are generally used, among them variable vapor space systems. As storage tanks are filled or emptied, or when the temperature changes, vapors are displaced into and out of a special vapor holding tank. Excess vapors are piped into a fuel system or to a smokeless flare for incineration. Vapor recovery systems operate much the same way, except that certain substances in the emissions are recovered.

Use of selected materials, such as proper paints for tank shells and roofs, and equipment can assist in controlling emissions. Plastic foam has also been proposed as a means to reduce evaporation losses.[80]

Scheduling liquids into and out of storage tanks so that they are pumped in during cool hours, withdrawn during warm hours, and pumped at short-time intervals can reduce emissions.

B. Transportation of Oil and Gas

1. Sources of Vapors

Hydrocarbon vapors are the major air contaminants associated with petroleum transportation. Their emission occurs primarily during filling operations of tank-type carriers.

2. Methods of Control

In either the bottom-loading or overhead-loading types of filling operations, some hydrocarbon vapors are displaced as the tank is filled. In the overhead method, a submerged filling technique results in lower hydrocarbon vapor concentration. Marine tankers are usually filled using the bottom-loading method; tank vehicles and rail tank cars use both.

Effective collection systems have been developed for the control of vapor emissions during loading operations.

C. Marketing of Petroleum and Products

1. Sources of Vapors

As in storage and transportation, the significant pollutant in marketing is hydrocarbon vapors.

While delivery from terminal to service station is a marketing function, losses to the atmosphere at this stage are negligible. However, hydrocarbon vapors are displaced from the station's underground storage tanks as they are filled. Submerged filling devices reduce the amount of these emissions.

Hydrocarbon emissions at service stations are responsible for only about 3 percent of total hydrocarbon emissions in uncontrolled urban areas.[81] Gasoline-powered motor vehicles themselves account for 52 percent. However, better information is needed on how much loss is actually incurred during the refueling of automobiles.

2. Methods of Control

It is not practicable to convert hydrocarbon vapors back to liquids at service stations. Instead, some form of vapor-for-liquid recycle seems technically feasible, although its cost-effectiveness is open to question.

Useful research could be continued on a means of eliminating vapor space in the automobile fuel tank.

Chapter Seven:

Major Oil Spills

Oil spills, large and small, have long been of concern. Unfortunately, as with oil-well blowouts, mechanical and human failures and the hostility of the environment cannot be completely removed as causes of occasional oil spills.

A recent comprehensive study by the Dillingham Corporation for the American Petroleum Institute included, among other things, (1) an analysis of past major spills, (2) a delineation of geographic regions of primary importance, and (3) an analysis of the environmental characteristics which could affect and be affected by oil spills.[82]

SECTION 1.
CONDITIONS ATTENDANT TO SPILLS

A. Relevant Facts About Past Major Oil Spills

Classification of an oil spill as major or minor is a value judgment usually based on the volume of oil spilled. Numerous leaks, spills and seepages of varying volumes have been recorded. Dillingham chose to limit their discussion to spills over 2,000 barrels and to label them "major."

Information was compiled on 38 such spills which occurred during the period from 1956 through 1969. The examination included the location of the incident, the petroleum product involved, the quantity of materials, the rate of spillage, the nature of any water or shoreline contamination that resulted, the duration of the incident, the weather conditions during the incident, the type of shoreline affected, and the control approach that was employed. A summary of the findings follows in Table 11.

Thus, on the basis of their analysis of past spills, the typical situation that will be encountered in a massive offshore spill is that (1) the source of the spill is likely to be a tanker, (2) crude or residual fuel oils are likely to be involved, and (3) the size of the spill will probably be more than 5,000 barrels. The spill will probably occur within a few miles of shore, and the duration of the spill incident will be more than five days. The shoreline threatened by the spill will be at least partially recreational, with a reasonable chance that only light coastal contamination will occur. Further, it is fairly likely that the spill will occur within 25 miles of a port suitable for staging control action, and more likely not more than 50 miles from such a port.

B. Geographic Regions of Primary Interest

In order to determine which coastal areas should receive primary attention regarding oil-spill control preparedness, Dillingham, utilizing statistical data on petroleum volumes, outlined those coastal regions with a large volume of tanker traffic in which large quantities of heavy oils are being transported. These include the Northeastern regions extending from Virginia to Maine, inclusive, where close to 2 billion barrels of petroleum products are handled annually; and the Central and West Gulf Coast regions from Alabama to Texas, inclusive, where approximately 1.3 billion barrels are handled annually and where the most extensive offshore oil fields in the world are located. Other regions with lesser volumes include the Florida Straits, with an annual transit of over 400 million barrels; the Pacific Coast's major ports, handling between 80 and 200 million barrels each; and the Panama Canal Zone with approximately 100 million barrels.

Comparison of the locations of 19 major spills in U.S. waters with areas designated as of critical or major importance shows that 15 of the 19 spills, or more than 75 percent, were in or near the areas designated. This close relationship tends to reinforce the rationale used in selecting areas likely to experience future spills.

TABLE 11. Past Major Oil Spills

Source	75% were associated with vessels
Composition	90% involved crude or residual oils
Volume	70% of the spills were greater than 5,000 barrels
Distance offshore	80% occurred within 10 miles of the shoreline
Duration	75% of the spill incidents lasted more than five days
Extent	80% contaminated less than 20 miles of coastline
Coastline	85% occurred off shoreline considered to be recreational
Distance from port	75% were within 25 miles of the nearest port

C. *Environmental Factors Affecting Control*

In examining the environmental characteristics associated with a major oil spill in coastal waters, an analysis was made of those factors which appear to be most significant with regard to their effect on floating oil and possible constraints on control activities:

- Little effective control action is possible from smaller vessels in wave heights above 6 feet.
- Contaminant booms or oil recovery devices are not useful in wave heights above 3 feet.
- Wind data should be maintained to predict the approximate direction of a drifting oil slick and the onshore area most likely to be affected.
- Successful containment of floating oil is unlikely where surface currents of 1 knot or better are setting the oil against a floating boom or fence, or, conversely, where the boom is being moved through the water toward the oil at this speed.
- The effects of tides, in addition to generating tidal currents, may significantly complicate shoreline protection and cleanup where large tidal ranges are experienced.
- Changing tides will distribute oil over a band on the beach marked by the high- and low-water lines.
- Low air or water temperatures increase the viscosity of the oil, thus increasing the tendency of the heavier fractions to persist.
- Temperatures above 60 degrees Fahrenheit appear to be necessary for successful use of dispersants.
- Poor visibility because of fog, rain or snow may have the most significant effect by restricting vessel operations and by limiting observation of drifting oil slicks.

SECTION 2. OIL-SPILL CONTROL MEASURES

A. *Containment and Recovery*

1. Mechanical Methods

Spilled oil can be contained by floating booms constructed to prevent the oil from carrying under or slopping over. Booms are used primarily to contain oil by encirclement, to sweep oil to a collection point, or to direct oil by forming a barrier along which a slick moves to a collection point. Currently available booms are ineffective for containing oil except in protected harbors and calm inland waters. However, for such service, they are easily positioned and are effective.

Air barriers have been used in harbors at oil tanker terminals, but to be successful must be tailored for each installation. They have been found effective in offshore operations.

Containment of ocean-floor seeps has been accomplished by using underwater hoods or tents to collect the seep oil and carry it to surface containers through flexible piping.

Mechanical devices for recovering floating oil fall into three classifications: oil adhesion, open skimmer and floating-surface skimmer. None of these systems are satisfactory for recovery of large oil spills in heavy seas.

2. Use of Sorbent Materials

Next to containment and mechanical recovery, the sorption of oil and subsequent removal of sorbent from the water surface provides the most desirable method of oil-spill control. Generally speaking, sorption materials present logistical problems of both dispersal and collection which are not adequately met with present equipment. Disposal of oil-soaked mixture can be by incineration or landfill.

B. *Treatment*

1. Natural Processes

There is substantial evidence that many microorganisms in both saline and fresh waters have great capacity to degrade hydrocarbons. Given no other problems, the best treatment of an oil spill would be the natural dispersion by winds, waves and currents, and microbial degradation. Unfortunately, this natural treatment is precluded except when prevailing winds and currents carry the oil away from shorelines and areas of habitation, recreation and commerce. Biological conversion of spilled oil could possibly be accelerated by addition of nutrients and agitation.

2. Combustion

Destroying oil slicks by combustion has been attempted, but with little reported success. Generally, ignition in the early periods of an oil spill is not desirable because of danger to both personnel and property. After weathering on the ocean surface, crude-oil volatiles are lost, making ignition and continuous burning difficult.

3. Sinking

Materials for sinking oil have been available for many years, but their use has never been widely accepted because of objections by regulatory agencies responsible for fish and game. There is widespread concern that sinking merely transfers a pollution problem from the water surface to the bottom environment.

4. Dispersants

Chemical dispersants have been widely used to control past oil spills. There are a large number of effective products available and their method of application is relatively simple. However, the use of dispersants is frequently restricted because of the possibility of toxicity to marine life, espcially in enclosed or shallow waters.

C. Contingency Plans and Cooperatives

Late in 1969 the American Petroleum Institute prepared and distributed to the industry a model contingency plan dealing with oil spills.[83] In addition, the API has been urging its member companies to form harbor cooperatives for the pooling of equipment when an oil spill occurs beyond the capabilities of the individual company. In early 1970 there were 42 such industry cooperatives in existence and 35 more under development.

D. Cleanup and Rehabilitation

Cleanup and rehabilitation entail a tremendous variety of problems, particularly when beaches are involved.

1. Beaches and Harbors

As shown by the Torrey Canyon experience, the use of detergents and dispersants in sea operations can make cleanup of sandy beaches particularly difficult by forming a detergent-laden quicksand. Greater success with the particular oil involved was obtained by the use of straw to collect oil at sea and on beaches, followed by the removal and disposal of the oil-soaked straw. Such straw mulches were also successfully used in beach cleanup following the Santa Barbara spill.

Boats fouled by surface oil present another cleanup problem when harbor areas are involved.

2. Marine Life and Birds

Crude oil has a variable toxicity to marine organisms, depending on its composition and period of weathering. Once the volatile fractions have evaporated, the residue is relatively nontoxic to marine life except birds. It is possible to reduce the impact of an oil spill on seabirds through prompt retrieval and correct treatment.

E. Research Needs

Much research is needed on containment and recovery methods at sea and a considerable effort is under way. Current efforts must be continued and additional funds allocated for oil spill control research. This is an appropriate area for joint industry-government effort.

In addition to research efforts on containment and recovery of oil at sea, some other specific areas for research to improve control are:

- Methods of off-loading tankers at sea in an emergency situation.
- Methods of identifying oils, both in producing areas and in transportation, for proper identification of sources of pollution.
- Definition and classification of oil-spill treating agents for both offshore and onshore, to provide guidance and safeguards in their use.
- Advanced techniques for rapid and efficient beach and shoreline cleanup, restoration of these areas, and methods of disposal of cleaned-up oil.
- Development of improved material specifications, testing procedures and instrumentation.
- The fate and behavior of oil on water and its true effect on the marine environment.

Use of Industry Products

Chapter Eight:

The Fundamentals of Product Use

The demand for petroleum products has grown enormously in the past quarter century in both volume and complexity. During this period demand for all products has increased from less than 5 million barrels a day to almost 15 million barrels a day in 1970. The most spectacular growth has been in the use of aviation fuels, where consumption has increased approximately 30 times the amount used at the end of World War II.

The quality of virtually all petroleum products has been improved significantly during this period. The result has been more efficiency with less polluting emissions, such as those caused by sulfur.

SECTION 1.
PETROLEUM FUEL DEMANDS SINCE WORLD WAR II

Petroleum products provide a major part of energy for transportation, a substantial part of the energy for the production of electrical power, and the raw materials for many of the products throughout our economy. They provide the mobility required for national security and contribute greatly to the economic welfare of our society.

The chief factors contributing to the rapidly growing demand for petroleum are the increasing population and the rapid growth in the demand for energy. The U.S. per capita demand for petroleum products has more than doubled since World War II. Table 12 summarizes the U.S. growth for all oil products since 1946.

The salient statistics of the factors affecting the demand for petroleum products are shown in Table 13.

The United States has become a nation on wheels. Four out of five workers use an automobile for commuting to and from work. Over 80 percent of the vacationing public use their own automobiles for transportation. The

TABLE 12: U.S. Domestic Petroleum Product Demand by Uses *

	1,000 B/D						Avg. Annual Increase %	
	1946	1950	1955	1960	1965	1970	1946/70	1960/70
GASOLINE								
Automotive	1,920	2,534	3,353	3,845	4,592	5,785	4.7	4.2
Aviation	35	108	192	161	120	54	1.8	(11.5)
Special Naphthas †	60	82	110	124	147	242	6.0	6.9
Total Gasoline	2,015	2,724	3,655	4,130	4,859	6,081	4.7	3.9
JET FUELS	......	......	154	371	604	965	......	10.0
INTERMEDIATES (Kerosine & Distillates)	909	1,405	1,912	2,143	2,393	2,803	4.8	2.7
RESIDUAL OILS	1,315	1,517	1,526	1,528	1,607	2,204	2.2	3.7
LUBRICANTS	96	106	117	117	129	136	1.5	1.5
ASPHALT & ROAD OIL	135	179	254	302	368	447	5.1	4.0
LP GAS	109	234	404	621	841	1,016	9.8	5.0
ALL OTHER	333	342	438	449	503	944	4.4	7.7
Total Domestic Demand All Petroleum Products	4,912	6,507	8,460	9,661	11,304	14,716	4.7	4.3

* Sources: U.S. Bureau of Mines, *Mineral Industry Surveys* (Monthly & Annual Petroleum Statements; Annual Sales of Fuel Oil & Kerosine; Annual Sales of Liquefied Petroleum Gases. Latest Survey: March 23, 1971).

† 1965 and 1970 include naphtha 400° for petrochemical use—65 and 157 MB/D, respectively. Earlier years estimates @ 3% of total gasoline demand.

TABLE 13: Factors Affecting U.S. Petroleum Product Demand

UNITED STATES	1946	1950	1955	1960	1965	1970
Total Population (000's)	141,936	152,271	165,931	180,864	194,572	205,400
Per Capita Income Current $	1,249	1,496	1,876	2,215	2,746	3,334
Per Capita Income Constant 1958 $	-----	1,810	2,027	2,157	2,507	2,521
GNP*—Billion Current $	211	285	398	504	676	977
GNP—Billion Constant 1958 $	313	355	438	488	610	724
FRB† (1957-9 = 100)	60	75	97	109	143	168
Motor Vehicle Registration (Millions)	34.2	49.2	62.8	74.5	91.8	109.0
Passenger Cars	28.2	40.3	52.1	62.3	76.6	89.9
Trucks and Buses	6.0	8.9	10.7	12.2	15.2	19.1

* Gross National Product—a measure of total goods and services produced by the nation.
† Federal Reserve Board Index—a measure of the nation's industrial production.

trend in automobile use and its effect on gasoline demand is shown in Table 14.

TABLE 14: Factors Affecting U.S. Gasoline Demand

	1946	1955	1965	1970
Annual Gasoline Usage				
Bbls. per person	4.94	7.36	8.61	10.28
Bbls. per household	19.20	27.40	28.70	33.41
Gallons per car	665	644	649	735*
No. of Passenger Cars, Millions, Year End	28.20	52.10	76.60	89.86
Persons per Car	5.05	3.20	2.61	2.29
Cars per Household	0.75	1.07	1.29	1.42
Total Gasoline Demand (MB/D per Billion Current $ GNP)	9.55	9.18	7.19	6.22
Population (Midyear Millions) Total	141.94	165.93	194.57	205.40

* Estimated.

Air travel developed rapidly after World War II, causing rapid growth in the demand for aviation gasoline. The jet age began in the 1950's, creating a demand for an entirely new fuel. Faster and larger planes were required to supply the very rapidly increasing demand for air travel. Although Americans travel more than the rest of the world combined, air travel in the United States is still in the early stages of growth.

The demand for oils for space heating increased sharply after World War II chiefly because of the switch from coal to oil and gas for home use. Today almost two-thirds of the homes are gas heated. In 1946, 2.7 million homes in the U.S. were centrally heated with oil; this increased to 11.2 million homes by 1969.

The demand for residual fuel oils for heating large buildings rose substantially after the War because of the large increase in new construction of such buildings. In the past few years the demand for residual fuel oils has taken a sharp increase as a result of industrial and electrical power plant usage. Nuclear power generation has not developed as rapidly as previously anticipated and coal has not been able to fill the increasing demand for low-sulfur fuels. During the period from 1946 to 1970, residual fuel oil has experienced an overall growth rate of 2.2 percent a year. However, annual growth for this fuel increased 8 percent in 1969 and over 11 percent for 1970.

Liquefied petroleum gas (LPG) is a large-volume product which has experienced an overall growth rate since World War II of approximately 10 percent a year and has continued at a rate of about 5 percent since 1960.

SECTION 2.
PRODUCT DEVELOPMENT—CHARACTERISTICS AND IMPROVEMENTS

A. Motor Fuels

1. Motor Gasoline

Since World War II gasoline has changed from a rather simple hydrocarbon to a product made by careful blending of refinery stocks prepared by involved new processes and special additives developed in extensive research programs. The most outstanding change in gasoline during this period has been vast improvement in antiknock quality. Higher octanes have permitted automobile manufacturers to produce high-compression, high-performance engines with better fuel economy and/or increased power, depending on the consumers' desires. Higher octanes have been obtained largely by new refining technology and processing, including better desulfurization of gasoline blending stocks which has made the lead antiknock additives more effective. During this same period the control of gasoline volatility has improved, contributing to better engine performance.

Many of today's gasolines contain special detergent or dispersant additives to help maintain a clear carburetion system, resulting in improved engine performance, better mileage in city driving, reduced carburetor maintenance and reduced exhaust pollutants.

At present, active consideration is being given to regulations limiting lead alkyl content of motor gasolines. The primary reason for these considerations is the expectation that low-lead or unleaded fuels will permit better operation of advanced control systems on automobiles. Voluntary action on the part of the oil industry has already resulted in general availability of low-lead and unleaded gasolines. This trend will undoubtedly continue, bringing about increasing supplies of these types of fuels and will result in major investments for new refinery facilities.

2. Diesel Fuels

Like gasoline, distillate diesel fuels for use in automotive diesel engines have been changed during the past several years to meet requirements imposed by changes in engine design and operation. The most significant change in diesel fuels has been through the use of hydrogen treating in refineries primarily to reduce sulfur content. In addition, fuels have been gradually improved in viscosity and volatility, which has decreased engine deposits, smoke and odor. Railroad diesel fuels have not changed significantly since the large diesel engines used in railroad service operate satisfactorily on fuels with less exacting specifications.

The use of additives in diesel fuels has become more common to provide improvements such as lower pour points, ignition quality and storage stability. Recent air pollution regulations have generated an increased interest in antismoking additives.

3. Aviation Fuels

a) Aviation Gasoline

Quality control is particularly important in aviation gasoline production since engine failure is a very serious matter. Antiknock control is especially critical because, unlike the motorist, the pilot is not able to hear an engine knock over the noise level. Other important quality factors are volatility, freezing point, heat of combustion and oxidation stability. Quality control surveillance and close process control have enabled the industry to produce a uniform-quality premium product.

b) Jet Fuels

Commercial kerosine was first used as a fuel in early development on jet aircraft since it provided the necessary volatility and was a readily available commercial product of rather uniform characteristics. Jet fuels are exposed to both high and low temperatures in use. Therefore these fuels must have very low freezing points and must be stable when exposed to high temperatures. The JP-4 and JP-5 military jet fuels and equivalent commercial fuels have thermal stability properties satisfactory for operations up to speeds of Mach 2. Additives are important and attractive methods of producing jet fuels capable of meeting these severe requirements.

4. Other Petroleum Motor Fuels

Liquid petroleum gas has been used as a motor fuel since the 1920's in bus, truck and taxi fleet operations which have a central servicing center. The use of compressed and liquefied natural gas as a motor fuel is a recent development proposed for urban use in service vehicle fleets.

B. Heating and Industrial Fuels

1. Distillate Fuel Oil

Distillate fuel oil can be defined as Nos. 1, 2, and 4 heating oils, diesel oil and industrial distillates. Grade No. 2 fuel oil is the designation given to the heating or furnace oil most commonly used for domestic and small commercial space heating.

The period since World War II has seen marked changes in both the quality of home heating oils and the manufacturing techniques employed in producing them. Domestic heating oil should form no sediment in storage and leave no measurable quantity of ash or other deposits on burning. It should be fluid at storage conditions encountered during the winter months. The composition of the product must be controlled to assist in reducing smoke emission. Low-sulfur content has become quite important. The fuel must have a light color, an attractive appearance and an acceptable odor. It is these properties, along with sulfur removal, which have undergone the greatest change in the past 20 years.

In the early 1950's, hydrogen treating was adopted as a means of reducing the sulfur and nitrogen compounds content of fuel oil. Carbon residue is reduced to less than 0.10 percent. Hydrogen-treated products are of excellent quality from the standpoint of both a change in color and in sludge formation during storage.

The superior processing techniques used in producing fuel oils today, coupled with the improvements and developments in additives, result in a cleaner-burning product. The reduction in sulfur has been a significant improvement in air pollution.

2. Residual Fuels

Residual fuel oil can be defined as Nos. 5 and 6 heating oils, heavy diesel, heavy industrial and Bunker C fuel oils. Typically these fuels are used to provide steam and heat for industry and large buildings, to generate electricity and to power ships.

After the War, refining processes in the United States have continued to become more efficient in producing more profitable products until residual amounts to only about 8 percent of the crude refined.

Methods for desulfurizing residual oils have been developed and are being utilized as air pollution requirements become more widespread. The oil industry and boiler manufacturers have stepped up their efforts considerably in the areas of desulfurizing fuel oil and flue gas and reducing fuel oil metals content. Some of the problems in making use of residual oil as a fuel have been alleviated by improvements in burning and handling equipment and engineering practices.

Future advances in technology, particularly hydrogenation processes, will probably reduce the amount of residual oil while increasing the production of more valuable products, based on past relationships of product values.

3. Liquefied Petroleum Gas (LPG)

LPG has taken on increased importance during the past few years. The extensive use of catalytic cracking and catalytic reforming processes and the growth in hydrocracking have resulted in the production of large quantities of refinery LPG in addition to the production from natural gas processing. Prior to the start of the tremendous growth in the use of LPG in ethylene production, the major use was for household and industrial fuel, although LPG has long been used to a limited extent as a motor fuel.

C. Other Petroleum Products

1. Petroleum Solvents

A variety of petroleum solvents are produced and critical specifications are largely a function of the end product use. For example, rigid specifications are required for petroleum solvents used in the paint industry. These products must contain no materials that would discolor pigments. They must possess low odor for interior paints. Control devices make it possible to maintain consistent product quality under even the most rigid specifications.

2. Asphalt

The heaviest fractions of a great many crude oils include natural bitumens or asphaltenes and are generally called asphalt. Actually this material is the oldest product of petroleum and has been used throughout recorded history. However, new uses and new demands for asphalt are continually being developed. The industry has satisfied these demands by changing processing and types of crudes and by improving storage, transportation and blending facilities.

SECTION 3.
THE MANAGEMENT OF CHANGE

In manufacturing and marketing new products for the public needs over the years, just as in other industry operations, the oil and gas industries have gathered a vast amount of experience in the factors affecting efficient management of the wide variety of changes required to meet those needs.

Economic factors always come to bear on both the industry and the consumer, with the free-enterprise system permitting the forces of competition to ensure that the necessary products are provided to the consumer at the least cost. By limiting its controls to specification of performance standards, government will encourage individual innovation, with "marketplace regulation," and thus tend to obtain the optimum environmental quality control for each dollar of expenditure, yet avoiding governmental discriminations among competing enterprises.

A. Research for Progress

Petroleum industry research, on both a cooperative and an individual company basis, has contributed to a better understanding of atmospheric chemistry and to progress in the development of technology for controlling emissions from both mobile and stationary sources. The cooperative aspects of this research effort have been carried out in a variety of ways.

Within the framework of the antitrust laws, cooperative research by the petroleum industry will continue in the future with related industries and government. Major specific needs for such further research include:

- Health effects of emissions into the atmosphere
- Fuel-vehicle system to produce a "pollution-free car"
- Desulfurization of fuels and stack gases

1. Industry Association Research

Pioneering research in air pollution was begun by the American Petroleum Institute in 1953. Early research demonstrated that hydrocarbons and organic matters in the air react with oxides of nitrogen in sunlight to produce photochemical smog of the type found in the Los Angeles Basin. In 1966 and subsequent years the research program was substantially expanded and aimed toward resolving questions in the engineering, scientific and environmental health aspects of sulfur content of heavy fuels, lead levels in motor fuel, volatility and light hydrocarbon characteristics of gasoline, and related subjects. Research is continuing.

This activity has resulted in a closer liaison between the petroleum industry and government legislative and regulatory bodies and has supplied the industry with fundamental technical information on air pollution. Much of this information has also been helpful to government bodies in developing workable laws and regulations directed to air pollution abatement.

2. The Coordinating Research Council (CRC)

An outstanding example of an organization created as a vehicle for cooperation is the Coordinating Research Council (CRC), which provides an effective forum for the various segments of the automotive and petroleum industries to work together in noncompetitive problem areas.

To obtain the answers and arrive at a clearer understanding of the contribution of vehicle emissions to atmospheric pollution, the Coordinating Research Council, through its Air Pollution Research Advisory Committee (APRAC), has implemented a multimillion-dollar research program covering the engineering, atmospheric and medical aspects of air pollution attributable to vehicle sources. This program, initiated in 1968, covers a three-year period at a direct cost of over $12 million and is supported by the API, the Automobile Manufacturers Association and, on selected projects, by the Environmental Protection Agency. Continuation beyond 1971 is planned.

3. Inter-Industry Sponsored Programs

The Inter-Industry Emission Control (IIEC) Program was formed by a major motor company and a prominent oil corporation in April 1967, and now comprises these two companies plus nine others. These companies are conducting a multimillion-dollar research program to eliminate objectionable levels of automotive emissions.

The IIEC objectives are to achieve automotive emission levels no higher than 65 parts per million of hydrocarbons, 0.3 percent carbon monoxide, and 175 parts per million of nitrogen oxides. A portion of the IIEC program already has moved out of the research phase into the developmental and test-work phase.

In July 1967, representatives of two other well-known automotive and oil companies joined technical forces in a coordinated effort to develop low-level emissions control systems for gasoline-powered vehicles compatible with good driving performance at a reasonable cost. An example of the fruits of such cooperative efforts is a workable system for virtually eliminating the evaporation of hydrocarbons. Evaporation control systems were installed in the 1970 cars in California and are being installed nationwide in 1971 cars.

A recent SAE paper described the results of tests of the effectiveness of several emissions control concepts (thermal oxidation, catalytic oxidation, dual catalytic reactor, combined thermal and catalytic oxidation) on emissions of hydrocarbons, carbon monoxide and nitrogen oxides.[84] It is significant that none of the test cars equipped with the most advanced control systems developed will meet the 1970 Clean Air Amendments emissions standards.

4. Company-Sponsored Research

In any highly competitive industry such as the oil and gas industry, individual, competing companies carry on intensive programs of research and development to improve products and operations.

Investments by the petroleum industry for conservation of the environment already have been substantial and will undoubtedly increase in the future. In addition to capital expenditures there have been increased expenditures for research and development.

Expenditures for research and development in air conservation increased 35 percent between 1966 and 1967 and expenditures have continued to increase since that time.

B. Controlling Emissions from Mobile Sources

One of the major areas of interest today regarding atmospheric quality is control of air pollution caused by emissions of gases and particulates from mobile sources.

The effect of motor fuel composition on air pollution cannot be discussed meaningfully as an isolated proposition. The interrelationships between variables in vehicle design and fuel composition, as they affect emissions, are highly complex and to be treated effectively must be approached as a total system. The objective is to achieve the optimum combination to produce the greatest degree of pollution control per unit of additional cost.

If government limits its role to prescribing performance, as it now does, the record shows that individual manufacturers will compete to achieve that performance at minimum cost.

These, then, are the general factors which have been proved over the years to have a strong bearing on the efficient and economical management of change in technical products and have particular application to the control of undesirable emissions to the atmosphere from the use of petroleum fuels by mobile sources. These points can be illustrated by some specific proposals under consideration.

1. Gasoline

Air pollution from the gasoline engine is rapidly being reduced. Today's new cars emit less than one-third of the hydrocarbons and carbon monoxide emitted by the essentially uncontrolled models of the early 1960's, and the 1971 models are expected to control at least 85 percent of all hydrocarbon emissions.

a) Hydrocarbon Composition

There have been proposals to change the hydrocarbon composition of gasoline so as to reduce its front-end volatility. When economic study conclusions are taken together with the technical evaluations, it becomes apparent that a change in volatility would be inordinately expensive and would have no significant benefit on total vehicle hydrocarbon emissions that can be related to photochemical smog, for the current car population.

b) Lead in Gasoline

Lead antiknock usage is intimately bound up in the design, operation and economics of modern gasoline refineries. In order to meet present premium and regular-grade octane levels with unleaded gasolines, it is estimated that the petroleum industry would have to invest from $6 billion to $7.5 billion for manufacturing facilities. Under these circumstances unleaded gasolines would cost more than the corresponding leaded gasolines. However, lowering octane requirements for new automobiles would result in lowering manufacturing costs for gasoline and, consequently, reduce its cost to the consumer.

Nevertheless, the problem is not entirely one of capital resources and consumer cost. The physical problems of material and labor supplies for conversion of the entire industry to the production of unleaded gasoline must be considered, as must the time required for construction of new facilities. It is essential that any timetable established for solving the complicated problem of automobile emissions be reasonable and practicable—both from the standpoint of automotive hardware and fuel composition.

Regulations prescribing lead contents of gasoline are inappropriate and unnecessary. Low-lead and unleaded gasolines are now generally available and further restrictions on the use of lead will result in significant technical and economic effects on the production of gasoline. Furthermore, the use of lead alkyl additives in gasoline is by far the most economical method known to increase the octane quality of gasoline.

However, if required, regulations for the reduction of lead in gasoline should be planned realistically to provide for such reductions as are necessary to reach practical emission goals at a minimum overall cost to the public.

2. Other Petroleum Motor Fuels

Recently the performance, emission characteristics and utility of liquefied and compressed natural gas (methane) and LPG (propane and butane) have received increasing attention as possible alternative fuels to gasoline. As with other fuels, however, the final decision as to the relative utility of these fuels must take into account many other factors.

Economic factors can limit the application of LPG and CNG in vehicles. First, the additional cost of the vehicle fuel system for a gaseous fuel is a significant factor. The second unfavorable economic factor for vehicle application of light hydrocarbon fuels is a motor fuel tax based upon ¢/gal without regard to the energy content/gal of the fuel.

Either methane or propane could provide substantial benefits to the urban vehicle pollution problem. Supplies of either fuel could be expanded sufficiently to handle the commercial urban fleets which are adaptable to refueling from centrally located service centers. However, already-serious supply limitations and, in some instances, safety considerations, will limit use of these fuels for vehicles.

C. Controlling Emissions from Fixed Sources

A recent book on "The Economics of Air Pollution" defines the basic air pollution abatement problem from an economic point of view as "to reach a given pollution level by the least costly combination of means available; the level of pollution should be achieved at which the cost of a further reduction would exceed the benefits." Neglect of cost-benefit considerations in control measures may lead to restrictive legislation and air pollution regulations that can only be viewed as "control for control's sake" and has the effect of diverting financial resources from other pressing needs.

Another objectionable regulation permits the use of high-sulfur solid fuels and restricts use of liquid fuels to low-sulfur contents. This sort of legislation is in effect lowering the amount of sulfur emitted; however, it is attacking a *relatively small* source of sulfur and completely neglecting the *larger* source of sulfur. Discriminatory legislation of this type is actually encouraging the use of a high-sulfur fuel.

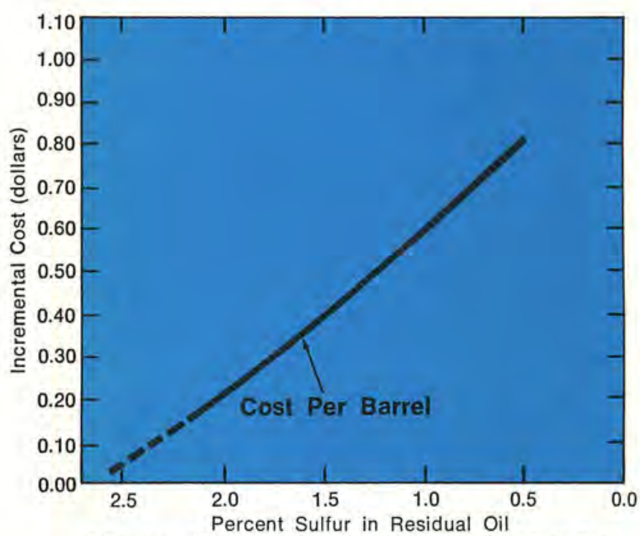
Industry, government and the public must be brought to realize that compromises will have to be made and the cost of air pollution ultimately shared by all, and that in a competitive market the burden of extreme pollution abatement on some companies may not be economically bearable. Abatement programs must take these factors into consideration.

The petroleum industry has made substantial progress in lowering the sulfur content of its products. Given adequate lead time, reasonable fuel sulfur regulations can be met, but this will entail some additional cost to the consumer. Reported investments by domestic refiners for reducing the sulfur content of fuel products through 1965 amounted to $582.6 million.

Although there are numerous variables involved which affect the costs of desulfurization in different cases, Figure 3 illustrates the relationship of costs of desulfurization to low-sulfur levels.

Figure 3

Incremental Desulfurization Costs Per Barrel *



* *Source:* "Desulphurization Costs (for) Residual Fuel Oil . . . Typical Caribbean Refinery . . . Venezuelan Crude Oil," Bechtel Corporation (February 1967).

Chapter Nine:

Mobile and Off-Highway Equipment—Emissions and Trends

Emissions from engines in mobile equipment are two kinds—gaseous and particulate matter. The important gaseous emissions are:

- Hydrocarbons (also aldehydes)
- Carbon Monoxide
- Nitrogen Oxides

While the standards for particulate matter from various engines have not yet been set, the effect of particulates on visibility, soiling, etc., is generally indicated by the weight of the particulates.

Emission trends have been projected, prior to the enactment of the Clean Air Amendments of 1970, for a 15-year period (Figure 4). These projections are useful for indicating general emission trends and the relative contribution of emissions from various sources. They also provide a good basis for assessing the progress which is being made and will be made in controlling the emissions from mobile and off-highway equipment. If the standards established by the 1970 Act prove to be attainable, estimated emissions after the 1975-76 period would be further reduced.

SECTION 1.
EMISSIONS FROM MOBILE AND OFF-HIGHWAY EQUIPMENT

Table 15 provides a breakdown of estimated emissions from mobile and off-highway equipment for the period from 1955 to 1985. Further analysis of emissions from various types of mobile and off-highway equipment is contained in the sections which follow.

Emissions estimates presented in this chapter are related to the emissions stan-

TABLE 15: Estimated Emissions from Mobile Equipment*
(Millions of Tons per Year)

	1955	1960	1965	1970	1975	1980	1985
Hydrocarbon							
Autos	9.9	12.0	13.0	11.0	5.9	2.4	0.9
Trucks & Buses	1.2	1.4	1.7	1.9	1.7	1.4	1.4
Aircraft	.3	.3	.2	.3	.2	.1	.1
Off-Highway	.7	.7	.7	.6	.6	.6	.5
Total	12.1	14.4	15.6	13.8	8.4	4.5	2.9
Carbon Monoxide							
Autos	37.3	45.7	55.2	54.3	40.6	24.3	12.7
Trucks & Buses	11.1	12.7	15.6	17.4	16.2	14.0	14.2
Aircraft	2.2	1.4	.9	.4	.5	.7	.8
Off-Highway	6.7	6.8	5.7	5.3	5.5	4.4	3.4
Total	57.3	66.6	77.4	77.4	62.8	43.4	31.1
Nitrogen Oxide							
Autos	3.3	4.0	4.8	5.7	5.0	2.8	1.3
Trucks & Buses	.8	.9	1.1	1.4	1.6	1.5	1.7
Aircraft	.01	.01	.03	.05	.06	.08	.09
Off-Highway	.8	.9	.9	.9	.9	1.1	1.1
Total	4.9	5.8	6.8	8.1	7.6	5.5	4.2
Particulate							
Autos	.2	.2	.2	.3	.3	.2	.1
Trucks & Buses	.1	.1	.1	.2	.2	.2	.2
Aircraft	.01	.01	.02	.04	.04	.04	.05
Off-Highway	.2	.2	.2	.2	.2	.2	.1
Total	.5	.5	.5	.7	.7	.6	.5

* Bases: 1968 Federal Test Procedure; vehicle registration data supplied by R. L. Polk & Co.

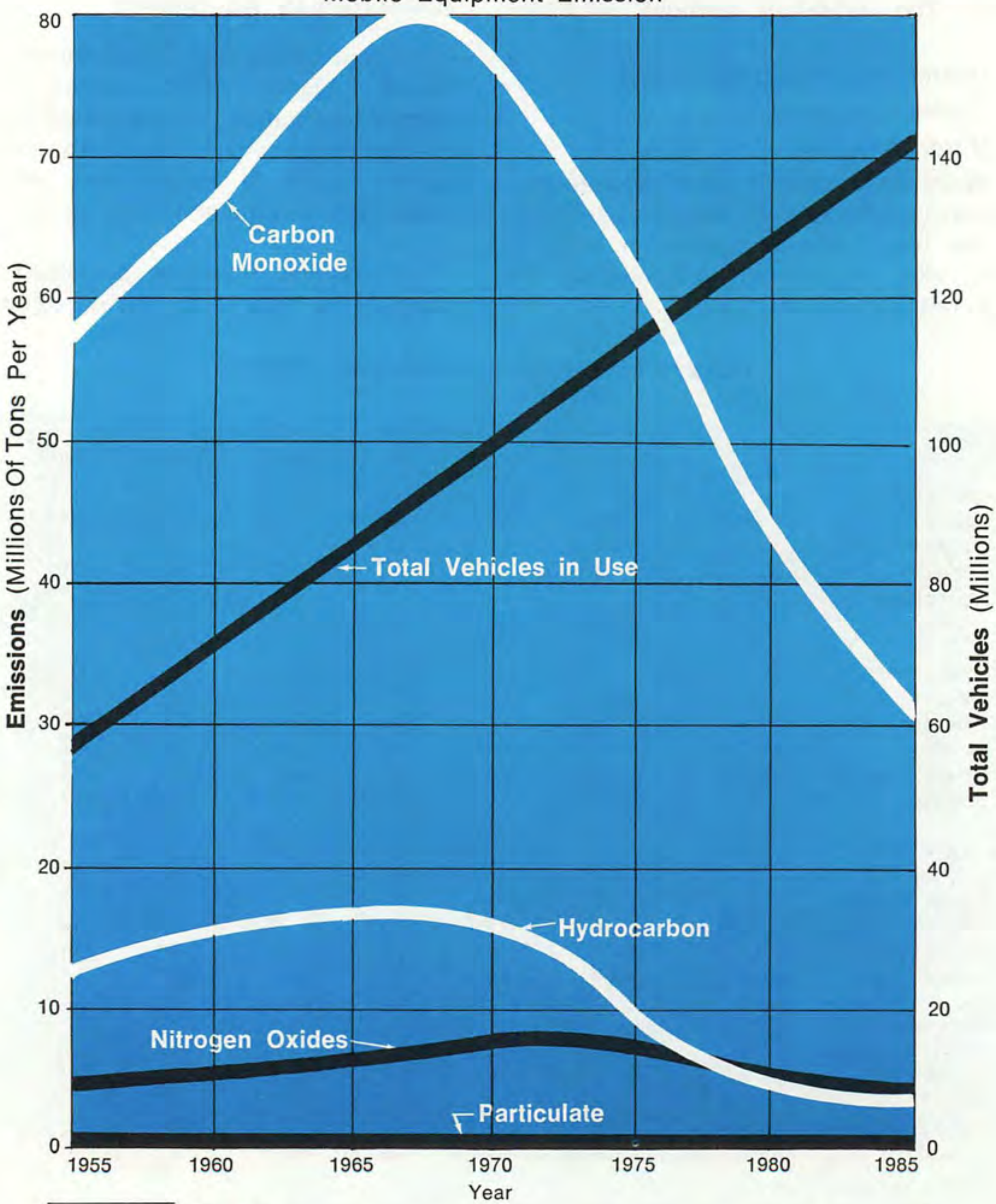
dards and factors listed in Table 16 and were made on the basis of the 1968 Federal Test Procedure, before the New Federal Test Procedure incorporating the Constant Volume Test System (CVS) was published. Because the emissions levels measured by the new CVS procedure are higher than those measured by 1968 procedure, the absolute emission levels estimated in this study would be increased if updated to the new CVS basis. Although the updated emission estimates would be higher, the trends of the emissions estimated by the two bases would be similar and similar conclusions would be drawn.

The summary data in this report show that the trend of emissions is down from the emissions peaks which were reached in the 1965-70 period and that by 1985 the peak emissions are expected to be reduced approximately by:

	Percent Reduction
Hydrocarbons	80
Carbon Monoxide	60
Nitrogen Oxides	45
Particulates	40

Figure 4

Mobile Equipment Emission *



* *Source:* Table 15.

The 80-percent reduction in hydrocarbon emissions and the reduction in the HC/NO_X ratio are particularly important because hydrocarbons and the HC/NO_X ratio exert an important effect on photochemical smog. The indicated reduction in hydrocarbon emissions is expected to reduce considerably the incidence of photochemical smog and the severity of its effects.

SECTION 2.
AUTOMOBILE EMISSIONS

The emissions which are estimated to arise from automobiles are shown in Figure 5. The emissions standards and factors on which these estimates are based are given in Table 16. The trend of carbon monoxide and hydrocarbon emissions is expected to be sharply down in the 1970's and by the 1980 to 1985 period will reach very low levels. Nitrogen oxides and particulates follow similar trends and will be reduced to very low levels by the end of the forecast period.

The emissions standards and factors presented in Table 16 indicate the degree to which the emissions from uncontrolled cars have been and would be reduced, not considering the Clean Air Amendments of 1970. However, technology is not now available to reduce emissions to the levels established in the 1970 Amendments for 1975-76. If and when these standards are met, emissions for new vehicles as compared to uncontrolled cars will have been reduced as follows:

	Percent Reduction
	1970 Amendments— 1975-76 Emissions
Crankcase	100
Hydrocarbon	98
Carbon Monoxide	97
Nitrogen Oxides	90
Particulates	90
Evaporative	95 +

TABLE 16: Emissions Standards and Factors: Automobiles * [1]

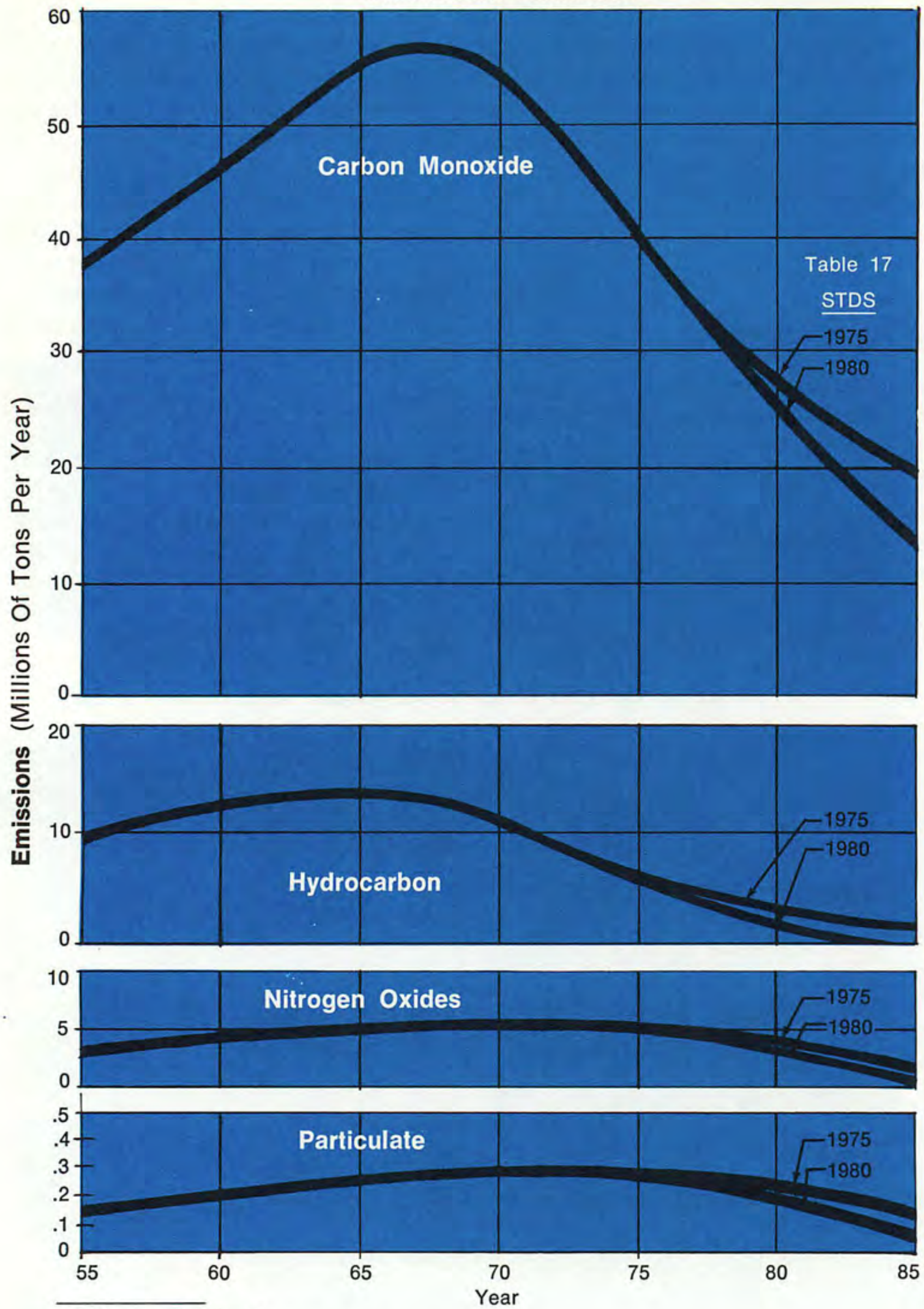
	Exhaust Emissions (g/mi)										Evap. (g/Test)	
	Crankcase		Hydrocarbon		Carbon Monoxide		Nitrogen Oxides		Particulate		Hydrocarbon	
Year	Calif.	U.S.	Calif.	U.S.	Calif.	U.S.	Calif.	U.S.	Calif.	U.S.	Calif.	U.S.
[2]	5.9	5.9	10.6	10.6	73	73	6.4	6.4	.36	.36	2.7 [9]	2.7 [9]
61	NIL[3]											
62		NIL[3]										
63	NIL[4]											
64	NIL[5]											
65												
66		NIL[6]	3.4 [7]		35 [7]		7					
67												
68				3.4 [7]		35 [7]		7				
69												
70			2.2	2.2	23	23					6 [8]	
71							4					6 [8]
72			1.5				3	4				
73				1.5				3				
74							1.3	1.3				
75			.5	.5	12	12	1.0	1.0		.1		
80				.2 [10]		5 [10]		.4 [10]	.03 [10]			
Control	100%		98%		93%		94%		92%		95%+	

* Sources: State of California Motor Vehicle Pollution Control Board, "California Procedure For Testing Motor Vehicle Exhaust Emissions" (revised March 9, 1966); 33 *Fed. Reg.* 108, Part II (June 4, 1968); *Wall Street Journal* (January 22, 1970).

[1] Light-duty vehicles under 6,000 pounds.
[2] Uncontrolled cars.
[3] Semiclosed system—new cars.
[4] Semiclosed system—used cars.
[5] Closed system—new and used cars.
[6] Closed system—new cars.
[7] 275 ppm HC, 1.5% CO.
[8] Emissions estimated at .05 g/mi.
[9] Evap. loss estimated at 2.7 g/mi.
[10] Figures released by President's Environmental Quality Council, November 20, 1969.

Figure 5

Automobile Emissions



* *Source:* Table 15.
Bases: 1968 Federal Test Procedures.

SECTION 3.
TRUCK AND BUS EMISSIONS

Truck and bus emissions data show that the hydrocarbon and carbon monoxide emissions from trucks and buses will trend down moderately after reaching peaks in the 1970 period, while nitrogen oxides and particulate emissions will remain essentially constant, based on the premises for Table 15.

If the use of diesel engines is greater (at the expense of gasoline engines) than that assumed in this study, then these emissions estimates could prove to be high. Available information suggests that emissions from diesel engines other than smoke are not much of a problem and can and will be controlled. It further suggests that smoke emissions will be eliminated.

Catalytic converters of various types may find increasing utilization on city trucks and buses in the future. It is expected that during the forecast period units will become available which will meet the needs of city truck and bus operation.

SECTION 4.
AIRCRAFT EMISSIONS

Aircraft emissions in Table 15 show the estimated emissions produced below 3,500 feet from air carrier and general aviation operations. Redesign and retrofitting of jet engine combustors is significantly reducing the smoke problem.

Thus the total level of pollutants emitted is low compared to other mobile sources. Although emissions from aircraft may be a local annoyance, they are not projected to become a major factor in the total air pollution burden over the period covered by this survey.

SECTION 5.
OFF-HIGHWAY EQUIPMENT EMISSIONS

The emissions from off-highway equipment in Table 15 show that off-highway equipment emissions are not large and based on this survey are expected to become even smaller in the future.

SECTION 6.
FACTORS AFFECTING EMISSIONS

Early work showed that gasoline composition modifications are generally the most ineffective way to reduce emissions and that by far the largest reductions in vehicle emissions were to be achieved by changing engine and vehicle design and operating conditions. This emphasis on changing the engine and vehicle has been followed for the past decade, resulting in large reductions in emissions. In order to reduce gasoline engine emissions to the minimum possible, changes in gasoline composition and properties are now being reevaluated to determine their role in making the "non-polluting" vehicle a practical reality.

The factors relating to gasoline composition which have a bearing on the ability to control evaporation and exhaust emissions are the volatility of the fuel, its aromatic and olefinic content, and additives.

A. Motor Fuel Volatility

The properties and characteristics of a blended motor fuel are controlled by the amount of the various hydrocarbons in the blend, with additives being included to provide specific performance benefits. One of the most critical and closely controlled properties of motor fuel that is related to the hydrocarbons in the blend is volatility.

Balanced volatility of the motor fuel is used to indicate the proper proportioning of the individual blending materials to provide a fuel that will ensure easy starting, good mileage, freedom from vapor lock and carburetor icing, fast warm-up and minimum crankcase oil dilution. A proper balance is obtained by control of the amount of various blending components to optimize the performance characteristics of the motor fuel for seasonal changes and different geographical zones. Very careful control and balance of the volatility of the motor fuels are needed to provide fuels that will perform satisfactorily in the modern automobile engine.

Studies by the Bureau of Mines combined with data for the Los Angeles area in a joint study of the California Air Resources Board, Los Angeles County Air Pollution Control District and the Western Oil and Gas Association concluded that a reduction in volatility in gasoline would produce no significant change in the reactive hydrocarbon emissions to the atmosphere for this location.

At various times spokesmen for the automotive industry have proposed that the volatility of gasoline be lowered to reduce the evaporative emissions of unequipped vehicles and gasoline distribution systems. More recently one major automobile manufacturer suggested that future cars equipped with advanced exhaust emissions control devices involving catalytic mufflers may require more volatile gasoline to improve the warm-up and cold-starting characteristics. In that regard, he indicated that (1) a fuel with the warm-up characteristics of propane but with lower volatility to avoid propane's fuel handling and evaporation problems would be ideal and (2) such a fuel would help to reduce emissions during the first minute or two in the new federal key-on to key-off cycle, a critical period for emissions because the catalytic muffler would be rather inactive in reducing CO and hydrocarbons.

B. Olefinic and Aromatic Content

It has been well established that all hydrocarbons do not participate at the same rate and to the same extent in atmospheric photochemical reactions nor do they produce photochemical products which are equally harmful. This was recognized early in the study of the Los Angeles smog problem and led to the limitation on the amount of total olefins permitted in Los Angeles Basin gasoline and to restrictions on the composition of industrial organic solvents used in that area.

A second joint committee representing the California Air Resources Board, the Los Angeles County Air Pollution Control District and the Western Oil and Gas Association examined the net effect of removing the light olefins. It was concluded that replacing the light olefins from the gasoline marketed in Los Angeles County with saturated hydrocarbons and maintaining the volatility constant should reduce the net reactive hydrocarbon atmospheric emissions only about 7 percent for the current car population.

The important negative aspect of replacing light olefins, particularly the C-5's, with saturates is, in the case of unleaded gasolines, a substantial drop in the octane number. The effect of the octane reduction is minimized in the case of leaded fuels. When this octane number drop is considered, it is evident that light olefins in unleaded gasolines will make an already difficult situation more difficult.

Of all the hydrocarbons emitted by a vehicle, aromatics are perhaps the most undesirable. By reactivity criteria, aromatics do not react as rapidly as olefins, but their photochemical reaction products appear to be worse with respect to particulate formation, visibility reduction and eye irritation. The question of the aromatic content of gasolines has not been completely resolved, however, and is being studied intensively.

C. Additives—Lead Antiknocks

In recent years, there has been an increased emphasis on examination of the additives used with petroleum fuels as a possible factor in atmospheric pollution. Lead in gasoline has been the primary focus of attention, with statements being made by senior government officials and automobile spokesmen to the effect that lead must be eliminated from gasoline when cars with advanced emissions control systems using catalytic reactors are produced.

1. Atmospheric Lead Levels

In December 1965, a symposium of scientific and technical personnel, sponsored by the Department of Health, Education and Welfare (HEW), reported, with respect to lead in gasoline at current usage levels, "no conclusive evidence that there is an extensive problem of effects on health."

Some investigators feel that the present atmospheric lead levels are safe, while others do not share this view. So far as is known, there has been no evidence found that the current airborne lead concentration and exposure levels have produced any important health effects in normal population. However, more information is needed and research to obtain this type of data is still being conducted on a wide scale.

2. Lead Levels in Gasoline

The other areas of concern over the use of lead antiknocks involve the effects of lead on the combustion process and on engine and emissions control equipment deterioration.

Probably the quickest possibility for the elimination of lead from gasoline is to reduce the octane requirement of the fuel by reducing the compression ratio of automobile engines. Relatively low compression-ratio engines, which might be equivalent to today's engines requiring regular gasoline, could then be used in conjunction with catalytic systems requiring lead-free gasoline. These engines are used in most 1971 cars, and therefore cars requiring fuel quality equivalent to today's leaded premium will form a progressively smaller portion of the total car population. Unleaded gasoline and catalytic mufflers, if developed for use, could be introduced in conjunction with the changed engines. However, lower compression ratio engines are somewhat less efficient in fuel consumption for equal performance.

It should also be recognized that producing a given quantity of unleaded gasoline requires the use of more crude oil than the same quantity of leaded gasoline of the same octane rating.

As indicated in the previous chapter, voluntary action on the part of the oil industry has already resulted in general availability of low-lead and unleaded gasolines. The trend will undoubtedly continue, bringing about increasing supplies of these types of fuel. If required, regulations for the reduction of lead in gasoline should be planned realistically to provide for such reductions as are necessary to reach practical emissions goals at a minimum overall cost to the public.

Resolution of the outstanding problems and the conversion to an unleaded economy, should this become necessary, would be speeded by a substantial measure of cooperation between the automotive and petroleum industries and the Government which is scarcely possible today because of antitrust considerations. In this event the Federal Government should establish procedures under which appropriate information can be developed by the automotive and petroleum industries which will lead to a value/benefit analysis of the continued use of lead antiknocks.

One current proposal for the stated purpose of encouraging the use of low-lead or unleaded gasolines is a tax on lead compounds used in gasolines. Such a tax would be grossly discriminatory and would penalize current owners of pre-1971 model cars who purchased them in good faith and who had no indication that the cost of driving these cars would be increased by such legislation. The tax would not assure the availability of low-lead or unleaded gasolines at all locations but would provide a license to continue to market leaded fuels for a specified customer charge. Moreover, the proposed tax is for the purpose of stimulating low-lead or unleaded gasolines. To be consistent with such a purpose, any gasoline containing 0.5 grams (or less) of lead per gallon should certainly be exempt from the proposed tax.

If the tax is a success in generating revenue, it would be a failure in reducing the lead used in gasolines.

Technology for the control of gasoline engine emissions is now well advanced and during the survey period will be applied to production engines to reduce emissions to low levels. Future work will be directed toward further development of these mechanical and gasoline systems and determination of those possibilities which will prove to be the most effective, reliable, economical and acceptable to the consumer.

Catalytic emissions control devices on vehicles using unleaded gasolines are capable of achieving very low emissions levels and will receive increasing attention. By 1980 it is estimated that these efforts will have produced an essentially "non-polluting" automobile. Heavy-duty truck and bus engines operating in congested areas may require special fuels and control equipment in order to reduce emissions to the absolute minimum levels needed for this service.

At the present time, it appears very unlikely that any alternate power source will be developed within the next decade to replace the internal-combustion engine and provide lower total undesirable atmospheric emissions.

Chapter Ten:

Stationary Plant — Emissions and Trends

Petroleum products are widely used in stationary plants for electric power generation, domestic and commercial heating, and manufacturing processes. When converted to fuels they generate emissions as part of the combustion process. Evaporative emissions can also occur in commercial processes. The emissions which are receiving primary attention because of their impact on atmospheric quality are sulfur oxides, particulates, nitrogen oxides, carbon monoxide and unburned hydrocarbons.

SECTION 1. **OVERVIEW OF OPERATIONS AND EMISSIONS**

Historically coal has been and is still the major fuel used in power generation. In the 1970's, low-sulfur petroleum fuels are expected to acquire a significant portion of the added fuel requirements of the electric utility market from coal.

The electric power industry is currently the largest single source of sulfur dioxides and particulate air pollutants from fuel combustion. Emissions from domestic and commercial units are those commonly associated with fossil fuel burning. Although the total quantities are less than from power generation, their effect on ground level concentration can, in some cases, be greater since they are emitted to the atmosphere close to the ground. Generally speaking, the emissions from manufacturing processes related to use of petroleum are the result of its being used as a fuel. Emissions from solvents are a notable exception.

SECTION 2. **SULFUR OXIDE EMISSIONS AND CONTROL TECHNIQUES**

A. Emissions

Sulfur dioxide (SO_2) has been a major pollutant ever since the world started burning large quantities of soft coal and since the first smelting of copper sulfide ore.[85] Of the estimated 1965 annual worldwide SO_2 emission rate, an estimated 70 percent resulted from coal combustion and 16 percent from the combustion of petroleum products, mainly residual fuel oil. Of the remainder, 10 percent came from non-ferrous smelting (copper, lead and zinc) and 4 percent from petroleum refining operations.

A study of the sources of SO_2 pollution shows that fossil fuels are responsible for 78 percent of the total SO_2, with the remaining 22 percent coming from other industrial sources.[86] However, it is estimated that only 19.6 percent of U.S. SO_2 production is from burning petroleum fuels, most of which is residual fuel.

B. Control Techniques

Fuel substitution is simply replacing high-sulfur fuels with low-sulfur fuels. This method would be the simplest one if availability and supply of low-sulfur-bearing fuels were no problem. The limited supplies, however, of low-sulfur liquid or solid fuels and natural gas could not begin to fulfill the Nation's requirements for fossil fuels.

From the point of view of atmospheric quality, the greatest gain is to have small users burn the lowest sulfur fuel available since they emit pollutants at low altitudes where the emissions have a greater effect on ground level concentrations. Larger sources are better equipped to handle higher sulfur fuels and, in the future, will either be equipped with flue-gas desulfurization processes, or supplied with low-sulfur fuel, or both.

Impending and current air pollution regulations setting strict sulfur specifications on fuels have hastened the development of desulfurization processes.

The largest single SO_2 source, coal, is the most difficult to desulfurize.

Stationary sources burning petroleum fuels contribute roughly 16 percent of the total SO_2 emitted to the atmosphere. Nearly 90 percent of the sulfur oxides produced by these petroleum fuels comes from burning the heavier residual fraction. The most common method of obtaining low-sulfur (1%) fuels is by blending high-sulfur resid with desulfurized low-sulfur vacuum distillates. This technique is being used to supply most of the low-sulfur fuel (1%) to the East Coast markets. The Caribbean refineries are the major source of this low-sulfur fuel.

Natural gas specifications usually call

for very low sulfur specifications; hence burning of this fuel contributes very little to the overall SO_2 problem.

Flue-gas desulfurization processes have received widespread attention but reliable commercial application for large installations is still at least 5 years off. Although impressive advances in research are being made, stack-gas removal techniques are not likely to be in wide use in time to meet existing and proposed legislation targets. When, however, these processes become practicable, power plants can utilize high-sulfur fuels more extensively, thus freeing low-sulfur fuels for space heating requirements.

Process improvements to increase the efficiency of the systems so that they use less fuel will, in turn, reduce SO_2 emissions.

Plant efficiency improves with increasing unit size. For example, large modern steam electric power plants use roughly 8,500 BTu per kilowatt-hour of electricity compared to 10,000 BTu per kilowatt-hour for older, smaller plants.

SECTION 3.
PARTICULATES EMISSIONS AND CONTROL TECHNIQUES

A. Emissions

Of the 11.5 million tons of particulate matter produced in the United States during 1966,* 6 million tons (52%) were emitted from industrial sources, including industrial fuel burning; 3 million tons (26%) from power generation; 1 million tons (9%) from incineration; 1 million tons (9%) from space heating; and 0.5 million tons (4%) from mobile sources.[88]

Combustion of fuels from stationary sources, both industrial and power plants, is the largest particulate source category. The percentage of heat supplied by each fuel is by no means proportional to its particulate emissions. For example, in the New York metropolitan area, burning of anthracite and bituminous coals provides only 15 percent of the area's heat requirements, yet contributes 60 percent of the combustion fuel particulate total. Residual and distillate fuels produce 63 percent of the heat, but only 37 percent of the fuel particulate, while natural gas provides 22 percent of the heat but only 3 percent of the fuel particulate total.[89]

* A more recent estimate[87] reports nationwide emissions of particulates to have been 28.6 million tons in 1968. However, this estimate includes apparent (as opposed to actual) changes due to changes in emissions factors and the inclusion of new sources such as forest fires (6.7 million tons per year). The net change in emissions from fuel combustion was reported to be down 0.3 million tons from 1966.

B. Control Techniques

The general methods of controlling particulate emissions include fuel substitution, removal of particulates from stack gases, fuel modification, more efficient fuel utilization, relocation of the emission source and stack dispersion.

Table 17 illustrates relative particulate emissions resulting from various fuel usages per unit of energy.

TABLE 17. Comparison of Energy Substitution Alternatives for Electric Power Generation*

Energy Substitution Alternative	Particulate Emissions (lb/10^6 BTu input †)
Hydroelectric	0
Nuclear	0
Gas (no control)	0.02
Oil (no control)	0.07
Coal—90 percent fly ash removal	0.67
Coal—99.5 percent fly ash removal	0.03

* HEW Publication No. AP-51, *Control Techniques for Particulate Air Pollutants* (January 1969).

† Based on the following gross heating values:
Coal—12,000 BTu/lb at 10 percent ash.
Oil—150,000 BTu/gal.
Gas—1,000 BTu/cu ft.

SECTION 4.
NITROGEN OXIDE EMISSIONS AND CONTROL TECHNIQUES

A. Emissions

Emissions of man-made oxides of nitrogen are mainly caused by combustion processes. Worldwide, over 50 percent of the total is due to coal burning, 42 percent to petroleum combustion, and 4 percent to natural gas burning.

In every combustion process, the high temperatures at the burner and the availability of oxygen result in the fixation of some oxides of nitrogen. The largest concentrations are found in gases from large combustion sources such as steam power plants, which are operated at high firebox temperatures.

B. Control Techniques

Since the use of a nitrogen-free fuel does not prevent the formation of oxides of nitrogen, effective controls must enter into the burning process of the fuel. Unfortunately, for NO_x control, conditions which lead to high NO_x production have been deliberately chosen as desirable for the control of other air pollutants. High flame temperatures and excess air have been engineered into combustion processes as a means of controlling pollution from smoke, carbon monoxide and unburned hydrocarbons.

Large oil- and gas-fired utility power plants may quite effectively utilize 2-stage combustion, flue-gas recirculation, steam or water injection, and combinations thereof.

SECTION 5.
CARBON MONOXIDE EMISSIONS AND CONTROL TECHNIQUES

A. Emissions

Carbon monoxide (CO) is formed when carbonaceous fuels are burned with insufficient oxygen. The concentration of CO in urban areas varies widely with time and location. CO has long been considered an important pollutant and for some time it was assumed that the only sources of CO were combustion sources. Recent studies, however, have indicated some important natural sources of CO.

Nationally, the quantity of CO emissions from oil- and gas-fired stationary combustion sources is insignificant compared to the 99 million tons emitted from all sources. Even coal-fired sources are estimated at less than 1 percent of the total U.S. CO emissions.

B. Control Techniques

The most common and effective known techniques for CO control are discussed below.

Replacing space heating with central power would provide for easier CO control since a larger installation is better equipped to control CO. The expense of using electricity for space heating would hardly be justified on the basis of CO reduction alone.

Good operational practice is the most sensible control technique. A well-adjusted gas-fired boiler may emit less than 1 ppm of CO but may emit more than 50,000 ppm (5%) if insufficient combustion air is supplied. For oil burners, proper maintenance of equipment by all concerned parties is the best method of CO control.

SECTION 6.
HYDROCARBON AND ORGANIC EMISSIONS AND CONTROL TECHNIQUES

A. Emissions

The amount of hydrocarbon emissions from stationary sources in the United States is shown in Table 18.

TABLE 18: Hydrocarbon Emissions Totals from Stationary Sources

Source	SRI's U.S. Annual Total * (tons/yr)	U.S. P.H.S. Figures for 1968 (tons/yr)
Coal	200,000	190,000
Fuel Oil	400,000	
Residual Oil	100,000	110,000
Kerosine	100,000	
Solvents	3,000,000	3,160,000
Incineration	5,000,000	1,480,000
Wood Burning	100,000	450,000
Forest Fires	200,000	2,180,000
Industrial Processes	no data	3,760,000
Total	9,100,000	11,330,000

* Calculated from Stanford Research Institute's worldwide estimates.

Organic solvents are derived mainly from petroleum sources and are used in a variety of industries such as chemical, drug and pharmaceutical, and evaporate during and after application.

Waste disposal by incineration, especially open burning, also contributes significant amounts of hydrocarbons.

B. Control Techniques

By far the most important technique for controlling organic vapor air pollution is in the design of basic equipment to efficiently utilize or completely consume the processed materials. Failing this, control equipment should be used in order to reduce organic emissions.

Hydrocarbon emissions from petroleum-based solvents can be adequately controlled by incineration, adsorption or absorption if the process will allow adequate collection. However, some sources of hydrocarbon emissions, such as evaporation from newly applied paint or other architectural coatings, cannot be eliminated if a petroleum solvent is present.

Incineration is the control of organic emissions by combustion. The objective is to oxidize completely the organic vapors and gases from a process or operation that emits them. Both thermal and catalytic combustion incinerators are used.

There are two main types of adsorption control methods to consider: physical adsorption, where the gas is attracted to the surface of the adsorbent; and chemical adsorption, where the gas chemically reacts with the adsorbent.

From an air pollution standpoint, absorption has been used only to control inorganic compounds, because low concentrations of organic vapors tend to require very large quantities of absorbent due to a long residence time.

Condensation is a satisfactory control for vapor emissions. Many organic vapors, due to their high boiling points, will readily condense even at low concentrations.

Good operating practices are the most practical techniques for reducing hydrocarbon emissions from existing stationary combustion sources. Adequate combustion time, high temperature, and a high degree of fuel-air turbulence will greatly reduce hydrocarbon emissions, increase combustion efficiency and reduce fuel consumption.

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Appendices

APPENDIX A

C
O
P
Y

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

April 15, 1969

Dear Mr. Abernathy:

One of the major national concerns today is the increasing pollution of our environment. Our increasing population, the growth of our cities and the expansion of our industry all create problems of air and water pollution. We feel it would be extremely useful and timely if the oil industry could present comments on the proper role of the industry in formulating or cooperating in corrective actions. A study and report by the National Petroleum Council would give the industry an opportuntiy to present proposals for the prevention or alleviation of pollution and would also serve as an indication of the willingness of the petroleum industry to cooperate with Governmental efforts in pollution abatement.

We, therefore, request that the National Petroleum Council undertake a study of air and water pollution by petroleum facilities and fuels and the impact of pollution control efforts on industry operations. We suggest that the study cover current pollution problems in the petroleum industry, measures for prevention of pollution in the petroleum industry, measures for counteracting accidents resulting in pollution of water by oil and the impact of pollution control regulations on the supply and cost of petroleum products and natural gas.

We are particularly interested in a study of the major disasters such as those which have resulted from tanker accidents and offshore well blowouts. We feel that the U.S. oil industry should be a leader in efforts to avoid or minimize these disasters since it plays such a predominant role in the operation of the facilities involved. This portion of the study should cover the frequency and causes of past accidents and the probability of future occurrences, the trends towards the use of larger facilities and the expected results of such trends, measures taken in the past to prevent or minimize such disasters, additional preventive and precautionary measures which might be taken, current research and suggested ideas for additional research for prevention and cleanup of pollution.

The study should also cover other sources of pollution in the petroleum industry. Specific areas are pollution from salt water flooding, waste oils, and storage and pipeline operations.

We also suggest that the study specifically cover the impact of environmental control regulations on the availability and cost of petroleum products and natural gas. This part of the study should include a careful analysis of regulations on raw material development, environmental controls and direct specifications on product properties.

In summary, we believe that this study should reflect efforts to assure that all pertinent facts are placed before the Government officials who are charged with the making of policy decisions involving pollution control regulations which may affect oil and gas operations.

Sincerely yours,

/S/ HOLLIS M. DOLE

Assistant Secretary of the Interior

Mr. Jack H. Abernathy
Chairman
National Petroleum Council
1625 K Street, N.W.
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APPENDIX B

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Glossary

Absorption—the physical assimilation of one or more components of a gaseous or liquid phase into a second phase (liquid or solid) with the equilibrium distribution of absorbed material in the absorbent tending toward homogeneity, as contrasted to the surface phenomena of adsorption.

Adsorption—the adhesion of molecules of gases or liquids to the surface of other bodies, usually solids, resulting in a relatively high concentration of the gas or solution at the point of contact.

Aerosol—a suspension of microscopic solid or liquid particles in air or gas, as smoke, fog or mist.

Air Oxidation—oxidation of petroleum products such as asphalt or of spent chemicals for disposal by contacting with air at elevated temperatures.

Alkylation—a refinery process for chemically combining isoparaffinic with olefinic hydrocarbons. The product, alkylate, has high octane value and is blended with motor and aviation gasoline to improve the antiknock value of the fuel.

Antiknock—the quality of a material to reduce autoignition knock in internal combustion engines.

Aromatic Hydrocarbons—hydrocarbons characterized by the pressure of a six-membered, unsaturated ring structure of carbon atoms. Examples include benzene, toluene and xylenes.

Ash—the amount of inorganic, nonvolatile matter which remains after complete burning of a combustible material.

Asphalt—a brown to black solid or semisolid bituminous substance occurring in nature, but also obtained as the residue from the refining of certain petroleums and then known as artificial asphalt.

Base Stocks (Gasoline)—a hydrocarbon fraction which makes up the bulk of a commercial gasoline. "Straight-run" and "cracked" gasolines are examples of a base stock. Smaller quantities of other hydrocarbons called "blending agents" or "blending components" are added to base stocks to produce a commercial gasoline.

Biochemical Oxygen Demand—the amount of oxygen utilized by organisms in the biochemical oxidation of organic matter in a waste water in a standard test procedure.

Blending—mixing of components in predetermined and controlled quantities to give a product of desired and uniform quality.

Bottom Sampling—obtaining a sample by collecting a portion of material on the bottom of a container or pipeline.

Carbon Residue—the amount of carbonaceous material left after evaporation and pyrolysis of an oil.

Catalytic Mufflers—an emissions control device designed to either catalytically oxidize the carbon monoxide and unburned hydrocarbons or catalytically reduce the nitrogen oxides in the exhaust from internal-combustion engines.

Catalytic Reforming—a catalytic process to improve the antiknock quality of low-grade naphthas and virgin gasolines by the conversion of naphthenes (such as cyclohexane) and paraffins into higher octane aromatics (such as benzene, toluene and xylenes). There are about 10 commercially licensed catalytic reforming processes.

Centrifugation—the process of separating two phases of differing density utilizing centrifugal force.

Chemical Oxygen Demand—a measure of the oxygen equivalent required for oxidation by chemical means of organic and oxidizable inorganic matter present in a waste water.

Chemical Treating (Acidizing of a Well)—a technique for increasing the flow of oil from a well. Hydrochloric acid is introduced into the well to enlarge and reopen pores in oil-bearing limestone formations. An inhibited acid is used to prevent corrosion of the tubing. Pressure is applied to force the acid into the rock channels and pores, which causes their softer parts to become soluble. After a predetermined time, the acid is flowed or pumped out, leaving enlarged pores in the oil-bearing stratum. The acid attacks the limestone formation in all directions, and, amenable to the law of gravity, the downward pressure is greater than the lateral pressure, assuming equal density of strata. A blanket of calcium chloride or some other heavy inert liquid may be required at the bottom of the well to arrest the penetration of the acid downward to the saltwater level.

Christmas Tree—the assembly of pipes and valves at the top of the casing of an oil well that controls the flow of oil from the well.

Coke—the solid residue remaining after the destructive distillation of crude petroleum or residual fractions.

Compound—chemically speaking, a distinct substance formed by the combination of two or more elements in definite proportions by weight and possessing physical and chemical properties different from those of the combining elements.

Contaminant—any undesirable substance not normally present in a material or present in an excessive amount. Contaminants may alter either the physical or chemical properties of a material and thereby interfere with its desired usage.

Core Drilling—the act of taking a core. The core bit is attached to the end of the drill pipe; this tool then cuts a column of rock from the formation being penetrated; the core is then removed and tested for evidences of oil or gas, and its characteristics are determined. Coring tools permit the taking of full-hole cores, small-diameter cores and side-wall cores. Many wells are now cored all the way through potentially productive formations.

Cracking—a process carried out in a refinery reactor in which the large molecules in the charge stock are broken up into smaller, lower boiling, hydrocarbon molecules, which leave the vessel overhead as unfinished cracked gasoline, kerosines and gas oils. At the same time, certain of the unstable or reactive molecules in the charge stock combine to form tar or coke bottoms. The cracking reaction may be carried out with heat and pressure (thermal cracking) or in the presence of a catalyst (catalytic cracking).

Cryogenic Storage—the low temperature storage of liquefied gases at atmospheric pressure.

Desulfurization—the process for removal of undesirable sulfur or sulfur compounds from petroleum products, usually by chemical or catalytic processes.

Detergent—a substance having the properties of washing away undesirable substances through lowering of surface tension; wetting, emulsifying and dispersive action; foam formation. Soaps are natural detergents. In a lubricating oil, it is the property which prevents the accumulation of deposits in engine parts.

Dispersants—additives used to prevent lubricating oil impurities (usually oxidation products) from combining to form sludge; also, a material used to dissipate oil spills.

Distillation—the general process of vaporizing liquids, generally crude oil or one of its fractions, in a closed vessel while collecting and condensing the vapors into liquids.

Drilling Mud—a suspension, generally aqueous, used in rotary drilling and pumped down through the drill pipe to seal off porous zones and to counterbalance the pressure of oil and gas; consists of various substances in a finely divided state among which bentonite and barite are most common.

Emission Factor—a statistical average of the rate at which air pollutants are emitted from the burning or processing of a given quantity of material.

Fixation—the act or process by which a fluid or a gas becomes or is rendered firm or stable in consistency, and evaporation or volatilization is prevented.

Flaring—the burning of volatile hydrocarbons in specially designed flares for safety purposes.

Flash—the lowest temperature at which vapors from a petroleum product will ignite momentarily on application of a flame in a standard test procedure.

Floating Roof—a special type of storage tank roof which floats upon the surface of the product in the tank, thereby eliminating tank breathing and reducing evaporation losses.

Flocculation—the gathering of suspended particles into aggregations; in drilling fluid a flocculating agent such as brine may cause the clay particles to flocculate with the result that the solids settle out.

Fog—vapor condensed to fine particles of water suspended in the lower atmosphere; formation is aided by presence of condensation nuclei such as dust particles.

Fractions—refiner's term for the portions of oils containing a number of hydrocarbon compounds but within certain boiling ranges, separated from other portions in fractional distillation. They are distinguished from pure compounds which have specified boiling temperatures, not a range.

Fuel Oils—any liquid or liquefiable petroleum product burned for the generation of heat in a furnace or firebox or for the generation of power in an engine.

Fuel Substitution—the use of an alternative fuel type, instead of installing emissions control equipment, in order to comply with air pollution regulations.

Gas Oil—a fraction derived in refining petroleum with a boiling range between kerosine and lubricating oil.

Hydraulic Fracturing—method in which sand-water mixtures are forced into underground wells under pressure. This pressure splits the petroleum-bearing sandstone, thereby allowing the oil to move toward the wells more freely.

Hydrocracking—the cracking of a distillate or gas oil in the presence of a catalyst and hydrogen to form high-octane gasoline blending stocks.

Hydrogenation—a refinery process in which hydrogen is added to the molecules of unsaturated (hydrogen-deficient) hydrocarbon fractions. It plays an important part in the manufacture of high-octane blending stocks for aviation gasoline, and in the quality improvement of various petroleum products.

Hydrotreating—the removal of sulfur from low-octane gasoline feedstocks by replacement with hydrogen.

Lead—petroleum industry parlance for any motor fuel antiknock additive containing lead.

Liquefied Natural Gas (LNG)—natural gas which has been liquefied at a temperature of minus 258°F for ease of storage and transportation.

Liquefied Petroleum Gas (LPG)—as a rule, it is a mixture of natural and/or refinery gases reduced to a liquid and contained under pressure in steel cylinders. It is used as fuel for many different purposes, such as tractors, buses, trucks and stationary engines; for domestic and industrial purposes; and for power generation where commercial natural gas is not available. New uses are constantly being found. A recent development is the use of LPG as a direct quick-freezing agent in the frozen foods industry. It is also known and marketed as butane, propane, bottled gas, etc.

Mach Number—the ratio of the speed of a body through a fluid to the local speed of sound.

Mercaptans—organic compounds possessing a thiol group (—SH). The simpler mercaptans have a strong, repulsive, garlic-like odor which becomes less pronounced with increasing molecular weight.

Motor Gasoline—a volatile, liquid hydrocarbon fuel generally for use in the internal-combustion engine, typically a blend of six to eight base stocks and additives to obtain proper qualities.

Naphtha—liquid hydrocarbon fractions, generally boiling within the gasoline range, recovered by the distillation of crude petroleum. It is used as solvents, dry-cleaning agents and charge stocks to reforming units to make high-octane gasoline.

Natural Gas Liquids—hydrocarbons found in natural gas which may be extracted or isolated as liquefied petroleum gas and natural gasoline.

Neutralization—making neutral or inert, as by the addition of an alkali or an acid solution.

Nutrients—organic and inorganic materials required by microorganisms for normal growth.

Octane Requirement—the minimum octane number necessary to operate a specific internal-combustion engine without producing an audible knock.

Olefins—a class of unsaturated (hydrogen-deficient) open-chain hydrocarbons of which butene, ethylene and propylene are examples.

Organic Solvents—ones having an organic source such as alcohols, ketones, esters, etc. When used as a lacquer solvent, it is known as an organic lacquer solvent.

Oxidation—the chemical reaction or process of combining substances with oxygen, generally taken from the air. All petroleum products are subject to oxidation.

Oxygen Demand—the oxygen-consuming characteristics of a waste water in a standard test. See Biochemical Oxygen Demand and Chemical Oxygen Demand.

Particulate Matter—any matter, except water, that exists in a finely divided form as a liquid or solid.

Petroleum Solvents—ones derived by the distillation of crude oil of which naphtha is an example.

Petroleum Industry—as used in this report, the term includes both the oil and gas industries.

Photochemical Reactivity—a measure of the ability of a volatile organic material to participate in photochemical reactions to produce smog.

Photochemical Smog—an eye-irritating atmospheric condition resulting from a very complex series of chemical reactions involving reactive organic substances and nitrogen oxides and initiated by ultraviolet light from the sun.

Pollutant—any contaminant which when present in the air or water detracts or interferes with its desired usage.

Polymerization—the process of combining two or more simple molecules of the same type, called monomers, to form a single molecule having the same elements in the same proportion as in the original molecule but having different molecular weights. The product of the combination is a polymer. The combination of two or more dissimilar molecules is known as copolymerization. The product of this combination is a copolymer.

Pour Depressant, Pour Point Depressant—an additive which, when added to a wax-containing lubricating oil, reduces the solidification temperature of the oil.

Reserves—the quantity of mineral which is calculated to lie within given boundaries. It is described as total (or gross), workable or probable working, depending on the application of certain arbitrary limits in respect to deposit thickness, depth, quality, geological conditions and contemporary economic factors. Proved, probable and possible reserves are other terms used in general mining practice.

Residual Fuel Oils—topped crude petroleum or viscous residuums obtained in refinery operations. Commercial grades of burner fuel oils Nos. 5 and 6 are residual oils and include Bunker fuels.

Saturated Hydrocarbons—a class of hydrocarbons containing the maximum ratio of hydrogen to carbon atoms and possessing no double or triple bonds.

Solvent—a substance, usually a liquid, capable of absorbing another liquid, gas or solid to form a homogeneous mixture.

Stocks—petroleum in storage, both crude and refined products; includes crude awaiting processing and products awaiting transfer to the point of utilization.

TOVALOP (Tanker Owner Voluntary Agreement Concerning Liability for Oil Pollution)—plan put into effect in 1969 by seven international oil companies, available to all tanker owners who wish to become participants. TOVALOP provides for reimbursement by participating ship owners to national governments at the rate of $100 per gross ton of tanker capacity up to $10 million, for expenses reasonably incurred by them to prevent or clean up pollution of coastlines as a result of the negligent discharge of oil from a participating tanker.

Turbidity—the state or condition of having the transparence or translucence disturbed, as when sediment in water is stirred up, or when dust, haze, clouds, etc., appear in the atmosphere because of wind or vertical currents.

Vapor Lock—a malfunctioning of carburetor and fuel feed system of motor vehicles caused by vaporization of light ends in the gasoline. Vaporization occurs when the temperature at some point in the fuel system exceeds the boiling point of the volatile light ends.

Vapor Pressure—the pressure exerted by the vapors released from an oil at a given temperature when enclosed in an airtight container. For motor gasoline it is a criterion of vapor-lock tendencies; for light products it is generally an index of storage and handling requirements.

Viscosity—the measure of the internal friction or resistance of an oil to flow.

Volatility—that property of a liquid which denotes its tendency to vaporize.

Well Completion—in a potentially productive formation, the well must be completed in a manner to permit production of oil; the walls of the hole above the producing layer (and within it if necessary) must be supported against collapse and the entry into the well of fluids from formations other than the producing layer must be prevented. A string of casing is always run and cemented, at least to the top of the producing layer, for this purpose. Some geological formations require the use of additional techniques to "complete" a well such as casing the producing formation and using a "gun perforator" to make entry holes, the use of slotted pipes, consolidating sand layers with chemical treatment, and the use of surface-actuated underwater robots for offshore wells.

Well Stimulation—the use of secondary recovery methods such as water-flooding to increase the production rate of crude oil from a well or to prolong the useful life of the well.