Controlling Hydrocarbon Emissions from Tank Vessel Loading

Committee on Control and Recovery of Hydrocarbon Vapors from Ships and Barges, Commission on Engineering and Technical Systems, National Research Council

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Controlling Hydrocarbon Emissions from Tank Vessel Loading

Committee on Control and Recovery of Hydrocarbon Vapors from Ships and Barges
Marine Board
Commission on Engineering and Technical Systems
National Research Council

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PREFACE

Several states are considering placing controls on vapor emissions from the loading and ballasting of tankships and barges carrying volatile organic compounds, mainly hydrocarbons. The object is to attain federal standards for ambient air concentrations of ozone under the National Ambient Air Quality Standards administered by the U.S. Environmental Protection Agency (EPA). Hydrocarbon vapors contribute to ozone formation in the lower atmosphere, which triggers atmospheric phenomena (smog) that exacerbate lung conditions and related health problems in the general populace.

Controls would require loading of cargo and ballasting in such a manner that vapors could be piped ashore, for disposal or recovery, or retained aboard. The U.S. Coast Guard and industry have identified a number of safety and operational concerns. Safety concerns include the risk of fire and explosion associated with handling vapors and the dangers and accompanying risks associated with overloading and spills. Operational concerns include the need for perhaps costly modifications to vessels and loading terminals; better qualification, training, and management of personnel; and improved operational controls to ensure safety. Another potential problem is the possibility that regulations in different locations could require equipment and procedures that are incompatible with one another.

The Coast Guard, responsible for the safety of waterborne commerce, requested that the National Research Council (NRC) conduct an assessment to provide a sound technical basis for any contemplated state, federal, and industry action. Accordingly, the NRC's Commission on Engineering and Technical Systems (CETS) convened the Committee on Control and Recovery of Hydrocarbon Vapors from Ships and Barges. Committee members were selected with regard for the expertise necessary for the assessment, and to achieve a balance of experience and viewpoints. (Biographical information is presented in Appendix A.) The principle guiding the constitution of the committee and its work, consistent with NRC policy, was not to exclude the bias that might accompany expertise vital to the study, but to seek balance and fair treatment. The committee operated under the auspices of the Marine Board, a unit of CETS.

The committee was asked to assess the technical, safety, and economic aspects of maritime hydrocarbon vapor control and recovery systems. It agreed to review the available and prospective technology for vapor control; to identify engineering, operational, and cost con cerns for vessels associated with control systems; to examine safety concerns and potential safety-related technical developments; and to develop alternative procedures for achieving adequate national standards and practices. The committee also agreed to recommend government and industry initiatives for ensuring safe operation of maritime hydrocarbon vapor control and recovery systems.

Two topics were judged to be outside the scope of the study: (1) emission controls on vessel engine exhausts, and (2) the justification for, or the environmental impacts of, air quality requirements.

The committee began its study by surveying 62 state and local environmental or air pollution agencies to assemble an inventory of current and contemplated regulations affecting the control of hydrocarbon vapors from loading and ballasting vessels. A summary of its findings is presented in Appendix B.

The committee estimated the extent of these emissions nationally and their distribution by state and air quality region. Using detailed cargo data, the committee applied emission estimating models used by the EPA. The estimates showed that gasoline and crude oil account for the overwhelming majority of hydrocarbon vapor emissions from cargo loading; the committee therefore restricted its further investigations to these two cargoes.

The committee visited several large gasoline and crude oil loading terminals to obtain a clear picture of operating procedures and technology. The site visits included several to terminals using vapor recovery systems designed and installed for special cargoes.

The committee developed hypothetical but realistic technical systems suitable for vapor control in situations typifying a variety of the affected industries' operations. To put the costs of compliance in perspective, the committee obtained independent estimates of the capital and operating costs of these vapor control systems. It also conducted a case study of two actual gasoline terminals in Texas to estimate the costs of vapor control on the basis of throughput.

Committee meetings included site visits and briefings by government and industry representatives and others with an interest in the study topic. The committee also reviewed working papers prepared by its members and consultants. The conclusions and recommendations represent the committee's consensus.

ACKNOWLEDGMENTS

The committee benefited from the interest and contributions of a number of individuals and organizations. Frits Wybenga and Kathy Barylski of the U.S. Coast Guard worked closely with the committee in all areas of its study, and provided much useful information on tank vessel operations and safety. David Markwordt of the EPA also participated actively in committee deliberations and contributed to the cost-effectiveness analysis.

Early discussions with the American Institute of Merchant Shipping, American Petroleum Institute, American Waterways Operators (AWO), and Independent Liquid Terminals Association (ILTA) assisted the committee in understanding the issues. John Prokop and Clement Mesavage of the ILTA helped the committee identify marine terminals that load gasoline or crude oil and the operators of the terminals. Joseph Farrell and Thomas Allegretti of the AWO organized a task force of their organization to assist the committee. This task force, chaired by Joseph H. Pyne of Hollywood Marine Company, provided supplemental analyses of the costs and operational implications of regulatory controls. These analyses were performed under contract to the AWO by Booz-Allen & Hamilton; John Wing and David St. Amand of the Transportation Division of Booz-Allen & Hamilton met with the committee to convey the results.

Austin P. Olney and Laurie Frost of LeBoeuf, Lamb, Leiby & MacRae provided an analysis of statutory and case law (Appendix C). Cordell Haymon and other members of the Petroleum Services Corporation met with the committee to discuss the training and responsibilities of inland barge tanker personnel. Robert Conn of Shell Oil Company assisted in the understanding of closed loading operations. Philip Wolfe and David Noble of United Technical Design estimated the costs of sample vapor control systems at the direction of the committee.

Several companies generously showed the committee their operations and discussed marine loading and vapor recovery operations. These included Exxon Baytown refinery and terminal, Houston, Texas; Bay Tank Terminal, Houston; Chotin Marine Transportation, Baton Rouge, Louisiana; Hall-Buck Marine Services Company, Baton Rouge; Exxon Terminal, Baton Rouge; and Shell Terminal, Norco, Louisiana.

While committee members serve as individuals, several experts from their organizations provided invaluable assistance. Thomas Grimmett of the Massachusetts Institute of Technology assisted with the analysis of tank vessel emissions. Harald Lyche of Chevron contributed to the description of vapor control technologies and assisted in other ways. Alex Opiela, Beverly Fowler, John Turney, and Freylon Coffey of the Texas Air Control Board also undertook substantial assignments at the direction of the committee. Jim Montenieri and Gary Weslowski of IMO-Delaval, Inc., briefed the committee on closed-tank gauging systems.

CONTENTS

EXECUTIVE SUMMARY 1

1 INTRODUCTION 7
- Laws and Regulations Concerning Air Quality and Maritime Safety 8
- Estimating Emissions 10
- Focus for Assessment 22

2 CURRENT PRACTICES ON TANK VESSELS 33
- Inland Tank Barges 34
- Tankships 41

3 VAPOR CONTROL TECHNOLOGY 58
- Maximum Control of Emissions 59
- Vapor Balancing as an Adjunct to Vapor Control 80
- Operating Procedures to Reduce Emissions from Tankships 81
- Hydrocarbon Vapor Control Systems: Assumptions for Purposes of Assessment 83

4 SAFETY CONCERNS 93
- Accident Scenarios 93
- Historical Accident Data 94
- Potential Hazards of Vapor Control and Recovery Systems 98
- Technologies to Reduce the Risk of Fire and Explosion 101
- Mitigation Measures 103
- Risk Analysis 104

5 COST-EFFECTIVENESS 108
- The Cost of Control 108
- Operating Cost Estimates for Inland Barges 115
- Cost-Effectiveness of Hydrocarbon Vapor Emission Controls at Marine Loading Terminals in Texas 119
- Cost-Effectiveness as a Function of Terminal Throughput 129
- Cost-Effectiveness Compared to Control of Other VOC Sources 131

6 CONSIDERATIONS IN DEVELOPING NEW POLICY 134
  Federal Air Pollution Control Authority: The Clean Air Act 136
  Federal Marine Safety Regulatory Authority 136
  Safety and Operational Complexity 137
  Energy Conservation and the Choice of Control Technologies 138
  International Considerations 138
  Impacts on Commerce 138
  Regulatory Alternatives 139

7 CONCLUSIONS AND RECOMMENDATIONS 141

REFERENCES 143

BIBLIOGRAPHY 145

APPENDIXES

A: Biographies of Committee Members 149

B: Status of State and Local Vapor Control Requirements Affecting Maritime Operations 152

C: Legal Issues Affecting Regulation of Vessel Cargo Vapor Emissions 166

D: Calculations of Vessel Emissions 222

E: Tank Barge Surveillance--An Overview 232

F: Loading Operation of Straight Cargo Gasoline into Barges with Deepwell Pumps 239

G: Calculations of Cost-Effectiveness as a Function of Terminal Throughput 243

EXECUTIVE SUMMARY

Several states are considering regulations to control vapor emissions from the loading and ballasting of tankships and tank barges carrying liquids such as volatile hydrocarbons. These vapors, displaced by entering cargo or ballast as vessel tanks are filled, totaled 56,600 metric tons in the United States in 1985. About 95 percent were from crude oil and gasoline cargoes; two-thirds came from inland barges and the rest from tankships.

These emissions amounted to about 0.2 percent of all volatile organic emissions nationally. For comparative purposes, this is about one-tenth the volume of the vapor emissions from automobile refueling. However, vessel hydrocarbon vapor emissions may be very important locally. State efforts to meet federal air quality standards have therefore focused on emissions from marine loading terminals, among other sources.

Under current air quality regulations, these emissions are generally not subject to control. Nevertheless, hydrocarbon vapors are important contributors to ozone generation. Several states are considering controls as a way to meet federal air quality standards for ozone set by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act. A number of major metropolitan areas in the United States are not in attainment of National Ambient Air Quality Standards (NAAQS) for ozone.

THE FEASIBILITY OF VAPOR CONTROL

Technology for controlling these emissions is available and in use; vessels and marine terminals that load liquefied natural gas, acrylonitrile, and other hazardous fluids routinely capture and reuse or dispose of loading vapors. It is technically feasible to locate equipment for vapor recovery or disposal either on the vessel or at the shoreside terminal. Controlling vapors from hydrocarbon loading would require extending this practice broadly, and undertaking vapor control at higher loading rates than currently practiced.

Handling potentially explosive vapors could present an added hazard at barge and tankship terminals. It would also entail substantial investments and operating costs in the tankship and barge industries. Loading terminals and vessels would need to install and operate the necessary systems. Terminals with low throughputs, inland barges, and smaller, older tankships would face greater cost impacts than larger units of the industry.

Equipment needed for vapor control includes systems aboard vessels that make closed loading possible: devices to protect tanks from overpressurization, level monitoring and alarm systems to prevent overfilling, and devices for final cargo gauging and sampling. Closed loading is done with hatches and ports shut, but it does not necessarily preclude venting of vapors to the atmosphere. Most tankships are equipped for closed loading, to maintain the required pressure of fire-preventive inert gas in cargo tanks. Tank barges generally do not use inert gas, and are usually open loaded.

Terminals would need vapor transport piping, incinerators, or other equipment for disposal or recovery of vapors, and inert gas generating and piping systems to prevent the formation of flammable or explosive vapor-air mixtures in tanks and pipelines. Vessels would need piping and manifolds to collect vapors and carry them ashore or elsewhere for disposition. Tank gauging and alarms, detonation arrestors, and other inline safety devices on vessels and at terminals are needed to prevent overpressurization and prevent or limit the effects of fires and explosions.

The complexity of these systems could challenge the engineering, operational, and personnel training standards of some sectors of the industry, especially at the lower technology end of the scale, such as inland barges and small product terminals. Some items of safety equipment, such as detonation arrestors, might require further development and testing at sizes appropriate to tank barge or tankship loading rates.

SAFETY AND OPERATIONAL COMPLEXITY

The loading of tank vessels with hydrocarbon cargoes presents three main hazards: (1) fire due to the ignition of spilled liquid or unconfined vapors, (2) explosion due to the ignition of vapor-air mixtures in confined spaces, (3) water pollution as a result of spills. An additional consideration is possible personnel exposure to vapors. The addition of vapor-handling systems, it has been suggested, could increase the risks of such events by adding to the operational complexity of loading operations, and in particular by requiring additional handling of potentially explosive vapors. Experience to date is too limited to justify firm conclusions, although it does suggest that proper personnel training and management can keep the risks of vapor control within the bounds of normal risks in the industry. Redundant safety systems would be required at terminals and on board vessels to ensure that the unnoticed failure of one system would not expose operations to undue risks.

Certainly, vapor control would require raising operating and training standards throughout the tank barge and tankship industries to the levels that obtain in the most technically advanced sectors of those industries. The operation of vapor control systems would entail stan dards of precision and care, for example, well above those considered normal in the industries. Control of hydrocarbon vapors from vessels would require raising standards of care and management to levels similar to those in the most technically sophisticated sectors of the marine transportation industry. Furthermore, human error is the major cause of industrial accidents, and management and training programs should address this fact.

Tank barges generally, and tankships occasionally, are loaded with hatches and vents open, to allow visual inspection of cargo levels. Containing vapors will require closed loading, with closed-tank gauging systems, and will also require vapor collection systems to carry vapors to disposal or recovery facilities. Experience suggests that the necessary operations could be carried out with little or no increase in spills or other accidents. The U.S. Coast Guard would have to proceed on the basis of risk analysis while it and the industries involved gather the experience necessary to quantify the risks. Such a risk analysis has not yet been made.

COSTS AND ECONOMIC IMPACTS

The economic impacts of vapor control requirements could be substantial. First, vessel and terminal owners and operators would suffer the direct costs associated with installing and operating the necessary systems. The committee's assessment suggests that these costs would vary widely from vessel to vessel and terminal to terminal. For example, estimates indicate that an inland river barge would incur the same retrofit cost--$168,000--as a 70,000 deadweight-ton crude carrier with 25 times the cargo capacity. Case studies of two actual terminals (see Chapter 5) show added capital and operating costs that range from more than $5,000 per ton of emissions abated for a small terminal, loading 1.3 million barrels of gasoline per year, to less than $3,000 per ton of emissions for a larger terminal, loading 14.9 million barrels per year. In general, the committee's cost studies show that the cost effectiveness of emission abatement improves with cargo throughput. This could put small terminals and small inland barge companies at a competitive disadvantage.

Second, the hydrocarbon vapor control standards under consideration for marine terminals and vessels would affect the cost-competitiveness of tank vessels in relation to other forms of transport. Tank vessel carriage of petroleum cargoes is already declining.

Third, the imposition of standards only in nonattainment areas for ozone, it has been suggested, would lead many vessel operators to limit their operations to areas where vapor control is not required, or where requirements are less stringent. This situation would be exacerbated by varying and possibly incompatible standards.

Without detailed economic study, it is impossible to gauge the sizes of these economic impacts. Appropriate regulatory coordination, with attention to safety and uniformity, can minimize them, but not avoid them altogether.

POTENTIAL REGULATORY CONFLICT

Neither the Coast Guard nor the EPA has taken a major initiative to coordinate or standardize state regulatory development. However, without coordination between these two agencies, state air quality regulatory bodies, and industry, a high potential exists for a clash of regulatory interest between marine safety and air quality goals.

Marine vessels, unlike other mobile emissions sources such as automobiles, are not expressly regulated by federal air quality legislation. It is unclear whether EPA may require states to regulate the emissions of so-called mobile sources (such as vessels) indirectly, by attributing them to their stationary gathering points (in this case, marine terminals). The agency has taken no positive action on hydrocarbon vapor emissions from vessels, beyond that involved in reviewing state ozone compliance plans. Its authority to coordinate state initiatives is limited.

The Coast Guard, whose responsibility is marine safety, must ultimately approve the vapor control systems that may be installed on vessels and at terminals. Uncoordinated development of state regulations could increase risks by fostering a lack of standardization.

Thus, the drive to clean up the air in this case raises the potential for conflict of national interest between safety and environmental goals.

The committee found that vapor control is technically feasible with available technology, that appropriate care by industry and regulators could satisfy the above concerns, and that uniformity of equipment and procedures is important. It recommends a coordinated national approach to developing regulations under the leadership of the Coast Guard, with the involvement of the EPA, states, and industry. Special attention should be directed to risk analysis, uniform technical standards, personnel training and certification, and investigation of new technologies.

CONCLUSIONS AND RECOMMENDATIONS

1. Of the estimated 56,600 metric tons of hydrocarbon vapor emissions from tank vessels in 1985 (about 0.2 percent of national volatile organic compound emissions), about 95 percent came from gasoline and crude oil loaded in tankships and tank barges. Almost all of these emissions were from vessels in domestic trade. About two-thirds were from inland tank barges, and the rest were from tankships.
2. Control and recovery of more than 90 percent of hydrocarbon emissions from tankships and tank barges are technically feasible with available technology. Hydrocarbon vapor emissions may be abated by any of several technologies to recover or destroy hydrocarbons. Technologies vary in their efficiency of abatement, with destruction technologies generally higher in efficiency than recovery technologies.
3. Abatement of hydrocarbon vapor emissions from tank vessels raises legitimate concerns of safety, cost, economic impact, and operational reliability. With appropriate government and industry attention, these

concerns can be addressed. There is as yet too little experience to project conclusively the safety of planned operations.

RECOMMENDATION: In the absence of historical safety experience, the U.S. Coast Guard should employ risk analysis in assessing the safety of the various hydrocarbon vapor emission control alternatives.

4. Safe handling of hydrocarbon vapors will require standardized equipment and procedures, which include redundant, automated gauging and alarm devices to prevent overfilling and over or under pressuring, as well as in-line safety devices such as detonation arrestors.

   RECOMMENDATION: Development and testing programs should be pursued to advance the state of the art in gauging and alarm systems and also to assure and improve the reliability of large (> 6-in. diameter) detonation arrestors. The gauges and alarms program should include addressing the requirements of small, unpowered vessels, i.e., tank barges.
5. Safe hydrocarbon vapor emission abatement will require trained, experienced personnel and adequate control of operations by safety-conscious management. The level of operational control in the tankship industry is, in general, adequate. However, that in the barge industry will need to be strengthened.

   RECOMMENDATION: The U.S. Coast Guard should revise its personnel certification requirements for tankermen to ensure that responsible personnel are fully qualified and trained to maintain the safety of vapor control operations.

   RECOMMENDATION: The tank barge industry should undertake a voluntary safety consciousness education campaign directed to operations. This campaign should complement any federal and state regulatory initiatives.
6. Controlling hydrocarbon vapors from vessels may be cost-effective in a particular nonattainment area for ozone if tank vessels are a significant source of hydrocarbon vapor emissions and cargo-loading throughput is sufficient to justify control measures.
7. The economic impact of vapor control regulations will be related to how the regulations are applied: their timing, the categories of vessels or terminals that may be controlled, and the geographical locations in which the regulations are imposed.
8. If emission controls are to be put in place, a coordinated national approach is essential to ensure the implementation of uniform and effective safety practices, with appropriate regard for the effects on interstate and international commerce. The necessary coordination could be achieved by amendments to the Federal Clean Air Act, or by a cooperative interagency program of regulatory development.

RECOMMENDATION: The U.S. Coast Guard should lead the development and implementation of a coordinated program to ensure the safety and standardization of maritime hydrocarbon vapor emissions controls. Such an interagency program should involve, at a minimum, the U.S. Coast Guard and the U.S. Environmental Protection Agency, operating according to appropriate federal rule-making procedures. Elements of the program should include:

- vessel safety;
- terminal safety;
- control of emissions; and
- industry safety education.

9. New vapor control, recovery, and disposal methods may hold promise as replacements for currently available methods.

RECOMMENDATION: A program of technical research, development, and testing should be directed to changes in operational procedures that may reduce emissions, to recovery and disposal technologies that may offer safer, less costly control measures, and to vapor barriers and foams that could help reduce hydrocarbon emissions by controlling vapor generation in cargo tanks.

1

INTRODUCTION

When loading their cargo tanks, tankships and barges carrying volatile liquids expel vapors, displaced by entering cargo or ballast. The vapors contain volatile organic compounds (VOCs), which can exacerbate respiratory conditions. Thus, the maritime emissions are part of the larger national air pollution problem.*

About 95 percent of tank vessel VOC emissions are from crude oil and gasoline cargoes. About two-thirds come from inland barges, and the remainder from tankships. These emissions amount to only about 0.2 per

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*An analysis of the impact of volatile organic compound emissions from tank barges and tankships on ozone concentrations in port areas was conducted by Booz-Allen & Hamilton, Inc. at the request of the American Waterways Operators (Booz-Allen & Hamilton, Inc., 1987b).

The analysis shows that marine VOC emissions represent a small percentage of the total VOC emissions in four selected port areas--New York/New Jersey, Houston, Philadelphia, and Los Angeles/Long Beach. In three of the port areas, each of the largest ten point sources of VOCs exceeded the total of all marine VOC emissions. Control of hydrocarbon emissions from loading and ballasting operations would produce decreases in VOC emission levels in the four port areas of from 0.03 to 2.3 percent. Furthermore, analysis of wind direction during exceedances indicates that marine sources do not normally contribute pollutants toward ozone monitors during days of nonattainment conditions. Of the four ports evaluated, only the New York/New Jersey area could possibly expect any measurable reduction in ozone levels if emissions during marine transfer operations were controlled. In contrast, the Los Angeles/Long Beach and Philadelphia marine VOC emission levels are very low in comparison to total VOC emission levels. Marine emission levels in Houston were higher than Los Angeles/Long Beach and Philadelphia, but prevailing wind conditions indicate that the marine VOC emission sources were not contributing to nonattainment levels. The analysis concludes that, “Marine tank vessel operations are a minor contributor of VOC emissions, particularly when viewed in context of automobiles and major industrial sources. . . . [I]n the ports of New York/New Jersey, Houston, Philadelphia and Los Angeles/Long Beach, controlling marine emissions would have no or minimal impact on measured ozone levels and exceedances.”

cent of all volatile organic vapor emissions nationally; they are about one-tenth as great as vapor emissions from automobile fueling (EPA, 1986). However, they may be significant locally.

Under current air quality regulations, emissions from tank vessels are generally not subject to controls. However, several states, in order to meet federal air quality standards for ozone, are considering controls (see Appendix B). The national standard for ozone is not being met in most large centers of population, and the statutory deadline for attainment is December 31, 1987. Areas in nonattainment by that date will be required to submit plans for additional control of volatile organic compound emissions. Figure 1-1 shows the ozone nonattainment areas by county. In general, heavily populated areas fail to meet the standards. In attainment areas, new source review requirements being considered in some states may involve vapor emission controls for new terminals.

Technology for controlling vapor emissions from marine cargo loading is available and in use for some cargoes. Vessels and marine terminals that load liquefied natural gas, acrylonitrile, and other hazardous fluids (and a few that load crude oil or gasoline in areas of strict air quality control) routinely capture and reuse or dispose of vapors emitted during cargo operations, piping the vapors to incinerators, flares, or recovery systems. Safety devices are employed to prevent or limit the effects of fires and explosions.

Controlling vapor emissions from gasoline and crude oil loading would require extending this practice broadly. Processing flammable vapors could present an added hazard at barge and tankship terminals, and would entail substantial investments by the tank vessel and terminal industries. These prospects have raised concerns on grounds of both safety and economic impact.

Regulations being considered in several states would require loading terminals to install and operate systems for piping hydrocarbon vapors to recovery or disposal equipment. Vessels, too, would be retrofitted. Installing and operating these systems could challenge the engineering, operational, and training standards of some sectors of the industry, especially at the lower technology end of the scale, such as inland barges and small product terminals. The drive to clean up the air in this instance raises a potential conflict of national interest between air quality, as regulated by the U.S. Environmental Protection Agency (EPA) and the states, and operational safety, the primary concern of industry and the U.S. Coast Guard.

LAWS AND REGULATIONS CONCERNING AIR QUALITY AND MARITIME SAFETY

The Clean Air Act and the States

The federal Clean Air Act (CAA) of 1970, as amended, created the basis for a cooperative federal and state program to control air pollution. Under the act, National Ambient Air Quality Standards (NAAQS) are established by the EPA for certain “criteria pollutants.” For areas not

FIGURE 1-1 Ozone nonattaining areas, September 1985. Source: Adapted from U.S. Environmental Protection Agency data.

in attainment of a standard, each state must develop and enforce a State Implementation Plan (SIP), with specific emissions limitations to meet the standard by statutory deadlines.

Ozone in the lower atmosphere is one of the criteria pollutants, with a compliance deadline of December 31, 1987, and several states are now considering regulating sources of volatile organic compounds. VOCs, mainly hydrocarbon vapors, are precursors of ozone. Among the sources being considered for control are marine terminals serving tank barges and tankships.

Marine vessels, unlike other mobile emission sources such as automobiles, are not expressly regulated by federal air quality legislation. The extent of EPA's power to regulate the emissions of so-called mobile sources indirectly, by attributing them to their stationary gathering points (in this case, marine terminals), is not explicitly defined. It is unclear whether EPA may require states to regulate indirectly marine vessel emissions. In the absence of explicit guidance, some states have determined that loading and ballasting emissions from vessels can be attributed to the adjacent shore facility.

However, the CAA does not preclude states from doing so in a SIP. (Appendix C discusses the CAA and related legal and policy issues as they apply to the control of hydrocarbon vapor emissions from tankships and barges.) Under the pressure of the ozone deadlines, and the severe penalties for nonattainment, several states are considering this step.

Coast Guard Authority in Marine Safety

The U.S. Coast Guard, under the Port and Tanker Safety Act (PTSA) of 1978 (33 USC section 1221-31 and 46 USC chapter 37) and other statutes, has clear and comprehensive responsibility for marine safety and for preventing the pollution of water by vessels. Under this authority, the Coast Guard regulates the design, construction, repair, maintenance, operation, and manning of tank vessels.

The Coast Guard, except to a limited degree, has no specific regulations in place to address the safety of vapor control devices on board tank vessels, although it does approve and inspect vapor recovery equipment under its general regulatory and inspection authority. The Coast Guard has general authority to review and approve the safety aspects of shoreside facilities at terminals. It may shut down terminals whose operations are identified as unsafe.

Vapor control regulations might apply equally to both domestic and foreign vessels visiting a port in which controls are in force. Therefore, issues of national uniformity and deference to international regulation require careful consideration.

ESTIMATING EMISSIONS

To estimate emissions of VOC vapors from maritime sources, it is necessary to develop an understanding of the marine terminals and vessels that handle petroleum cargoes, and of the cargoes themselves.

Sources of Emissions

When liquid cargo is loaded into a tank, some vaporizes into the tank atmosphere.* As the tank is filled, the vapors are displaced and forced out of tank vents. The displaced gases contain the VOC vapors of the cargo being loaded and vapors from the previous cargo, if the tank was not purged of gas or "gas-freed" since the last time it was loaded. A cargo tank that has undergone crude oil washing (see Chapter 2) releases more vapors than a tank that has not. Figure 1-2 illustrates the emission of vapors while loading.

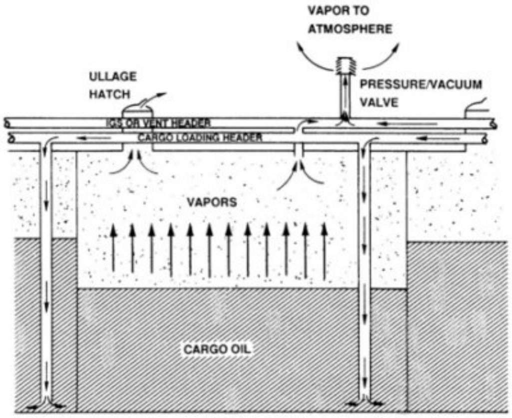

FIGURE 1-2 Emissions from cargo loading.

Vapor emissions from tankship ballasting are also of some concern, although diminishing in importance. After unloading, many tankships travel without cargo. For stability, they must carry water as ballast. When ballast water is loaded into cargo tanks full of vapor from the preceding cargo, the vapor is displaced and emitted in much the same way as in loading cargo. Most tankships built since 1980 are required by domestic law and international agreement to use segregated ballast tanks and thus do not emit vapors during ballasting. Older and smaller tankships remain unaffected by the requirement. Inland barges do not carry ballast.

VOC vapors are also released by tank "breathing," the result of pressure changes in the cargo tank owing to changes in temperature. These emissions are small, and they occur mainly away from ports while vessels are underway, or, in the case of barges, while they are fleeted. Small vapor emissions also occur during cargo gauging, when a hatch cover is opened to permit inspectors to measure the cargo; no attempt was made to calculate this small amount of emissions.

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*Emissions from unloading are not addressed in this report because emissions from unloading tank vessels are released, if at all, on shore. These emissions are subject to state regulation and licensing.

TABLE 1-1 EPA Emission Factors in Pounds Per 1,000 Gallons of Liquid

	Loading Operations		
Emission Source	Ships	Barges	Tanker Ballasting
Gasoline	1.8	3.4	0.8
Crude oil	0.61	1.0	1.2
JP-4	0.5	1.2	Unknown
Kerosene	0.005	0.013	Unknown
Distillate oil no. 2	0.005	0.012	Unknown
Residual oil no. 6	0.00004	0.00009	Unknown

Source: U.S. Environmental Protection Agency (1985).

Facilities that clean cargo tanks are also sources of vapor emissions. These facilities are outside the scope of this study.

Emission Factors

Emissions of VOCs are estimated by multiplying the amount of liquid cargo loaded by an emission factor, generally expressed in pounds per 1,000 gallons of liquid. Emission factors have been developed for many organic compounds. Table 1-1 summarizes typical emission factors developed by the U.S. Environmental Protection Agency (1985) and given in the agency's AP-42 publication. Table 1-2 lists additional emission factors from Scott Environmental Technology, Inc. (1981). The difference in emission factors between tankships and tank barges is due to differences in tank configuration. Tankship tanks are deeper and have less surface area; consequently less cargo is evaporated.

Vessel Population

Tank vessels include both tankships, which are self-propelled, and tank barges, which are not. Aside from some oceangoing barges and a few oceangoing integrated tug-barge combinations, the tank barges generally ply the inland waterways of the United States. The tankships other than for petroleum importation are used mainly in coastal traffic, since almost no petroleum is exported.

Tankships in active trade in and with the United States range in size from less than 1,000 deadweight tons (dwt) to 406,000 dwt. Data on tankships holding active U.S. Coast Guard certificates of inspection or compliance (necessary documents for entry into U.S. ports) at the end of 1986 show 152 U.S.-flag tankships of more than 20,000 dwt trading in U.S. waters (9.4 million dwt) as well as 990 foreign-flag tankships of more than 20,000 dwt (77.3 million dwt). In 1986 there were only 81

TABLE 1-2 Scott Environmental Technology Emission Factors in Pounds Per 1,000 Gallons of Liquid

Product	Loading/Ballast Emissions
Benzene	1.0
JP-4	0.6
JP-5	0.005
Kerosene	0.005
Mixed chemicals	0.005
Lube oil	0.005
Naphtha	0.3
Solvents	0.3
Distillate oil	0.005

Source: Scott Environmental Technology (1981). U.S.-flag tankships of less than 20,000 dwt, whose total tonnage of 240,000 dwt reflects the very small size of many of these vessels.

In 1986, 3,968 barges in the United States were certificated to carry subchapter D cargoes (generally flammable liquids, including crude oil and gasoline) or both subchapter D cargoes and subchapter O cargoes (chemicals with hazards beyond flammability).* Inland barges generally range in size from 10,000-40,000 barrels (bbl).**

U.S. and international regulations require most tankships to have segregated or clean ballast tanks. (The amount of ballasting emissions depends on the amount of ballasting in uncleaned cargo tanks.) They require most ships to have inert gas systems to charge the atmosphere above the cargo with a nonreactive gas as a safety measure. The gas piping of inert gas systems can be used as a vapor header, through which cargo vapors could be piped to vapor recovery or disposal units. It can also be used in transferring vapors from tank to tank during ballasting, thus limiting emissions (see Chapter 2). Figure 1-3 is a diagram of the international regulatory requirements.

U.S. regulations incorporate and implement international regulations, and, because of a U.S. statutory provision, are somewhat more stringent in their requirements for existing product tankships of

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*The terminology refers to the subchapters of Title 46, Code of Federal Regulations (CFR), under which liquid cargo is regulated when carried in bulk on a vessel. Subchapter D is found in 46 CFR parts 30-38, and subchapter O is in 46 CFR parts 150-154. Subchapter D covers roughly 400 liquid and liquefied gas cargoes having only the hazard of simple flammability. Subchapter O covers approximately 300 liquid and liquefied gas cargoes having hazards beyond simple flammability.

**Approximately seven barrels are equivalent to one dwt.

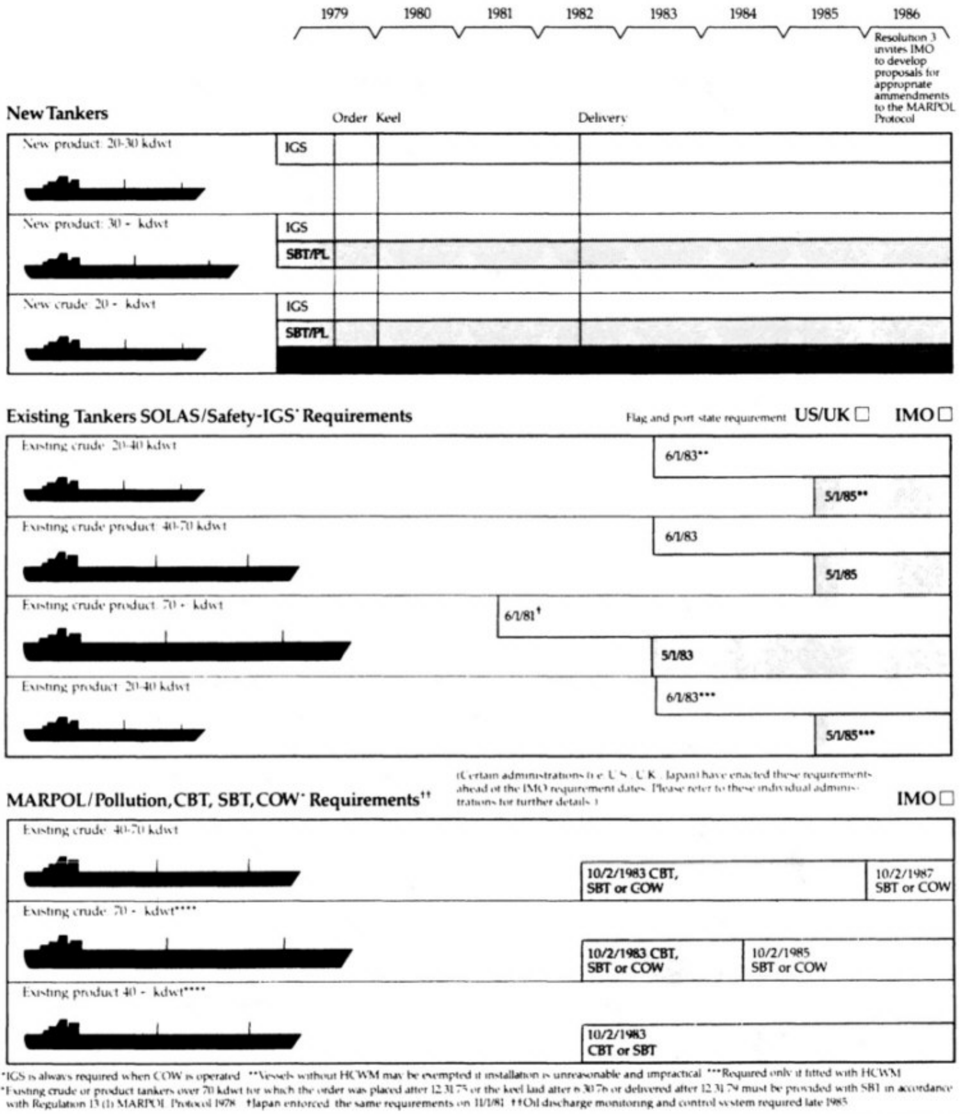

FIGURE 1-3 Tanker safety and pollution prevention design requirements. Source: *Exxon Marine*, 1987.

LEGEND: SBT (segregated ballast tank). When a tanker discharges its cargo, it must take on ballast water to maintain a seaworthy condition. Under present regulations, ships take water into empty cargo tanks. Before the ship reloads, the ballast water is discharged either into shore reception facilities or as clean ballast after a load on top (LOT) operation. SBT requires sufficient tanks for carrying only ballast water so that under ordinary circumstances ballast water does not enter the cargo tanks. As the chart shows, this measure was adopted for newbuildings.

PL (protective location). With the PL concept, SBTs are placed in selected areas of the vessel where it is believed they can provide a degree of optimum protection for the ship's crew and cargo in the event of a grounding or collision.

CBT (clean ballast tank). In existing ships, CBTs are cargo tanks dedicated to carrying ballast. As the chart shows, this option was available for existing tankers only during the specified interim, until the SBT became mandatory. Although similar in concept to SBTs, CBTs do not require separate pipes and pumps for taking on and discharging ballast.

COW (crude oil washing). COW is the cleaning of cargo tanks with high-pressure jets of crude oil while the ship is discharging. The crude oil pumped through the ship's tank washing machines acts as a cleaning agent and removes oil residues, which are then pumped ashore with the cargo. COW requires the installation of fixed-in-place washing machines and IGS.

HCWM (high-capacity washing machine). HCWM is a tank-cleaning machine with a capacity of 60 cubic meters per hour or more.

IGS (inert gas system). IGS permits a ship to maintain an inert, that is, nonflammable, atmosphere in cargo tanks. In a typical system, boiler flue gas is cleaned, cooled, and pumped to tanks. Although hydrocarbon vapors might also be present in the tanks, oxygen levels in the inert gas are too low to support combustion.

LOT (load on top). LOT is a system based on the principle that when oil and water mixtures are left standing, the oil separates and rises to the top. The heavier clean water at the bottom can be drawn off and returned to the sea; oil and water mixtures that remain are transferred to a slop tank. After a period of time, the mixtures separate further, and clean water can again be removed from the bottom of the tank. At the next loading port, new cargo is loaded on top of the reclaimed oil in these tanks. LOT, in use for many years, has contributed significantly to the reduction of operational pollution from tankers.

20,000-40,000 dwt. Domestic product tankships of this size range, and foreign product tankships visiting the United States, must have segregated or clean ballast tanks by January 1, 1986, or by the date on which the vessel is 15 years old, whichever is later.

Figure 1-4 and Figure 1-5 show the numbers of vessels affected by these domestic and international regulations.

Trade

The committee estimated the volumes of relevant liquid cargoes loaded in U.S. ports to determine which cargoes make the most important contributions to vapor emissions. Table 1-3, Table 1-4, and Table 1-5 summarize data from the U.S. Army Corps of Engineers on the 1984 transport of crude oil, oil products, and chemicals in the United States.

Most U.S. harbors are too shallow to admit large tankships. At these harbors, large ships must remain outside and off-load to a series

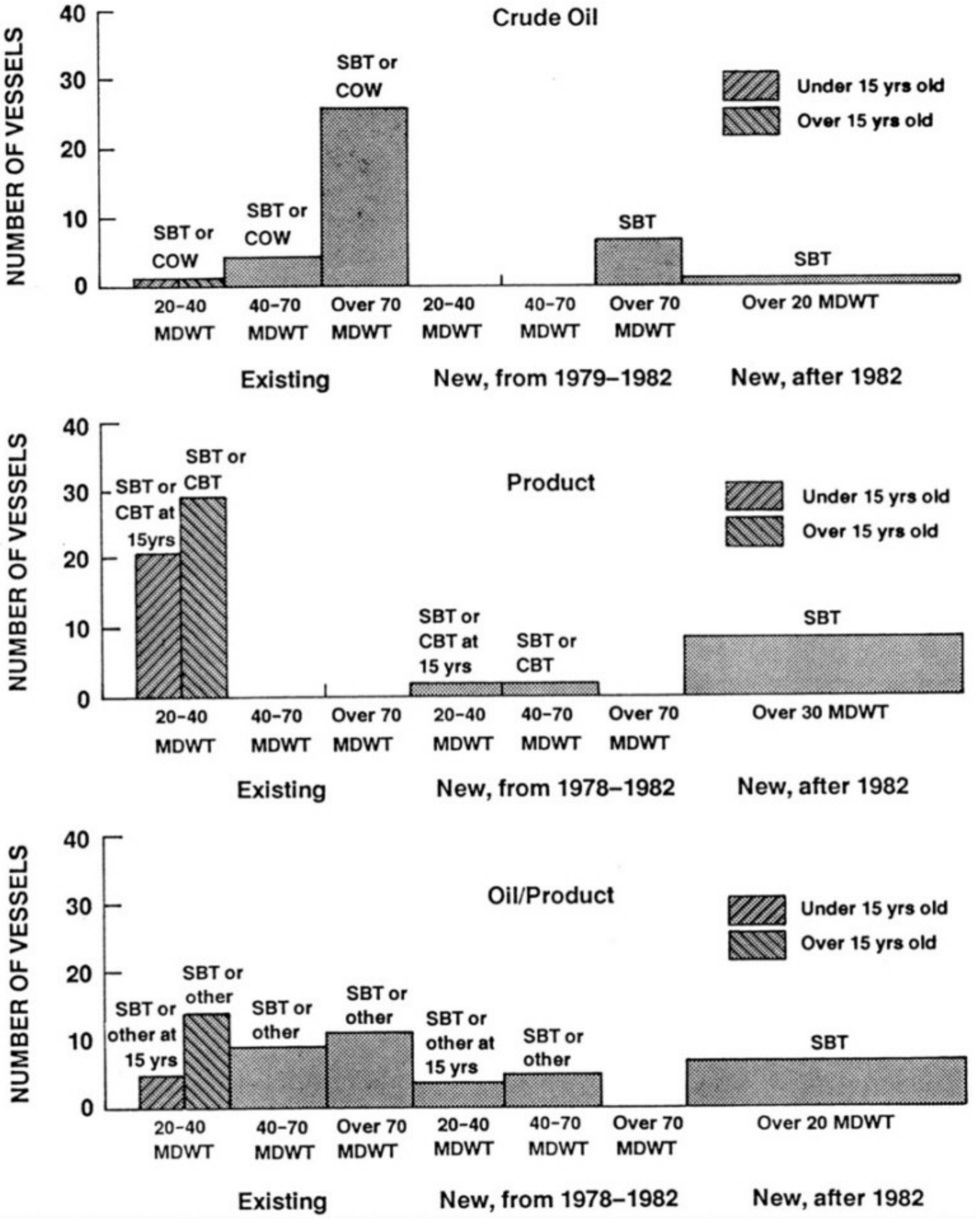

FIGURE 1-4 U.S.-flag tankships in compliance with U.S. safety and pollution-prevention requirements. Source: Based on U.S. Coast Guard data.

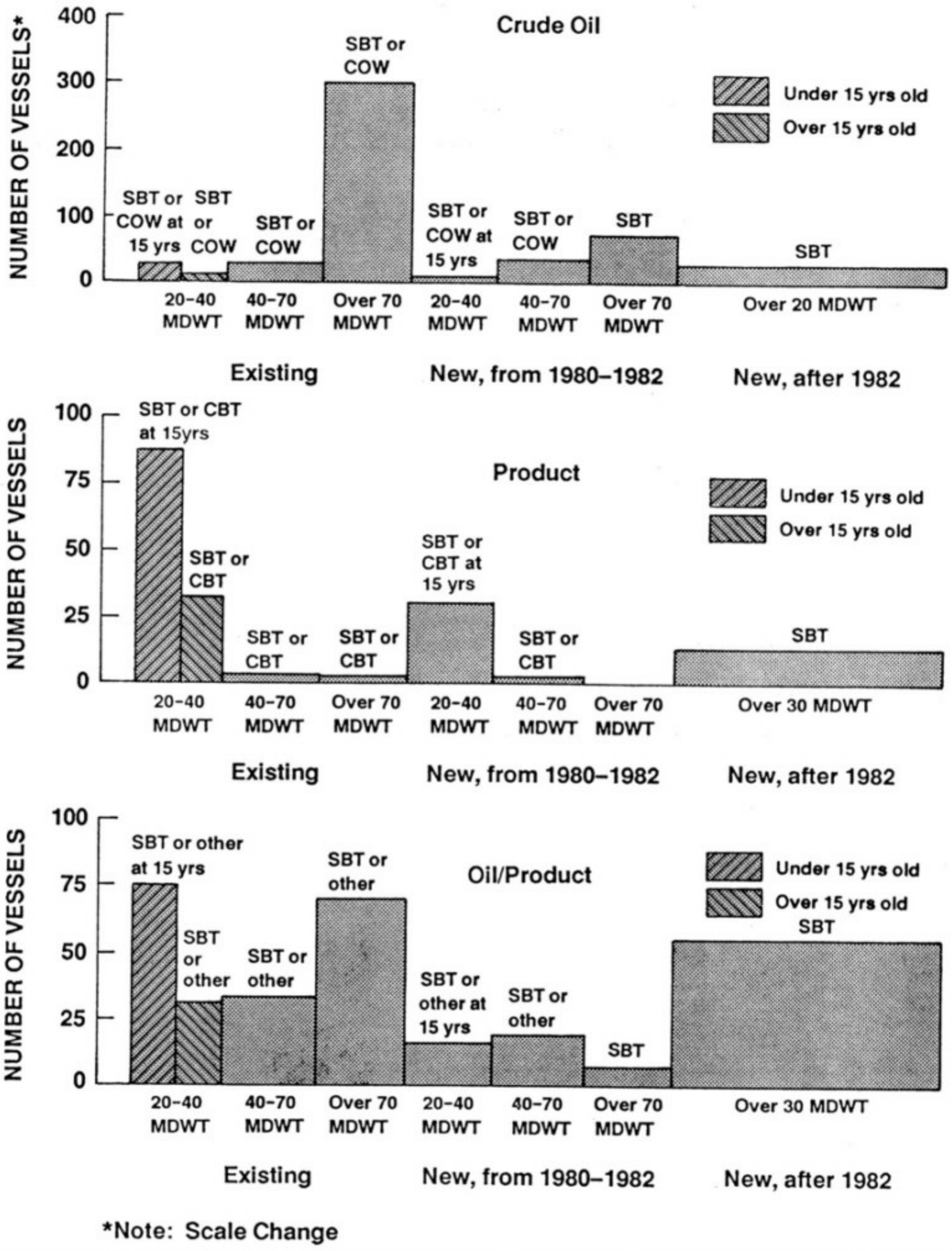

FIGURE 1-5 Foreign-flag tankships (trading at U.S. ports) in compliance with safety and pollution-prevention requirements. Source: Based on U.S. Coast Guard data.

TABLE 1-3 1984 Summary of Trade in Millions of Short Tons

Type of Trade	Crude Oil	Gasoline	Organic Chemicals	Other Petroleum Products
Foreign				
Import	171.64	12.55	19.68	68.37
Export	0.02	0.44	13.15	17.53
Subtotal	171.66	12.99	32.83	85.90
Domestic				
Ship	135.00	17.40	3.86	43.57
Barge	45.80	59.61	29.64	139.11
Subtotal	180.80	77.01	33.01	182.68
Total	352.46	90.00	66.33	268.58

TABLE 1-4 1984 Organic Chemicals Trade in Millions of Short Tons

Type of Trade	Crude Tar, Oil, Gas Products	Alcohols	Benzene and Toluene	Basic Chemicals	Miscellaneous Chemicals
Foreign					
Import	0.406	1.036	0.802	16.20	1.24
Export	0.436	0.913	0.173	10.69	0.94
Subtotal	0.84	1.95	0.98	26.89	2.18
Domestic					
Ship	0.12	0.48	0.53	2.51	0.23
Barge	1.17	3.81	3.69	20.44	0.53
Subtotal	1.29	4.29	4.22	22.95	0.76
Total	2.13	6.24	5.20	49.84	2.94

Source for Table 1-3 and Table 1-4: U.S. government data obtained from the Maritime Administration.

of smaller vessels, in a process known as lightering. Approximately 60 million tons of cargo is lightered at U.S. ports annually. Most lightering is done from more than 30 miles offshore, so that emissions from these operations are well dispersed before reaching land. About 20 million tons of cargo, mainly crude oil, were lightered nearer to shore in 1985.

TABLE 1-5 1984 Other Petroleum Products in Millions of Short Tons

Type of Trade	Jet Fuel	Kerosene	Distillate Fuel Oil	Residual Fuel Oil	Lube Oil	Naphtha and Solvents
Foreign						
Import	2.12	0.28	14.68	40.86	1.20	9.23
Export	0.39	-	3.14	12.22	1.65	0.13
Subtotal	2.51	0.28	17.82	53.08	2.85	9.36
Domestic						
Ship	4.63	0.60	14.71	20.34	2.18	1.11
Barge	9.11	1.69	45.81	74.89	3.02	4.59
Subtotal	13.74	2.29	60.52	95.23	5.20	5.70
Total	16.25	2.57	78.34	148.31	8.05	15.06

Source: U.S. government data obtained from the Maritime Administration.

In total, tank vessel loadings of crude oil and gasoline are declining, as pipelines exploit their cost advantages and as oil consumption has remained stable. Figure 1-6 illustrates this trend.

Emissions Calculations

The committee calculated VOC vapor emissions on a national basis, using methods derived from a study by the EPA (1986), but with more detailed information on vessel characteristics. Table 1-6 summarizes the committee's estimates of VOC emissions from vessel loading and ballasting. Appendix D presents the details of the calculations.

Vessel loading emissions are calculated using the quantity of cargo loaded (in tons), the emission factor f, and the density of the cargo (tons per 1,000 gallons). Emissions are calculated by the following equation:

$$E = (c/d)f,$$

where E = mass of emissions; c = mass of cargo; d = density of cargo (mass per unit volume); and f = cargo-specific emission factor (mass per unit volume). Lightering emissions are calculated by the same formula.

Ballasting emissions are calculated from the quantity of cargo off-loaded (in tons), the density of the cargo, the percentage of ballast loaded, the fraction of ships using cargo tanks for ballast, and an emission factor. The committee's calculations assume that, in port, tankships ballast up to 30 percent of their deadweight. U.S. regula

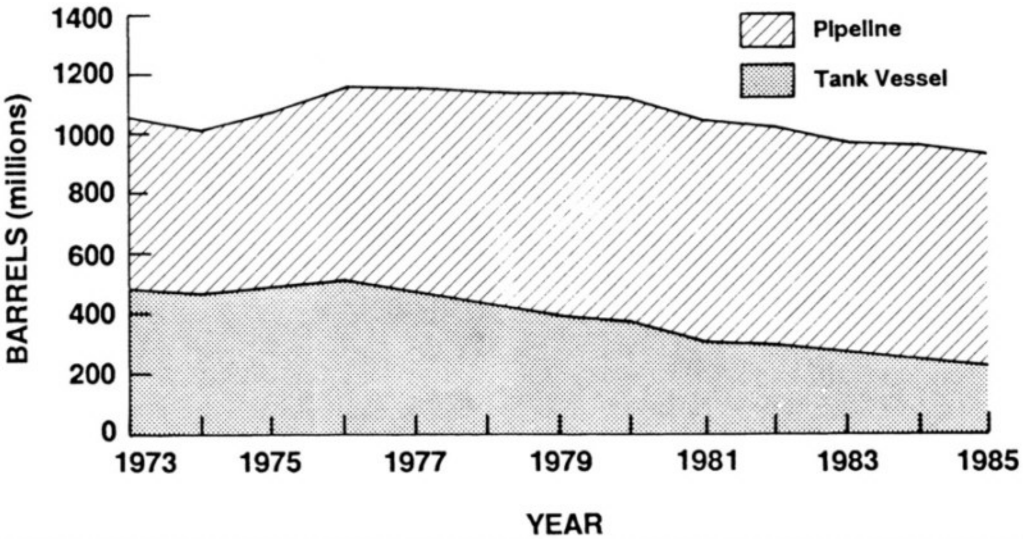

FIGURE 1-6 Comparison of tank vessel and pipeline flows--Gulf to Atlantic regions, 1973-1985. Source: U.S. Department of Energy data. Cited in Booz-Allen & Hamilton, Inc., 1987.

tions forbid vessels with segregated or clean ballast tanks to ballast into uncleaned cargo tanks, except in emergencies. They also require vessels with crude oil washing systems to provide a method to prevent VOC emissions during ballasting of cargo tanks. The ballasting emissions estimates in Table 1-6 account for the 30 percent assumption. The formula for estimating ballasting emissions is as follows:

$$E = (c/d)x \text{ x } 0.30 \text{ x } f,$$

where E = mass of emissions; c = mass of cargo; d = density of cargo (mass per unit volume); x = percentage of tankships without equipment to prevent ballasting emissions; and f = cargo-specific emission factor (mass per unit volume).

Locations of Emissions

More than 98 percent of vapor emissions occur at the port of loading. If that port is in a nonattainment area for ozone, the state government may be particularly concerned about vessel emissions.

TABLE 1-6 Estimated Annual Emissions in Metric Tons, 1984

Activity	Crude Oil	Gasoline	Organic[a] Chemicals	Other Petroleum	Total[e]
Foreign					
Loading[b]	--	113	63	32	208
Ballasting	413	109	9	14	544
Lightering	2,503	--	--	--	2,503
Domestic					
Ship loading[b]	10,317	4,544	77	404	15,342
Barge loading[c]	5,737	29,415	562	1,909[d]	37,623
Ballasting	259	127	5	23	414
Totals[e]	19,229	34,308	717	2,381	56,635

[a] Organic chemicals include alcohols, benzene and toluene, crude tar, oil and gas products, basic chemicals, and miscellaneous chemicals. While not all the basic chemicals are organic, because there was no method of separating trade data for organic and inorganic basic chemicals, all basic chemicals for the purpose of the emissions calculations were assumed to be organic. Emissions from organic chemicals are calculated using the Scott emission factor (Table 1-2) of 0.005 pounds per 1,000 gallons for mixed chemicals. These assumptions result in higher emissions.

[b] Ship-loading emission calculations assume that cargo tanks are not gas freed. On specialized chemical tankers, the tanks are usually gas freed. These assumptions lead to higher emissions estimates.

[c] Because data on ocean barges are aggregated with those on inland barges, it was necessary to use identical emission factors for the two classes of vessels. This simplification results in a small overestimate of emissions since ocean barges are much like tankships in their operation and construction (aside from the lack of propulsion), and lower emission factors apply to tankships.

[d] An assumption here is that all jet fuel transported is JP-4. Since other grades of jet fuel have lower emissions factors, this assumption leads to a high estimate.

[e] Totals may not add because of rounding.

Source: Appendix D.

The estimates in Table 1-6 show that more than 95 percent of all VOC emissions from vessels are from crude oil and gasoline. With this fact in mind, the committee focused its attention on these two liquids.

Loading Ports for Domestic Oil and Gasoline

Table 1-7 and Table 1-8 list loading volumes of crude oil and gasoline, respectively, at U.S. ports loading more than 100,000 tons per year for domestic shipping. These ports account for more than 98 percent of crude loadings and 95 percent of gasoline loadings in domestic trade. The tables also give the ports' ozone attainment status.

Table 1-9 and Table 1-10 summarize the data by state. As the tables show, the only states where ports in nonattainment for ozone load more than 5 million tons of crude oil and gasoline annually are Texas, New York, Louisiana, and California.

Loading Ports for Crude Oil and Gasoline Exports

Table 1-11 is a list of all U.S. ports that export gasoline. None is in attainment of the ozone standard. Almost no crude oil is exported from the United States.

Table 1-12 lists all U.S. ports loading more than 1 million short tons of crude oil or gasoline, with their ozone attainment status. Exports of gasoline and crude oil are less than 1 percent of the total loadings for domestic movement of these cargoes.

FOCUS FOR ASSESSMENT

The foregoing estimates show that 95 percent of the VOCs emitted from marine cargo handling are associated with loading crude oil and gasoline at marine terminals, Accordingly, the committee focused on those cargoes and operations.

TABLE 1-7 Crude Oil Domestic Shipments at Ports Handling More Than 100,000 Short Tons Per Year[a]

Barge Loadings			Tankship Loadings			Oceangoing Barge Loadings		
Location	Thousands of Tons per Year	1985 Ozone Status[b]	Location	Thousands of Tons per Year	1985 Ozone Status[b]	Location	Thousands of Tons per Year	1985 Ozone Status[b]
Alabama			Alaska			California		
Mobile	2,318	N	Kenai	1,177	A	Ventura	602	N
Warrior and Tombigbee Rivers	171	A	Valdez	99,625	A	Florida		
			California			Port St. Joe	189	N
			Carquinez Strait	926	N	Texas		
Alaska						Port Isabel and Vicinity	2,940	A
Tyonek	435	A	Morro Bay	4,270	A			
California			Port San Luis	218	A			
San Francisco	3,746	N						
Delaware			Richmond	141	A			
Lower Delaware Bay	8,155	A	San Francisco	203	N			
			Santa Barbara Channel Island	2,048	N			
Illinois								
Madison County	809	N						
			Suisun Bay	538	N			
Louisiana			Ventura	103	N			
Baton Rouge	377	N	Florida					
Cameron County	2,757	A	Port Everglades	470	N			
Destrehan	278	N	Puerto Rico					
Donaldsonville	499	N	Mayaquez	483[c]	A			
			Texas					
Jefferson Parish	288	A	Beaumont	648	N			
			Corpus Christi	316	N			
Johnsons Bayou	243	A	Virgin Islands					
Iberia Parish	394	A	Christiansted (St.Croix)	283	A			
Iberville Parish	647	N						

La Fourche Parish	890	N
Lake Charles	1,735	N
New Orleans	347	N
Ostrica	3,130	A
Plaquemine City	832	A
Plaquemine Parish	2,006	A
Port Sulphur	304	A
Red and Atchafalaya Rivers	897	A
St. Bernard Parish	450	N
St. James	387	N
St. Mary Parish	608	N
St. Mary/Morgan City	687	N
Terrebonne Parish	2,011	A
Venice	766	A
Vermillion Parish	1,312	A
New Jersey		
Westville	197	N
New York		
Bay Ridge Channel	110	N
Upper Bay	851	N
Ohio		
Grand View	496	N
Marietta	247	N
Texas		
Beaumont	571	N
Corpus Christi	482	N

High Island	212	A
Houston Channel	866	N
Port Aransas	134	A
Port Isabel	185	A
Sabine Pass	694	N

[a] For all ports, total domestic crude oil tonnage is 159,827 thousand. Percentage of total U.S. tonnage in table is 98.7 percent. Total of tonnage in table for ports loading over 100,000 short tons per year is 157,704 thousand.

[b] N = area in nonattainment for ozone; A = area in attainment.

[c] Intraterritorial.

Source: Based on Maritime Administration data for 1985.

TABLE 1-8 Gasoline Domestic Shipments at Ports Handling More Than 100,000 Short Tons Per Year[a]

Barge Loadings			Tankship Loadings			Oceangoing Barge Loadings		
Location	Thousands of Tons per Year	1985 Ozone Status[b]	Location	Thousands of Tons per Year	1985 Ozone Status[b]	Location	Thousands of Tons per Year	1985 Ozone Status[b]
Arkansas			California			Delaware		
Helena	304	A	Carquinez Strait	325	N	Wilmington	798	N
Delaware						Connecticut		
Delaware City	317	N	El Segundo	140	N	New Haven	404	N
Illinois			Los Angeles	213	N	Hawaii		
Joliet	452	A	Richmond	190	A	Honolulu	196	A
Madison County	969	N	San Pablo Bay	686	N	Indiana East	260	N
Indiana			Suisun Bay	528	N	Chicago[c]		
Indiana Harbor	162	N	Delaware			Louisiana		
			Wilmington	200	N	Baton Rouge	175	N
Mount Vernon	501	A	Indiana			Destrehan	1,520	N
Louisiana			East	186	N	Lake Charles	836	N
Algiers	174	A	Chicago[c]			New Orleans	1,029	N
Baton Rouge	2,049	N	Louisiana			Massachusetts		
Cameron Parish	169	A	Baton Rouge	558	N	Boston	318	N
			Destrehan	166	N	Mississippi		
Donaldsonvilla	263	N	Lake Charles	129	N	Pascagoula	1,900	A
			Mississippi			New Jersey		
Iberville Parish	176	N	Pascagoula	260	A	Paulsboro	117	N
			New York			New York		
La Place	704	N	New York	3,386	N	New York	10,024	N
Lake Charles	252	N	Puerto Rico			Pennsylvania		
Red and Atchafalaya Rivers	296	A	San Juan	186	A	Marcus Hook	634	A
			Texas			Philadelphia	600	N
			Beaumont	509	N	Puerto Rico		
Taft	801	N	Corpus Christi	1,422	N	San Juan	118	A

Minnesota								
Hastings	785	A	Houston	1,300	N	San Juan[d]	310	A
Mississippi			Port Arthur	912	N	Texas		
Pascagoula	624	A	Texas City	1,079	N	Beaumont	858	N
Missouri			Virgin Islands			Corpus Christi	1,912	N
St. Louis/Missouri River	138	N	Christiansted	1,336	A			
						Houston	770	N
			Washington			Port Arthur	249	N
New Jersey			Anacortes	817	A	Texas City	984	N
Passaic River	919	N	Bellingham	292	A	Virginia		
Port Newark	521	N	Tacoma	107	N	Newport News	797	A
New York								
Gravesend Bay	136	N						
New York and New Jersey Channels	7,949	N						
Ogdensburg Harbor	196	A						
Upper Bay	1,426	N						
Ohio								
Cincinnati	624	N						
Oregon								
Portland	489	N						
Pennsylvania								
Marcus Hook	1,113	A						
Neville	111	N						

Tennessee		
Memphis	317	N
Texas		
Beaumont	314	N
Chocolate Bayou	315	N
Corpus Christi	3,226	N
Houston Channel	2,339	N
Port Arthur	179	N
Texas City	807	N
Virginia		
Norfolk	122	A
Richmond	349	N
Washington		
Anacortes	116	A
Seattle	112	N
West Virginia		
Cabell County	3,437	A

[a] Total tonnage in table for ports loading more than 100,000 short tons per year is 73,898,000. For all ports, total domestic gasoline tonnage is 77,853,000. Percentage of total U.S. tonnage in table is 95.0 percent.

[b] N = area in nonattainment for ozone; A = area in attainmeat.

[c] Intraterritorial.

[d] Lakewise.

Source: Based on Maritime Administration data for 1985.

TABLE 1-9 Domestic 1985 Crude Oil Movements by State with 1985 Ozone Nonattainment Status of Loading Ports Handling More Than 100,000 Short Tons

	Percentage of Loadings		
State	Nonattainment Areas[a]	Attainment Areas	Total Short Tons (thousands)
Alabama	93	7	2,489
Alaska		100	101,237
California	59	41	12,795
Delaware		100	8,155
Florida	100		659
Illinois	100		809
Louisiana	32	68	21,845
New Jersey	100		197
New York	100		961
Ohio	100		743
Puerto Rico		100	483
Texas	49	51	7,048
Virgin Islands		100	283
Total			157,704

[a] Loadings in nonattainment areas are about 23.5 percent of total.

TABLE 1-10 Domestic 1985 Gasoline Movements by State with 1985 Ozone Nonattainment Status of Loading Ports Handling More Than 100,000 Short Tons

	Percentage of Loadings		
State	Nonattainment Areas[a]	Attainment Areas	Total Short Tons (thousands)
Arkansas		100	304
California	91	9	2,082
Connecticut	100		40
Delaware	100		1,315
Hawaii		100	196
Illinois	68	32	1,421
Indiana	55	45	1,109
Louisiana	93	7	9,297
Massachusetts	100		318
Minnesota		100	785
Mississippi		100	2,784
Missouri	100		138
New Jersey	100		1,557
New York	99	1	23,117
Ohio	100		624
Oregon	100		489
Pennsylvania	29	71	2,458
Puerto Rico		100	614
Tennessee	100		317
Texas	100		17,175
Virginia		100	1,268
Virgin Islands		100	1,336
Washington	5	95	4,881
Total			73,989

[a] Loadings in nonattainment areas are 78.8 percent of total.

TABLE 1-11 Gasoline Exports by Port[a]

Port	Gasoline Exports (tons)
California	
Long Beach	8,957
Los Angeles	69
Suisun Bay	33,608
San Francisco	41
San Pablo	6,315
Carquinez Strait	48,796
Oakland	255
Total	98,091
Florida	
Port Everglades	1,394
Palm Beach	225
Miami	227
Total	1,846
Louisiana	
New Orleans	7,321
Lake Charles	254
Total	7,575
Maryland	
Baltimore	1,220
Total	1,220
Massachusetts	
Boston	8,998
Total	8,998
Michigan	
Detroit	82
Saginaw	186
Total	268
New Jersey	
Camden	150
Total	150
New York	
Albany	45
New York	23,521
Total	23,566
Pennsylvania	
Philadelphia	173
Total	173
Puerto Rico	
San Juan	10,298
Total	10,298
Texas	
Texas City	462
Houston	137,124
Corpus Christi	70,362
Port Arthur	17,682
Freeport	14,650
Total	240,280

[a] National total for gasoline exports is 392,455 tons.

Source: U.S. Army Corps of Engineers data for 1985.

TABLE 1-12 Ports Loading More Than 1 Million Tons of Crude Oil and Gasoline Annually, 1985

Port	1985 Ozone Attainment Status[a]	Loadings (thousands of tons)
Alabama		
Mobile	N	2,318
Alaska		
Valdez	A	99,625
Kenai	A	1,177
Delaware		
Lower Delaware Bay	A	8,155
California		
San Francisco	N	3,949
Carquinez Strait	N	1,300
Morro Bay	A	4,270
Santa Barbara Channel Islands	N	2,048
Suisun Bay	N	1,100
Illinois		
Madison County	N	1,777
Louisiana		
Baton Rouge	N	3,158
Cameron Parish	A	2,926
Destrehan	N	1,964
Lake Charles	N	2,952
New Orleans	N	1,383
Ostrica	A	3,130
Plaquemine Parish	A	2,006
Red and Atchafalaya Rivers	A	1,194
Terrebonne Parish	A	2,011
Vermillion Parish	A	1,312
Mississippi		
Pascagoula	A	2,784
New York		
Upper Bay	N	2,276
New York	N	13,434
New York and New Jersey Channels	N	7,949
Pennsylvania		
Marcus Hook	A	1,747
Texas		
Beaumont	N	2,900
Corpus Christi	N	7,428
Houston Channel	N	3,206
Houston	N	2,137
Texas City	N	2,870
Port Isabel and vicinity	A	3,125
Virgin Islands		
Christiansted	A	1,620

[a] N = area in nonattainment for ozone; A = area in attainment.

2

CURRENT PRACTICES ON TANK VESSELS

Barges and tankships differ substantially in size, complexity, manning requirements, and scheduling. River barges are relatively small, with uncomplicated cargo systems. They are generally unmanned except during loading and unloading when a Coast Guard certificated “tankerman” is required to perform operations. Tankships range upward in size and complexity to the extremes of maritime sophistication, with multiplecargo capability, closed-loading facilities, segregated ballast tanks, and inert-gas cargo blanketing systems to prevent fires and explosions. Tankships carry dedicated crews, including skilled personnel to supervise loading and unloading. (Their inert gas systems and flexible piping and pumping systems give tankships some ability to reduce vapor emissions by operational measures.)

Operationally, tankships and barges differ in many ways. A river barge may be thought of as comparable to a freight car in that--unlike a self-propelled tankship--it may lie unattended for periods of time, may be passed from carrier to carrier as multibarge tows are assembled and dispersed, and may have less available documentation of its cargo and construction. The personnel who load and unload barges in the United States are less rigorously certified, and often less experienced, than those aboard tankships.* For these reasons, the two types of vessels may require substantially different systems for vapor control.

A few companies carry out vapor disposal or recovery when loading tankships with crude oil and gasoline (e.g., in the Santa Barbara channel and the San Francisco Bay area), and certain hazardous substances, such as chlorine and acrylonitrile, are loaded in barges with vapor disposal or recovery. The technology for such operations is considered mature, but extending it to all marine terminals handling crude oil and gasoline would place increasing demands on safety systems and procedures, and would entail substantial costs to owners of both terminals and vessels.

All tankships and tank barges are inspected and certificated by the Coast Guard under extensive regulatory requirements that control the design and construction of the vessels, their manning and operation,

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*For the purposes of this study, oceangoing integrated tug-barge units are considered tankships.

TABLE 2-1. Inland Tank Barge Fleet Profile: Number of Vessels

	Capacity (thousands of barrels)				
Age of Barge (years)	8	9-15	16-25	26-50	Total
0-15	148	656	292	313	1,408
16-30	198	612	388	211	1,409
> 30	284	245	193	30	752
Total	630	1,513	873	553	3,569[a]

[a] The Booz-Allen & Hamilton estimates are less than the Coast Guard estimates cited in the text, because Booz-Allen & Hamilton only counted barges where their computer files were sufficiently complete for their purposes.

Source: U.S. Coast Guard Inspected Vessels Data Base, Maritime Administration, U.S. Army Corps of Engineers, and Booz-Allen & Hamilton analysis.

(including handling and stowage of cargo), and certain duties of the officers and crew. Vessels are reinspected annually, and new certificates are issued every 2 years following thorough inspection.

INLAND TANK BARGES

The inland waterway system encompasses 25,000 miles and includes the East and West coasts as well as the Mississippi River system, which is composed of the Allegheny, Monongahela, Kanawha, Ohio, Tennessee, Cumberland, Missouri, Illinois, Arkansas, Warrior-Tombigbee, and Mobile rivers as well as smaller tributaries. The Gulf Intracoastal Waterway, which stretches along the Gulf Coast from Brownsville, Texas to Apalachicola, Florida, is also considered part of the inland system. In 1982 there were 1,800 companies operating on the inland river system. The depressed state of business since 1983 has reduced this number to less than 1,000. The largest 50 companies operate about three-fourths of the fleet.

The 3,968 inland tank barges have a total capacity of 52 million barrels and an average individual capacity of 14,500 barrels. All are certificated to carry subchapter O or D cargoes. Their total market value is estimated by Booz-Allen & Hamilton (1987) at $730 million. The average 5-year-old, 10,000-barrel barge has a market value of about $250,000, but the typical inland barge is older than this. Table 2-1 categorizes the inland tank barge fleet by capacity and age.

The industry operates mainly under short-term contracts, with only a small part in dedicated commodity trade. This means that the typical barge carries a variety of products, depending on market demand, and moves flexibly through the inland waterway system, rather than traveling a regularly scheduled path.

The inland tank barge industry is struggling to break even financially. A study by Booz-Allen & Hamilton (1987) estimates that a typical inland barge loses about $1,000 per year before paying interest charges.

Common service river barges carrying grain, coal, and other cargoes are moved long distances in so-called tows: groups of 10 to 12 barges lashed together securely and pushed by a single towboat. A tow may consist of barges from a variety of sources. While awaiting incorporation in the tow, these barges are customarily stored temporarily in commercial “fleets,” mooring areas under the supervision of local towing companies. Thus, a given barge may be brought to the fleet by one towing company, moored by another, assembled in a tow for long-distance transport by a third, and then routed to its final destination.

To avoid accidents due to poor communications as barges are passed from hand to hand, barges carry diagrams of piping and tanks. They are also required to carry shipping papers showing cargo, consignee, and delivery point (46 CFR 35.01-10) and a certificate of financial responsibility (46 CFR 542).

Historically, liquid cargo has tended to move in “unit tows,” a string of barges and a tow boat serving one or several customers, with the boat and barges staying together as a unit. Many unit tank barge tows consist of two to four barges, are rarely “fleeted,” and are handled with a dedicated towboat that stands by during loading and unloading. The towboat's crew often performs the tankerman's operations. This results in high-speed product movement. The trend over the past several years has been toward less unit-tow business and more individual shipments.

Tank barges differ from tankships in the absence of propelling machinery and living spaces. River tank barges are rectangular or box-shaped, and may have a rake, or upward slope, to one or both ends. Tank barges range in length from less than 100 to several hundred feet. The simplest type, for petroleum and other liquids not considered to be highly dangerous, is a box divided by a longitudinal centerline bulkhead and several transverse bulkheads. All bulkheads are oil-tight, dividing the barge into a number of separate cargo tanks. The end spaces are left void, providing buoyancy when cargo tanks are full.

Each tank has piping and venting systems and an access hatch. The barge may be fitted with double bottoms and side voids as well as with pumps and diesel engine drives.

Cargo Handling

The hazards of cargoes, such as flammability, reactivity, or toxicity, place different demands on the design of the barges that carry them. No matter what the particular hazard, tank barges must have features built in to reduce the hazards. In the case of accidental discharge into the waterway, because of the need for different levels of safeguard against spills, the U.S. Coast Guard Rules and Regulations class barges according to whether their cargo requires moderate, significant, or maximum preventive measures against uncontrolled release into the water. Each dangerous cargo is then classified according to the needed amount of protection, which determines the type of barge used to carry it. The regulations also explain the differences in the three barge types in terms of protection against flooding, hull damage, and grounding.

Depending on the severity of hazard, hazardous chemicals regulated under subchapter O must be carried in a barge with a type I, II, or III hull. A type I barge, for example, must remain afloat if a transverse bulkhead is damaged, with compartments on both sides of the bulkhead flooded; must have space between the cargo and the bow and sides of the hull to avoid collision damage; and must be able to run aground without overstressing the hull. A type II barge must remain afloat if any single compartment is flooded, and must have space between cargo and bow and between cargo and sides (but a smaller space than in a type I barge). Less rigorous requirements apply to type III barges.

There are a number of common variations of tank barge arrangements (Figure 2-1): (1) single skin, (2) double skin, (3) double wall, and (4) independent tank.

A single-skin tank barge is divided into cargo tanks by a number of transverse bulkheads and may also have a centerline bulkhead running fore and aft. Only the steel shell or single skin separates cargo from the river water. This type of arrangement is allowed only in Type III barges and barges designed for petroleum products.

Double-skin tank barges have void spaces around the cargo tank sides and bottom. The double skin provides protection against cargo spills in case of grounding or collision and is, therefore, required when certain dangerous cargoes are carried. A double-wall barge is similar to a double-skin barge, except that only its sides, and not its bottom, are doubled.

The independent-tank barge differs from the other three in that its cargo tanks are not designed as part of the hull structure, but are built separately and then installed in a barge hull, fitted with special saddles or supports shaped to hold the tanks. The independent tank is generally not considered as contributing to the structural strength of the barge. Most of these tanks are in the form of long cylinders. These barges are employed mainly in transporting liquefied gases such as liquefied petroleum gas, ammonia, and chlorine.

Tank barges generally have simple piping systems. The main piping headers are used for both loading and discharge. One main header is located above deck and athwartship, and is flanged and valved for barge-to-shore connection with shoreside equipment. The other main header is oriented fore and aft, and is located inside the barge, just above the inner bottom. Lines from each tank, fitted with valves operated from the main deck via reach rods, are connected to this internal header.

The above-deck header is connected to the internal header by a vertical riser that passes through the deck. During loading, cargo enters the above-deck header and flows by gravity through the riser and the internal fore-and-aft header to the various cargo tanks. During

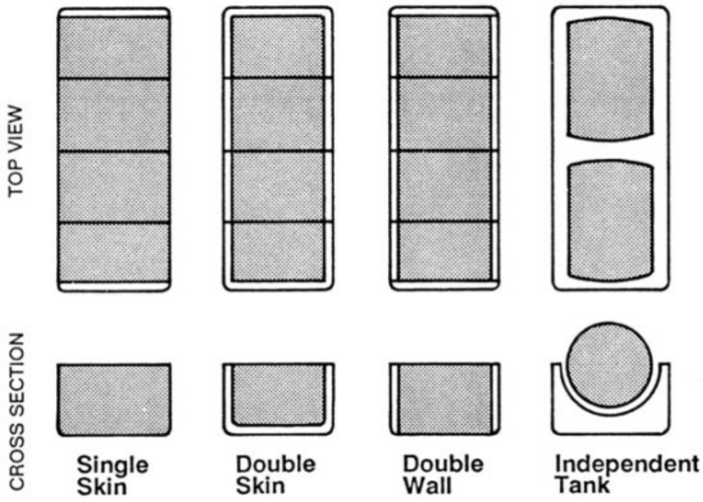

FIGURE 2-1 Tank barge arrangements.

discharge, a deepwell pump, also connected to the fore-and-aft internal header, sucks cargo from the various tanks and pumps it through the above-deck header to shore.

More complex piping systems may be installed for a number of reasons, such as the need to handle different grades of cargo (Figure 2-2).

A deepwell pump is a centrifugal pump with a long, vertical shaft. The impeller is located at the lower end of the shaft, near the bottom of the cargo tank. The prime mover is connected to the upper end of the shaft, above the deck. The drive shaft and impeller are enclosed in a discharge pipe, and the entire unit operates inside a larger suction barrel deepwell, extending from the deck to the bottom of the tank. Permanently installed in the tank, deepwell pumps are greatly favored because they are self-priming, since the impeller is in the lowest part of the tank. Pump rooms are not necessary when deepwell pumps are fitted.

On barges certified to carry cargoes with an open-cup flashpoint of 80°F or less, cargo tanks are fitted at their tops with pressure/vacuum (PV) relief valves. The PV valve remains closed and seals the tank, as long as the pressure in the tank does not exceed the pressure for which the PV valve is set and as long as the vacuum in the tank does not exceed the vacuum for which the PV valve is set. Normal diurnal temperature variations cause the cargo in the tank to expand and contract.

On tanks designed to operate at pressures of more than 10 pounds per square inch (psi), regulations require that safety relief valves, rather than PV valves, be installed.

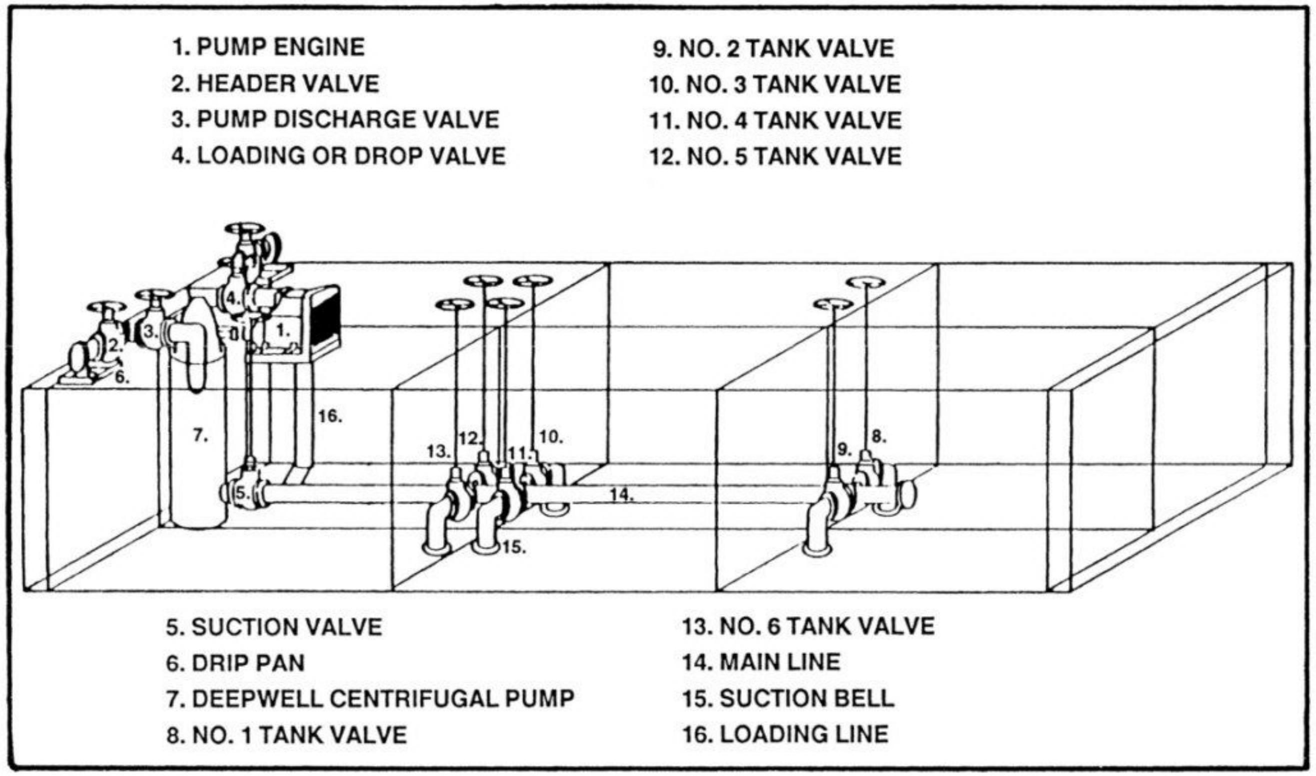

FIGURE 2-2 Piping systems.

In vessels carrying the more dangerous grades of cargo, the vent pipes from the cargo tanks must be led high above the deck. The vertical part of the vent piping, leading up to the PV valve or flame arrestor, is called a riser.

Depending on contractual agreements and the spot market, a typical inland barge operation carries gasoline on 50 percent of its petroleum movements, with the remaining 50 percent equally divided between No. 2 diesel fuel and jet fuel. There are occasional loadings of kerosene and natural gasoline.

Manning Requirements for Loading and Unloading

Cargo transfer operations involving unmanned barges are under the control of tankermen, certificated by the Coast Guard to handle certain liquid cargoes in bulk. Licensed masters, mates, pilots, and engineers are, by regulation, automatically certificated as tankermen.

Tankermen are classified by the kinds of cargoes they are authorized to handle. More hazardous commodities require greater precautions and more training and knowledge. Two sets of regulations cover most requirements for handling bulk hazardous liquid cargoes:

1. 46 CFR parts 30 through 40 (subchapter D)--“Rules and Regulations for Tank Vessels” (covering roughly 400 commodities, all of which have flammability as their main hazard).
2. 46 CFR part 151 (subchapter O)--“Certain Bulk Dangerous Cargoes” (covering roughly 300 commodities with hazards other than, or in addition to, normal flammability).

The exact requirements to qualify as a tankerman are contained in the regulations and are subject to change. Qualification is based on experience, training, examination, and physical standards.

A sufficient number of crewmen (as defined in the U.S. Coast Guard pollution and tankerman regulations) must be on duty to perform cargo transfers. At all times there must be a qualified person-in-charge on the vessel and on the dock. On tank vessels, this person will be a licensed officer or certificated tankerman. Tank-cleaning operations generally require the same qualified person-in-charge as cargo transfers. No one may connect, top off, disconnect, or take part in any other critical transfer procedure unless the person-in-charge supervises the operation. No one may start the flow of oil to or from a vessel unless instructed to do so by the person-in-charge, who must be in the immediate vicinity of the operation and immediately available to the transfer personnel. In addition, no one may serve as the person-in-charge of oil transfer operations on more than one vessel at a time, and no one may be in charge of both a vessel and the terminal facility, without the approval of the U.S. Coast Guard captain-of-the-port.*

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*Within this framework, cargo handling on barges adjacent to each other are routinely handled by one tankerman.

The terminal operations manual and posted vessel procedures, required by regulation, indicate the minimum number of qualified personnel for transfer operations, as well as the number of ships and barges that can be handled at the same time.

Tank barges need not be manned unless in the judgment of the marine inspection officer-in-charge such manning is necessary for the protection of life and property and for the safe operation of the vessel. However, any towing vessels, while towing barges that are not required to be manned, must carry in its regular complement and have on board at all times at least one licensed officer or certificated tankerman. A strict watch of each unmanned barge in tow is required to be maintained from the towing vessel while underway. Appendix E summarizes the requirements for barge surveillance.

When a barge is moored but not gas-free (flushed with air, as in cleaning), at least one of the following precautions shall be taken:

1. The barge shall be under the observation of a watchman who may be a member of the complement of the towing vessel, a terminal employee, or another competent person responsible for the security of the barge and for keeping unauthorized persons off the barge.
2. All cargo tank hatches shall be clearly marked in not less than 3-in. lettering, “Danger--Keep Out,” and all hatch covers shall be closed and dogged down, or otherwise secured, by a tool-operated device, such as a length of pipe, so that no person can open the hatch by use of bare hands alone.

Loading and Discharging Procedures

Before a fleet operator (“fleeter”) accepts a barge from a line vessel, his representative inspects the barge for damage and ensures that it has the proper Coast Guard documents (i.e., certificate of inspection, certificate of financial responsibility, and information on the last cargo [bottoms]). If these documents are in order, the barge is accepted into the fleet. The fleeter accepts full responsibility and must keep a site surveillance during the unit's stay.

Depending on the product, the customer may require that the barge be cleaned before loading and will designate an inspector to ensure that it is cleaned properly. A local cleaning plant will be contacted. When the barge is delivered to the plant, the plant operator assumes full responsibility for the unit. After the barge is cleaned and accepted by the customer's inspector, it is sent back to the fleeter. The fleeter again checks the barge for damage. If all is in order, he accepts the barge into his fleet.

When the loading facility is ready to accept the barge, it will contact the fleeter and request that the barge be delivered. On arrival at the dock, the barge is again inspected by both the loading foreman and the designated barge inspector, who also discuss loading procedures. A Coast Guard publication entitled *A Manual for the Safe Handling of Flammable and Combustible Liquids and Hazardous Products* (U.S. Depart ment of Transportation, 1975) describes the hazards in transfer operations and identifies applicable requirements.

Loading and unloading hydrocarbons from barges carries the inherent risk of fire and explosion. Vapor in the tanks may pass through the flammable or explosive ranges as the tanks are emptied or filled. Thus, a number of safety precautions are taken to avoid sources of spark or ignition. Appendix F sets forth gasoline loading procedures required by one large Ohio Valley towing company. Similar procedures are representative of responsible operators in the industry.

After loading, quantity and quality specifications are checked and the loading facility foreman places the proper loading manifest aboard. The loading manifest includes information on the product loaded, the loading port, the quantity loaded, the destination port, and any special handling hazards of the product. The barge is then released by the loading dock and returned to the fleeter, who again checks to be sure all required papers are aboard and the barge is in serviceable condition.

The line vessel operator, prior to pickup, lays out his tow configuration to accommodate his future delivery and pickup schedule, and to ensure proper towing and handling characteristics. Finally, the barge is picked up from the fleeter by a line vessel, who again inspects it for proper papers and seaworthiness. The barge is transported either directly to the discharge terminal or to an intermediate fleeting operation; the latter requires redispatching it to the discharge terminal, a procedure similar to that at the loading berth. At the discharge terminal, unloading is carried out according to set procedures.

TANKSHIPS

About 231 million tons of crude oil, refined products, and organic chemicals were loaded aboard tankships in the United States in 1984 (see Table 1-3). While tankships are inherently more complex than barges, they present many of the same operational problems, particularly where loading and unloading are involved. Some of the operational differences between the two types of vessels are that most tankships practice closed loading (loading with hatches and ports, but not necessarily vents, closed to the atmosphere), carry seawater as ballast (which can generate emissions under some circumstances), are equipped with systems to blanket cargoes with inert gas to lessen the danger of fire or explosions, and are manned continuously by licensed officers, most of whom have college educations.

National legislation and international regulations (summarized in Figure 1-3) are extending to more tankships the requirements for inert gas systems and closed loading, and for ballast tanks separate from cargo tanks (the latter under requirements for segregated ballast tanks and clean ballast tanks). These requirements are explained later in this chapter.

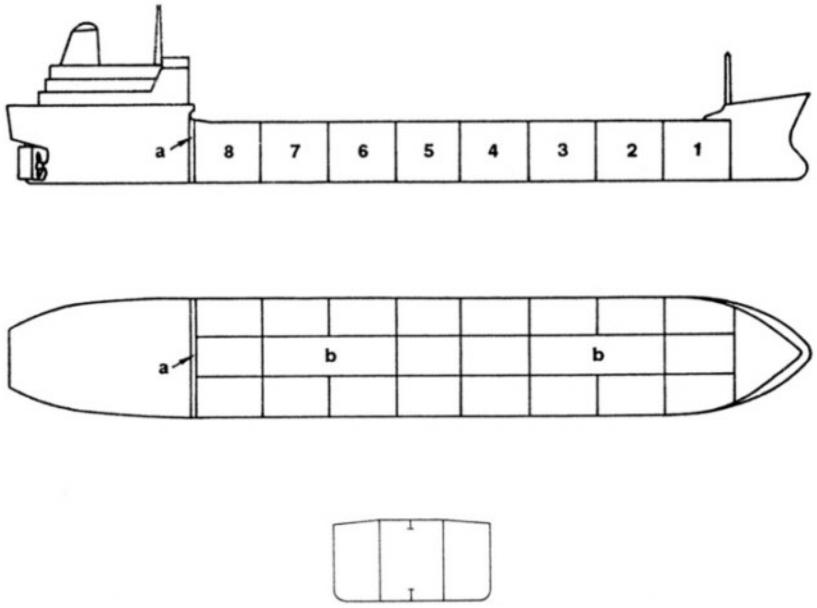

FIGURE 2-3 General arrangement of typical tanker, with a side view, top view, and cross-section; (a) indicates the main cargo pump room and (b) the extra large tanks for special parcels.

Arrangement of Typical Tankship

A typical tankship in the crude or product trade has three parts: spaces forward of the cargo tanks for service, cargo-carrying tanks midship (the tank body), and propulsion machinery aft. Figure 2-3 shows the general arrangement of such a tankship.

Vessels designed to operate mainly in the clean product trade usually have numerous cargo compartments to permit carrying multigrade cargoes. Crude-carrying vessels often have fewer separate cargo compartments, since one grade of crude oil is often the only cargo carried. Most tankers are single-hull vessels with the cargo carried in the tanks and separated from the outside by a single steel hull.

Combination Carriers

In addition to conventional tank vessels, there are several other types of oil-carrying vessels. So-called combination carriers, for example, are constructed to carry either oil or dry bulk cargoes. Most combination carriers carry only crude oil when in petroleum service.

Among the types of combination carriers are ore/oil carriers, bulk/oil carriers, and product/bulk/oil carriers.

Ocean Barges

Integrated tug barges (ITBs) are a relatively new type of tankship. Today 13 are in operation, all about 40,000 dwt. The tug and barge of an ITB are designed to operate as one unit, with the tug fitting into a specially designed slot in the stern of the barge. This arrangement improves the flow of water around the hull as compared with a tug towing a barge on a hawser. The barge component of an ITB is constructed similar to the tank body of a conventional seagoing tankship, with essentially identical cargo piping and pumping arrangements, ballast tanks, inert gas systems, and vent lines, for example.

There are a few seagoing barges towed by seagoing tugs delivering oil along the U.S. coasts. These barges are built similar to seagoing ships, except that they are usually unmanned and have no propulsion. The cargo-handling arrangements are very similar to river barges or to those of the ITB.

Cargo Tank and Pipeline Arrangements

Figure 2-4 is a simple drawing of a complete direct pipeline system on a nonsegregated ballast tankship with a pumproom forward of the engine room. Only the three main centrifugal pumps are shown. The stripping pumps have their own pipeline system, which can deliver into the main system, into the cargo tanks, or directly ashore. Also, the valves are not shown.

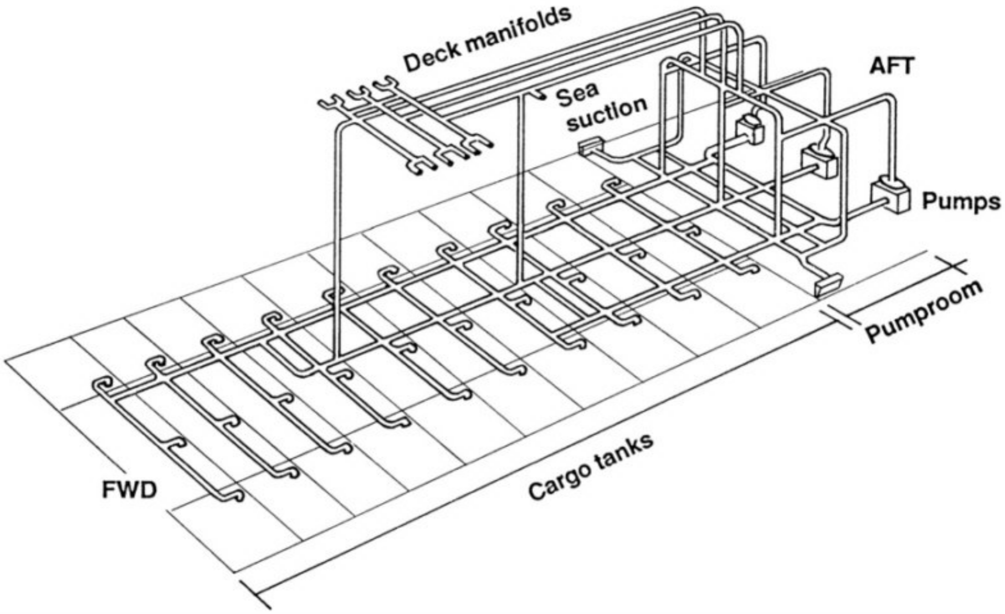

FIGURE 2-4 General piping and pumping arrangements of a tankship.

To show the details, the pumproom in the sketch is considerably out of proportion to the cargo tanks. In reality the pumproom in a fore and aft direction is only a fraction of the size of a cargo tank. The sketch is of a modest-size product or crude carrier with three “natural segregations,” meaning that the vessel can load or discharge simultaneously three separate grades of oil.

Three drop lines shown in the sketch, connecting the deck lines to the bottom suction lines, permit loading oil without going through the pumproom. Drop lines that are not connected to suction lines terminate a few inches from the bottom of the tank, so there is practically no free-falling liquid.

Hoses or articulated metal arms are connected to the deck manifolds for transferring cargo during loading or discharging. The sea suctions in the bottom of the pumproom, installed at the turn of the bilge, permit ballast water to be taken into the cargo tanks. Ballast water can also be discharged through the sea suctions.

Product and Chemical Carriers

Figure 2-5 shows a typical product carrier. The complex piping on the deck gives flexible loading layouts that can accommodate several different types of oils or chemicals. Smaller tankships often carry chemicals. The sophistication of the cargo tank and pipeline arrangements increases with the requirement for a greater number of small parcels of chemicals. Some chemical carriers have as many as 60 natural segregations.

The cargo tanks of chemical carriers often are made of stainless steel to carry corrosive chemicals. Double bottoms are usually installed in chemical carriers to ensure good drainage and easy tank cleaning. Sometimes a complete double hull is used. When many natural segregations are required, deepwell cargo pumps are installed in the cargo tanks.

Crude Carriers

Very large crude carriers (VLCC) have far fewer segregations, hence less complex piping and tank arrangements (Figure 2-6). The cargo is loaded through drop lines and flows through open sluice valves into other tanks. Essentially only one grade of oil can be carried in this type of vessel without significant commingling of different grades.

Cargo Pumps

Most main cargo pumps on crude and product tankers are gravity-fed centrifugal pumps. These pumps are compact and reliable, producing a steady rather than pulsating flow. They are easily adapted to different power sources such as steam turbines and electric or diesel motors.

FIGURE 2-5 Typical product tanker. Source: Exxon Shipping Co.

These pumps cannot be used to strip the last few feet of cargo out of tanks unless equipped with special recirculating devices.

Positive displacement pumps are used as stripping pumps, since they can suck the remaining liquid from the tanks, even though some air becomes entrained in the liquid. Reciprocating, gear, and screw pumps are of this type.

On VLCCs, the cargo tanks are also fitted with eductors driven by the discharge from a cargo pump to perform stripping and tank cleaning. Eductors, having no moving parts, are almost trouble-free, but they do not have a very high ratio of mechanical energy to work.

Deepwell cargo pumps are used extensively on chemical carriers or tankships carrying a great diversity of refined products. Each pump is installed in the cargo tank. Their impellers operate so close to the bottom of the tank that they can discharge nearly all cargo before losing suction. Additional stripping is usually unnecessary.

FIGURE 2-6 Typical medium-size crude carrier. Source: Exxon Shipping Co.

Tank Ventilation

Most tankships have closed-loading equipment that permits keeping hatches closed during loading and ballasting. A vent line is installed in each cargo compartment so that vapors displaced during loading are released into the atmosphere. Similarly, when discharging, air or inert gas can enter the tank to replace the liquid discharged. Typically a vent line rises 8 ft above the deck.

On some tankships the individual vent lines are connected to one or more common main vent lines that are carried up a king post or mast where the vapors are vented to the atmosphere. Flame screens are installed at the ends of these common vents.

PV valves are installed at the tops of the vents to permit controlled breathing and minimize cargo losses from evaporation. These PV valves are bypassed or opened during loading.

Individual tank vents also are fitted frequently with constant velocity (CV) vents at the tops of the vent lines. These devices increase the velocity of the emerging gas, throwing the vapors high off the deck, where they are diluted by air drawn into the plume by the velocity of the emission. The object is to lessen exposure of personnel to the vapors and to dilute the vapors so that they are no longer flammable. CV vents also impart a velocity to the vapors that exceeds the unconfined flame speed in the event of an ignition on deck, and thus prevent a flame from entering the tank through the vent outlet.

Inert Gas Systems

All new tankships of 20,000 dwt or more ordered after 1980 are required to be equipped with inert gas (IG) systems, and most trading in U.S. waters are so equipped. Inert gas equipment, properly installed, operated, and maintained, is a safety feature. However, IG is not a panacea for tankship fires and explosions (see Chapter 4).

There can be no explosion or fire in a tank if there is insufficient oxygen to support combustion. Therefore, inert gas with an oxygen content of 5-8 percent is obtained from the uptakes of the ship's boilers or from an independent inert gas generator. The inert gas is scrubbed free of most impurities and then blown into the cargo tanks. The inert gas is maintained under a slight positive pressure in the tanks. Air is permitted into the tanks only after they have been gas-freed of all hydrocarbon vapors.

Figure 2-7 illustrates the arrangement of a typical IG distribution system. When loading cargo or ballast into an inerted tank the displaced vapors are released through the vents (or a common header). The distribution lines for the IG system are connected to each cargo compartment.

Ballast Arrangements

Tankships without cargo carry water as ballast to ensure good sea-keeping characteristics. Ballast equivalent to 20-30 percent of the deadweight usually is required for operations in good weather; it may be increased during bad weather. Ballast is carried in SBTs, CBTs, or cargo tanks.

Ballast water, if placed in dirty cargo tanks, mixes with traces of the previous cargo clinging to the tanks and is called dirty ballast. Discharge of this dirty ballast at sea contributes to oil pollution. To minimize this pollution SBTs and CBTs have been mandated for certain tankships, while other operational controls apply to other tankships.

Segregated Ballast Tanks

The United States has adopted and supplemented international conventions that require new crude tankers of 20,000 (and product tankers of 30,000) dwt or more constructed after 1980 to have sufficient ballast capacity for good weather operations in U.S. waters that is completely separate and distinct from the cargo system. These SBTs have their own ballast pumps and suction lines separate from the cargo systems. Tankships and combination carriers fitted with double bottoms or double sides use the spaces thus formed for some or all of the SBT. If

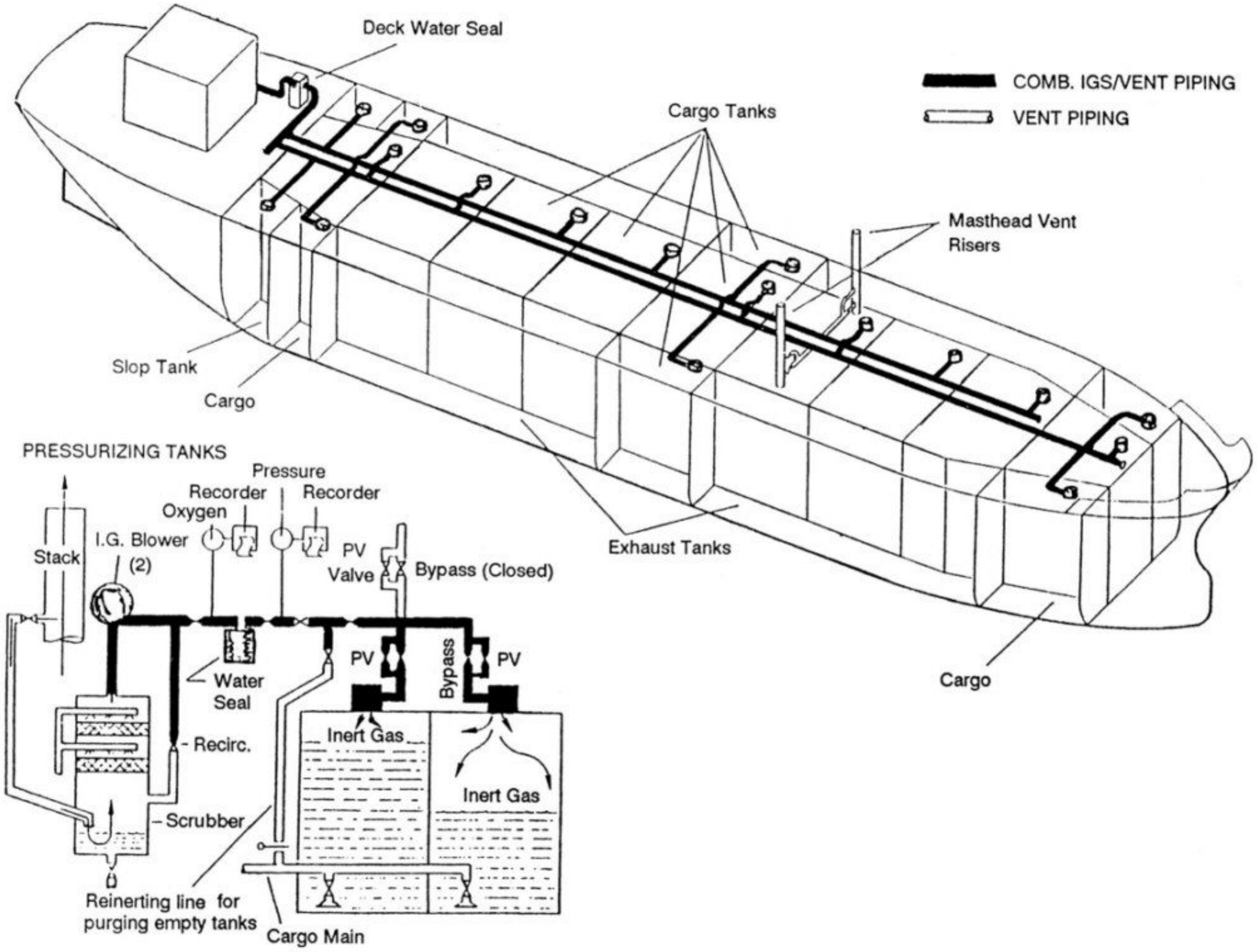

FIGURE 2-7 Inert gas (IG) system on typical tanker.

existing crude oil tankers of 20,000 dwt or more are fitted with crude oil washing (COW), they do not require SBT or CBT.

Clean Ballast Tanks

Existing product tankers of 20,000 dwt or more operating in U.S. waters are permitted to substitute CBTs for SBTs. CBT are cargo tanks reserved for ballast, without separate ballast pumps and suction lines. On CBT vessels the ballast is loaded and discharged using a cargo pump and suction line.

Ballast in Cargo Tanks

Tankships under 20,000 dwt generally put all ballast water into empty cargo tanks. On many of the existing larger tankers fitted with COW, part of the ballast is carried in SBT and the remainder in cargo tanks.

Ballast water pumped into cargo tanks displaces the cargo vapors through the vent lines into the atmosphere. Coast Guard regulations governing departure from any U.S. port require each tank vessel having a COW system without sufficient SBT or CBT to have a means to discharge hydrocarbon vapors from each cargo tank that is ballasted to a cargo tank discharging crude oil. Using this arrangement, VOC emissions from ballasting are eliminated. The IG distribution lines are used to transfer vapors from one cargo tank to another.

Figure 2-8 illustrates how a tankship with IG can load ballast into a cargo tank and transfer the ballast vapors into a tank discharging cargo. Figure 2-9 shows the arrangement when a tankship loads ballast into a cargo tank and puts the displaced vapors into one or more empty cargo tanks by compression.

Ullaging During Loading and Discharging

Ullage is the space between the tank top and the surface of the liquid in a tank. Tankships with IG are equipped with automatic ullaging devices that serve as “trend indicators” during loading and discharging. Figure 2-10 shows one type of such device that has been in use for many years.

The float rides up and down the guide wires, and the deck officer can read the ullage through the small window in the deck mounting near the tank hatch. This ullage measurement is not considered sufficiently accurate for cargo documentation purposes.

A more sophisticated system employed on a few tank vessels uses a radar-like device to determine the ullage. The readout is often in a control room in the afterdeck house at the main deck level. Other devices operate on a pressure measuring instrument that is easily arranged to read remotely in a control room.

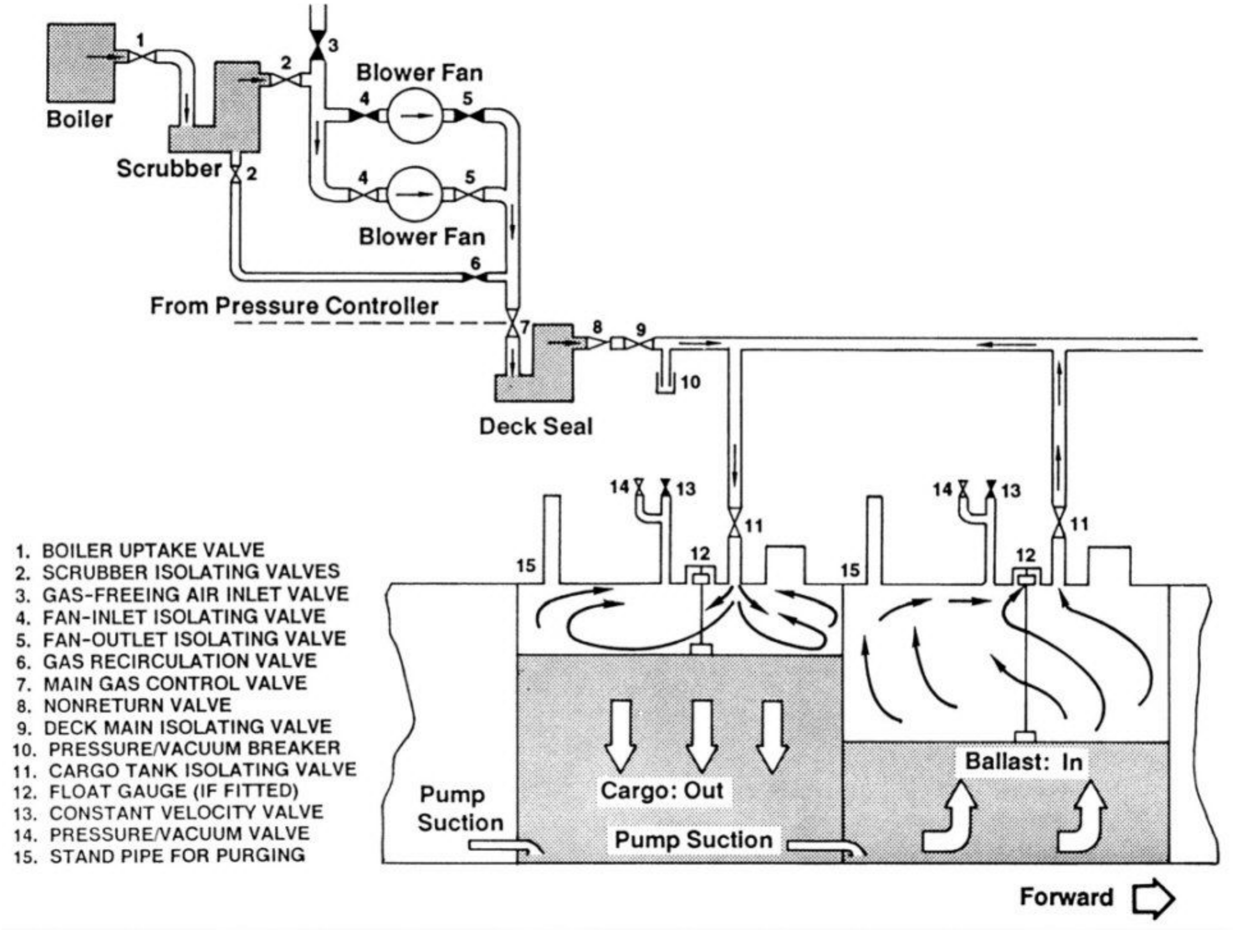

FIGURE 2-8 Transferring ballast vapors to a tank discharging cargo.

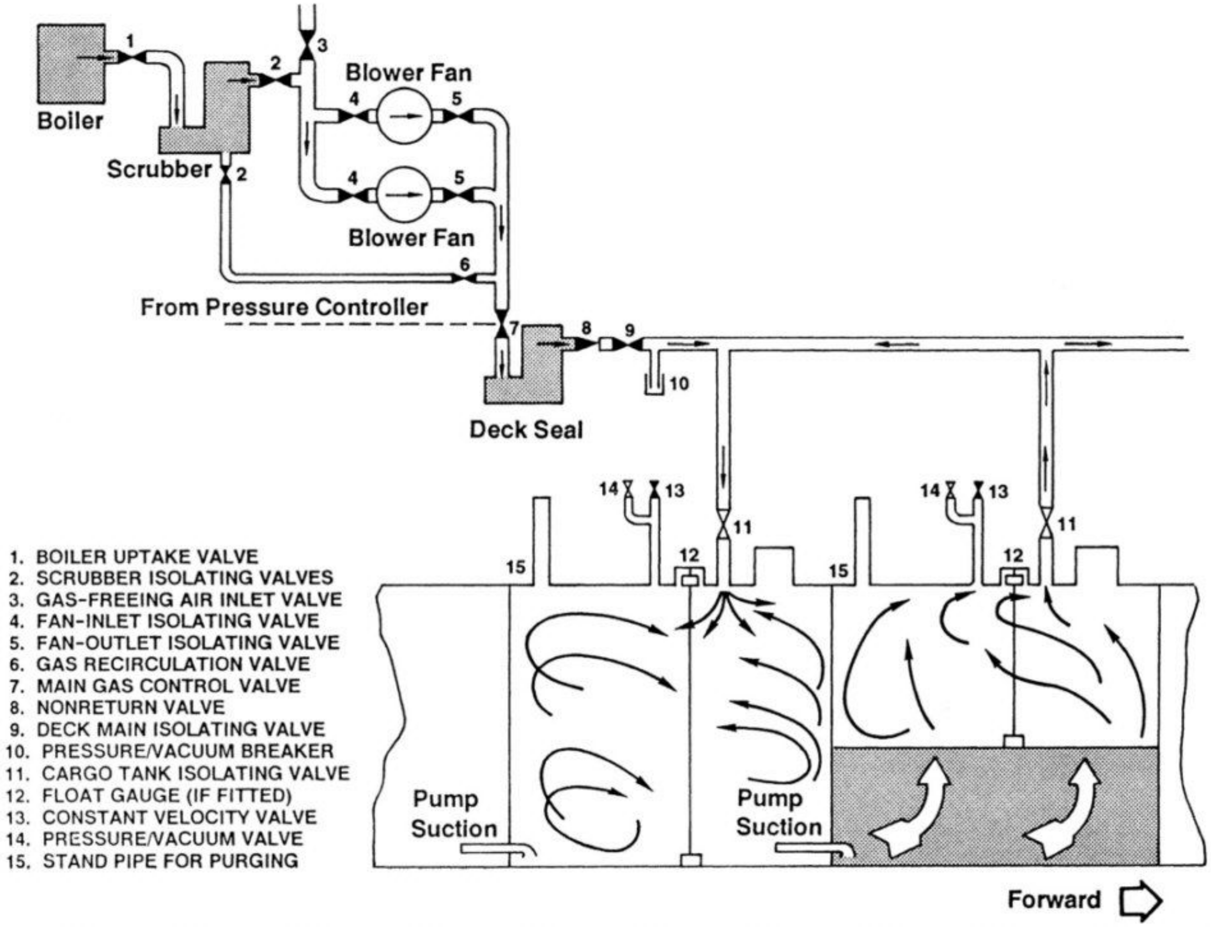

FIGURE 2-9 Transferring and compressing ballast vapors in empty tanks.

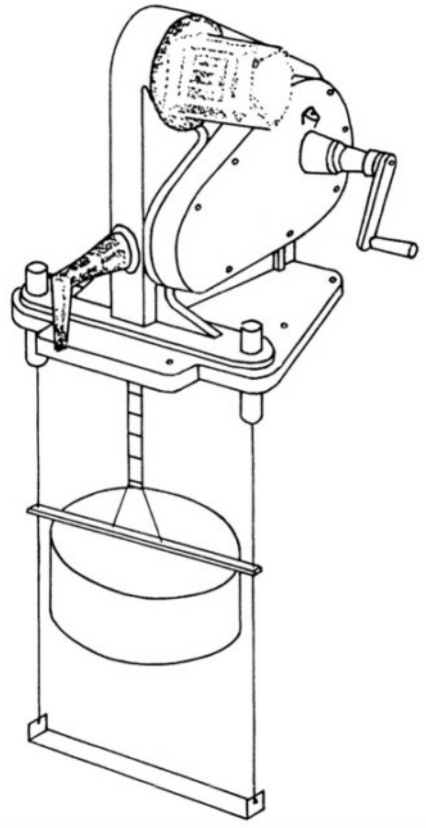

FIGURE 2-10 Typical ullage gauge (Shand and Jurs).

Modern tankships are equipped with control rooms that permit the mate to load and discharge cargo and ballast from one location. Remote reading ullage gauges, automated valves, and cargo pump controls in the control room improve efficiency and safety during the transfer of cargo. The trend is toward more automation of loading and discharging.

Older and smaller tankships under 20,000 dwt not equipped with IG or not fitted with remote-reading ullage devices monitor cargo levels by looking into the cargo tank through ullage ports on the tops of the tank hatches (the ullage ports are fitted with flame screens, which are removed to permit viewing cargo levels).

Manning and Personnel

Manning levels aboard tankers have been declining for many years. Automation of engine rooms and use of long-lasting coatings on exposed hull and superstructure surfaces have permitted large personnel reductions. The worldwide depressed tanker market during the past 10 years has accelerated this trend. Additional automation of mooring winches, anchors, and gangways, with changes in work rules, could bring large further reductions. There is no relation between the size of a tanker and its crew complement; it is common today for a small product or chemical tanker to have a larger crew than a VLCC.

Shipboard personnel can be grouped broadly into two classes: officers (who are licensed) and unlicensed personnel, or seamen (who are usually certificated). Most maritime nations have similar standards for licensing and certification. About one-third of all seagoing tankers fly the flags of nations known as “open registry.” These small nations usually issue licenses to officers already licensed by a recognized maritime nation.

Deck and Engine Officers

Most licensed officers have the equivalent of a college education. This formal education is usually undertaken at special maritime colleges with 4-year curricula. After completion of the formal training, including some time aboard ship, they are eligible to take the U.S. Coast Guard examination for deck officer (as a third mate) or engine officer (as third assistant engineer). Some officers have both deck and engine licenses. Each year they serve with their licenses, officers are eligible to sit for the next higher rank until they achieve their master's or chief engineer's license.

In the United States unlicensed personnel, after serving for several years aboard ship, may also take the examination for deck or engine officer. About 10 percent of U.S. officers are such so-called hawse pipe officers. Regulations governing licensed officers are contained in 46 CFR part 10.

Unlicensed Personnel

Most unlicensed personnel have relatively minimal formal training and start aboard ship in the lowest job category, called “entry ratings.” They usually are initially certificated only to show they are in reasonable health.

After serving aboard ship for a period of time, U.S. seamen are eligible to take a Coast Guard test certifying to their increased competence. After many years of shipboard experience, they may be assigned by the shipowner to higher ratings as petty officers. Usually there is no certification as petty officer. The regulations concerning unlicensed personnel are contained in 46 CFR part 12.

Loading Procedures

The chief mate, also called first mate or first officer, traditionally serves as the cargo officer. He is responsible for loading, discharge, and general stewardship of the cargo, assisted by the second and third mates. A petty officer called the pumpman works for the chief mate in port; at sea he assists the engineers in maintaining the cargo equipment.

On arrival at the loading terminal, a formal meeting is held with the responsible ship's officer and the terminal representative. Meanwhile, the hoses or articulated metal arms are connected by dock workers. The loading terminal advises of cargo characteristics, preferred loading order, venting requirements, number and size of hoses or articulated arms, maximum loading rates and pressures, bunkering plans, and so on. The ship's officer advises of the general arrangement of cargo, ballast, and bunker tanks and other data pertinent to loading. On the basis of this information exchange, a written agreement is prepared and signed by both parties.

If there is ballast in some of the cargo tanks, the vessel will use its cargo pumps to discharge this ballast. At most U.S. ports this ballast is discharged into ballast receiving facilities ashore, where the separation of any oil in the ballast is accomplished most effectively. Generally it takes about 6 hours to discharge the ballast from the cargo tanks. If the tanker has some or all of its ballast in segregated ballast tanks the delay for deballasting is reduced or eliminated entirely.

Petroleum inspectors, paid by the vessel's charterer, inspect all tanks to be sure they satisfy the requirements for the cargo. When the inspection has been approved the vessel notifies the shore to start loading slowly using pumps at the terminal. The chief mate is on deck when loading begins. A check is made to ensure there are no leaks at the cargo manifolds and that the cargo is entering the tanks designated to receive it.

The chief mate decides the sequence to be followed in the loading operation, taking into account stresses caused by the loading, and fills out a cargo plan that gives precise information to the other deck officers on the loading sequence, final ullages for each tank, final draft and trim, and so on.

Frequent checks are made of the tank ullages during loading. As the cargo level in the first tanks loaded nears 10 ft from the tank top, personnel are alerted for the topping-off operation: bringing the level of liquid up to a foot or so below the main deck. The loading sequence is arranged so that only a few of the tanks reach the topping-off point at the same time. If the cargo will expand during the loaded trip the mate calculates the additional space required to permit expansion.

When carrying a full cargo, the tankship is loaded to its draft marks. The bunkers are filled before loading is completed. The last of the cargo is usually loaded into fore and aft tanks to put the vessel on the proper trim for the voyage.

When loading is completed, petroleum inspectors, accompanied by a ship's officer, check the ullage, cargo temperature, and any free water under the cargo in each compartment. If the ship measurements are in close agreement with the shore loading figures, the cargo documents are placed aboard and the vessel departs for the discharge port.

Unloading Procedures

On arrival at the discharge berth, the hoses or articulated arms are connected while a petroleum inspector, accompanied by a ship's officer, repeats the check of ullage, temperature, and free water under the cargo in each compartment. Simultaneously, a formal meeting is held with the responsible ship's officer and a terminal representative. All pertinent information about the cargo, proposed discharge arrangements, pumping rates, operation of any shipboard inert gas system, the ballasting plan, and so on are reviewed in considerable detail.

When the hoses or arms are connected and all tests and meetings have been completed (these steps may take 30 to 45 minutes), the ship notifies the terminal that it is ready to discharge. When the shore facility confirms its readiness to receive the cargo, discharge will start slowly, often using only one cargo pump at slow speed. The terminal makes sure the cargo is entering the correct shore tank. The ship checks the cargo manifold connections and the pump room for leaks.

The chief mate leaves detailed written discharge instructions for the other mates. With only one grade of oil, the cargo is discharged in sets, with several tanks comprising one set. Set one is discharged with the main cargo pumps down to within 2-3 ft of the bottom of the tanks. Then the main cargo pumps are switched to the second set. At the same time, the stripper pumps are activated to take 2-3 ft of oil out of set one. Usually the stripper discharge is put into a partially filled cargo tank instead of trying to discharge ashore against the pressure of the main cargo pumps. Long before the main cargo pumps have finished discharging set two, the stripping has been finished from set one. This method minimizes the delay for stripping the last set to not more than 2-3 hours.

If the vessel is equipped with an IG system, the cargo leaving the tanks is replaced with inert gas maintained under slight pressure. Ballasting is timed to be finished when the cargo discharge is completed.

On tankers equipped with COW facilities, the vapor from ballast loaded into cargo tanks is either compressed into empty cargo tanks or transferred into tanks from which the cargo is being discharged. COW delays a tanker 2-10 hours beyond the normal discharging time, depending on the number of tanks washed. In the COW process, the tank atmosphere becomes saturated with hydrocarbon vapors. While hydrocarbon emissions at the ballasting port can be avoided through vapor balancing on a COW tankship, the total atmospheric emissions of hydrocarbons are higher than what would be emitted from a similar tankship not practicing COW.

In COW operations, one or more of the tanks is washed with the crude oil cargo during discharge to minimize the amount of oil clingage in the cargo tanks. Cargo tanks selected to receive ballast water are usually crude oil washed during discharge. Also one or more other tanks are often washed on a regular pattern to minimize the buildup of sludge. The discharge from COW goes ashore with the cargo stream.

Generally it will take 16-24 hours to discharge most single-grade cargoes; multigrade cargoes may take considerably longer. The petroleum inspector returns after discharge is completed, and checks all compartments to see if they are dry of cargo. Any small amounts of cargo remaining in the tanks, if considered pumpable, are measured. In many of the smaller and older tankers not equipped with IG systems, ballast must be pumped into some of the cargo tanks after discharge is finished. Ballasting may take an additional 3-4 hours.

Washing Cargo Tanks

The cargo tanks are washed (1) to free the tanks of gas so personnel can perform repairs or remove sludge, (2) to remove traces of previous cargoes so ballast water will remain clean, (3) to remove traces of previous cargoes that might contaminate the next cargo, or (4) to remove all traces of previous cargoes so shipyard workers can perform welding or other hot work safely inside cargo tanks.

Water Washing

Water washing of some or all cargo tanks generally takes place at sea on the ballast passage. Tankships bound for loading ports without ballast receiving facilities wash 20-30 percent of their tanks during each ballast voyage, then fill the washed tanks with clean seawater ballast. Tankships proceeding to loading ports with dirty ballast receiving facilities may not wash any tanks for ballast.

The washing on small- and moderate-size tankships is usually performed with portable machines attached to hoses connected to a water source and lowered into the cargo tanks. The machine sprays the inside of the tank with water at 150 psi. A pump in the engine room supplies the water to the machines through the fireline that runs the full length of the vessel. On the larger tankships, high-capacity washing machines (HCWM) semipermanently installed in the tanks receive water from a cargo tank filled with recirculating wash water. Tankers using HCWM are required to have IG systems, since the greater water volumes from the HCWM are more prone to sustaining electrostatic discharges.

The stripping pump or eductor removes the dirty wash water and slop oil as the washing proceeds, to prevent buildup of water on the bottom of the tank being cleaned. The dirty wash water and slop oil are put into a cargo tank called the slop tank. The slop tank is allowed several hours to settle, and then the fairly clean separated water is pumped out. On most crude oil tankships, the next incoming cargo is loaded on top of the slop oil that has been separated from the water. Slop should be discharged ashore to slop oil or dirty ballast receiving facilities.

If gas-freeing is required, portable blowers are installed in the deck openings and fresh air displaces the vapors in the washed tank. If sludge removal by hand is necessary, personnel enter the tanks and scoop the traces of sludge and oil off the bottom for disposal ashore.

Crude Oil Washing

Crude oil washing is allowed on some existing crude oil carriers as an alternative to segregated ballast. Crude carriers fitted with HCWM and IG also use the equipment to wash the tanks with crude oil cargo during discharge. Crude oil is more effective than water because it removes clingage and sludge. The crude oil washings and sludge are discharged ashore mixed with the cargo.

COW minimizes ocean pollution, but increases atmospheric emissions. COW is performed while the tanker is discharging its crude cargo. Vessels with COW must have IG systems. By this crude oil washing of a tank which is to be ballasted, the amount of oil which is discharged at sea as a result of ballasting is greatly reduced. Crude oil washing is also practiced on crude tankers with segregated ballast because it tends to improve overall efficiency.

If additional cleaning is necessary for clean ballast, the vessel goes to sea and cleans the tanks with water. It takes considerably less time for water washing after crude washing, because most of the clingage has been removed.

3

VAPOR CONTROL TECHNOLOGY

Attaining the emission reductions proposed in several state implementation plans to meet the ozone deadlines in the National Ambient Air Quality Standards would require substantial investments by the operators of marine vessels and terminals. Special vapor handling systems would be needed at loading terminals and aboard vessels. Compartments on both tankships and barges would need to be closed to the atmosphere during loading (with appropriate automated gauges to prevent overfilling and overpressuring). Vapors would need to be collected and piped to recovery or disposal systems such as flares, incinerators, refrigeration systems, carbon adsorption beds, or lean-oil absorption units.

The essential technologies for these measures are available commercially. They are used routinely in tank farms and tank truck terminals, although the scales of these systems are often smaller than those required to control vapor emissions during tank vessel loading or ballasting.

Vapor control technology is used at marine terminals mainly for handling highly toxic or noxious cargoes with volatile vapors, such as ammonia, chlorine, acrylonitrile, and epichlorohydrin. Applying these technologies more widely, particularly to the high volumes and loading rates typical of gasoline and crude oil, will challenge the ability of vessel and terminal operators to maintain safe operating practices. Operations throughout the industry will need to be raised to the level of subchapter O cargo handling. Communications must be fail-safe, procedures must be consistent and thorough, and equipment must be well maintained.

The modest skills required of the barge-trained tankerman, especially in smaller operations/ports, should be taken into account in devising technical solutions and management approaches. Coincidentally, the Coast Guard is in the process of revising and upgrading tankerman certification requirements for a number of safety oriented purposes.

Among the technical challenges is the gauging of closed tanks on barges as they are loaded. In loading some tankships and most barges, the practice generally is to gauge the height of the cargo by eye, through open hatches. With vapor recovery systems, tanks will be loaded with hatches and vents closed to the atmosphere, so that accurate gauges will be needed. The closed gauging requirement is particularly important since overfilling can result in spills, ruptured tanks, and damaging mechanical shocks to vapor handling equipment, with possible subsequent fires and explosion. In addition, detonation arrestors adequate for the sizes and flow rates of vapor pipelines will need to be developed and tested.

MAXIMUM CONTROL OF EMISSIONS

Loading and ballasting emissions from vessels carrying crude oil and gasoline can be reduced by over 90 percent, using components that are commercially available. However, since few complete systems of the appropriate scale have been constructed and used, some engineering challenges would have to be met to ensure a safe and cost-effective solution to the regulatory requirement for such control. The following sections describe the available options and comment on the technical uncertainties.*

Closed Loading of Tank Vessels

Controlling vapors from tank vessels, obviously, will require loading with all hatches and ports closed. Closed loading departs from barge practice, but it is routine on most tankships. It presents certain problems not confronted when loading with open hatches, but the practice does not present any unusual risk if the vessel is properly outfitted and operated.**

Liquefied gas carriers, specialty vessels carrying certain hazardous chemicals, and most tankships have been closed loaded for many years with very good safety records. The installation of inert gas (IG) systems on the majority of tankships during this decade has resulted in a great increase in closed loading experience, since closed loading is necessary to maintain the legally required minimum inert gas pressure above the cargo.

Equipment for closed loading falls into three categories: (1) protection from tank overpressurization, (2) final (custody transfer) gauging and sampling, and (3) level monitoring and alarms. With some greater risk, closed loading could be done without specifically address

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*Two possibilities for eliminating volatile organic compound (VOC) emissions from tank vessels were not deemed appropriate for further consideration by the committee. The first was to construct the cargo tanks of all tank vessels as pressure vessels, to retain the VOC in the tankships. This was considered to be too expensive. The second possibility was to equip vessels so that VOC loading emissions would be transferred to the segregated ballast or clean ballast tanks and eventually discharged at sea. This would require changing or abrogating U.S. and international regulations, which was judged impractical.

**The term “closed loading” does not necessarily imply the capture of vapors. Closed loading today is generally carried out with tank vents open to the atmosphere.

ing each of these, but each category should be given careful consideration to determine the degree of risk an operator is willing to assume.

Tank overpressure protection should especially be considered for barges, since the installed pressure/vacuum (PV) relief valves are not normally designed to pass the full volume flow rate of liquid during loading. Three types of protection are available: spill valves, rupture disks, and full-flow relief valves in conjunction with proper piping design.

Spill valves are high-volume, quick-acting relief valves that are closed when gas is being exhausted and open when liquid is present. Their principal disadvantages are the very large size and high cost of valves that handle high-loading rates (more than 5,000 bbl per hour). Rupture disks are devices with carefully machined carbon or metallic disks that rupture at a preset level below the design pressure of the vessel tank structure. Their major disadvantage is that, when actuated, they provide a free path from the atmosphere back to the cargo tanks, with the associated fire hazard. The main purpose of either device is to prevent rupturing the vessel's hull.

If practical, the spill valve or rupture disk should be piped to a tank or enclosure to prevent oil from spilling into the water. Even if this is not possible, the spill that might result from the operation of one of these devices could be expected to be much smaller than that from a hull rupture.

PV valves are available on the market in a variety of configurations. These valves, however, are designed to vent gas rather than liquid at full-loading rates. The limitation can be overcome with a piping design, so that any liquid overflowing one tank and entering a gas exhaust header can flow down into a tank that is not being loaded.* Even if this contaminates one cargo with a different one, the cost of reprocessing the contaminated cargo should be considerably lower than the costs of potential damages and cleanup of a major spill.

Final manual gauging and sampling of cargo is a routine practice in ship and barge operations. Cargo quantity and quality are verified for both the cargo owner and the transporter, and this practice can be expected to continue as an accepted standard for some time. Manual gauging and sampling on close-loaded vessels, however, cannot be carried out in the same manner as on open-loaded vessels. Whether or not a vessel is inerted with a pressurized inert gas, residual pressure in the tank could present a hazard to the gauger and create inaccuracies in measurement. Several methods are available to overcome these problems and should be included in the design of the gauging and sampling system.

On noninerted vessels, when loading is stopped and there is no pressure in the tank above the cargo, a restricted ullage cover in the tank top may suffice. As an alternative, many operators use a standpipe

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*Such piping designs employ vapor headers equipped with valves to permit selection of an empty versus a full tank for possible overflow. The very presence of such valves carries with it the risk of shutdown against a stream of vapors and therefore tank overpressuring, a major risk of closed loading.

extending from the deck to just above the bottom of the tank. Measurements taken in the standpipe will always be higher than the actual level, if there is pressure in the tank ullage and there are no pressure-equalizing ports. However, if pressure-equalizing ports are provided, gas can flow into the vicinity of the gauger. (Monitoring of the unequalized standpipe level during the first 70-80 percent of loading can be useful, in that the positive ullage pressure will provide a conservative indication of the tank level.)

Samples and accurate level readings can be taken from pressurized tanks using a vapor lock and valve. This device consists of a length of pipe extending above the deck to a ball valve, with an additional length of pipe above the valve terminating in a fitting that mates with the gauging tape. The fitting height is set to a datum for which the tank is calibrated. A special ullaging tape in a vapor-tight reel can be mated to the fitting on the end of the pipe, the ball valve opened and measurements taken without releasing tank pressure (Figure 3-1). Samples, water interface measurements, and temperature readings can also be taken with attachments to the tape. At least two companies make these devices.

One consequence of closed loading is there may not be the opportunity to observe the cargo level directly, as done with open loading. Indirect determination of cargo levels has generated concern about knowing the “true” cargo level. Before the transition to closed loading aboard inerted ships, many operators feared that cargo levels would not be reliably known and that overfilling of tanks and spill incidents would increase significantly. While there has been very little reported on recent closed loading experience, the absence of casualty reports suggests not only that there has been no serious increase in overfill incidents, but that the incident rate has actually decreased.

Virtually all the cargo level measuring and indicating systems for closed loading incorporate some redundancy. Simple systems may have two independent passive devices. More sophisticated ones may have multiple active and passive devices, independent alarms, and remote repeaters. At the simple end of the spectrum is an unpowered tank barge with a tank viewing port and one other unpowered device to provide warning of nearly full tanks. Among the most complex systems are those of chemical carriers, which by regulation are required to have a full-range, level-measuring instrument and two independent, high-level alarm instruments.

One large domestic operator, which loads all of its 20 operating tankships closed, modified five ships of its fleet from 1980-1981 for use with a vapor recovery system at an offshore facility in the Santa Barbara Channel. Each of these tankships is equipped with a full-length, float-and-tape gauge and a magnetic float-with-reed-switches gauge for the top 10 ft of each tank. In addition, two independent dual-float alarms and a vapor lock for manual ullaging are installed in each tank.

Because the vessels are of the older two-houses design, there is no cargo control room and all cargo operations must take place on deck. To provide visual indication of high-level warning and alarms, mimic displays are mounted on the fronts and backs of the midships houses. This arrangement has been very successful. None of the vessels has had a

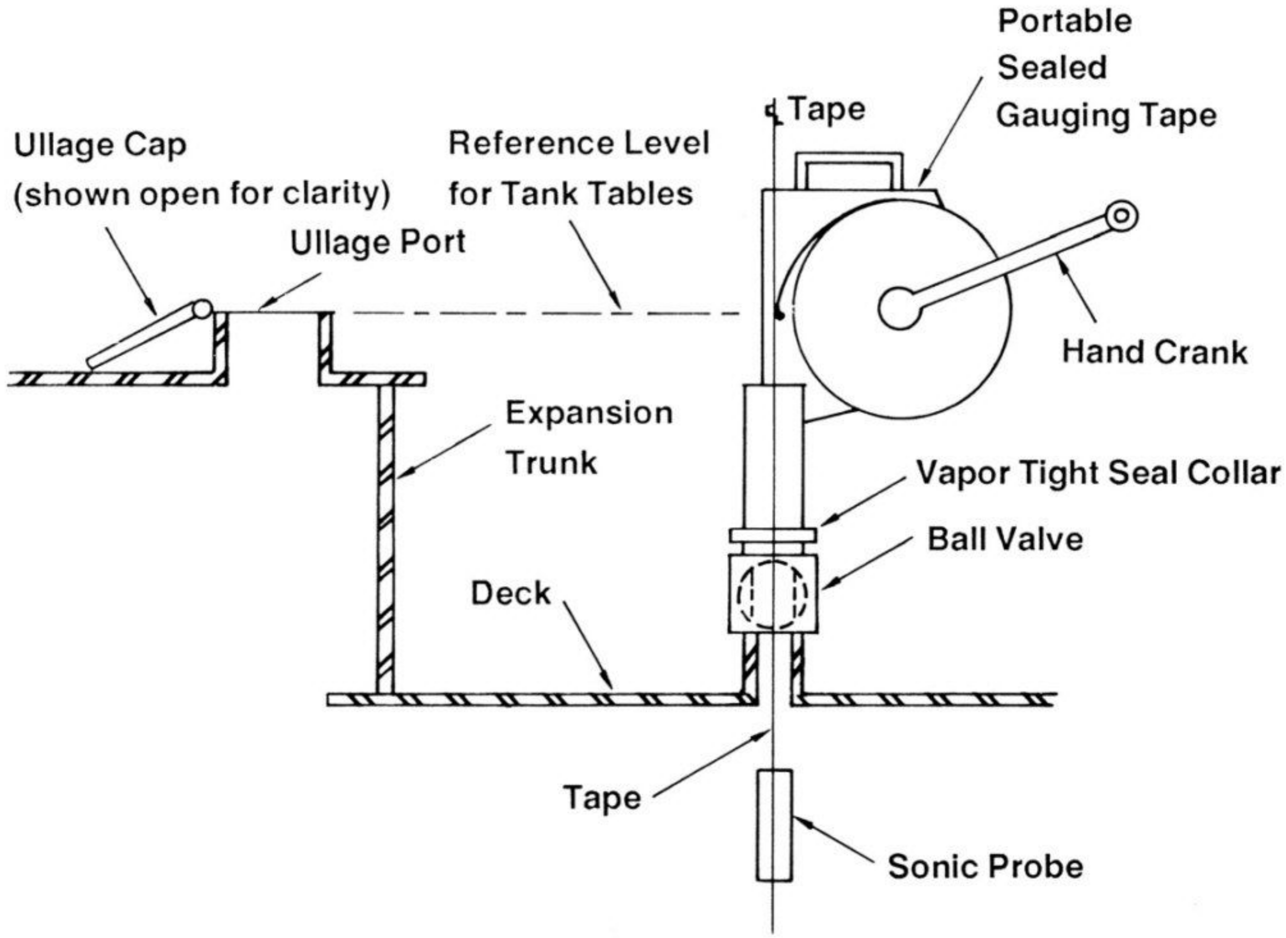


FIGURE 3-1 Vapor lock and valve.

cargo spill during the 6 years since the system was installed. In fact, this company has had no cargo overflow spills in its entire fleet since converting to closed loading.

In contrast with these complex systems, some operators of barges carrying benzene and other hazardous chemicals regularly load closed with nothing more than a glass viewing port for observing the cargo and a restricted standpipe for final gauging. Even with this arrangement, there was no evidence of cargo overflow incidence rates in excess of open-loading experience. If anything, the overflow incidence of close-loaded barges is lower than that on open-loaded barges, perhaps because of the higher degree of operational control that is necessary in closed loading.

Level-monitoring equipment can be conveniently categorized by actuation method and display technique, as done by Southwest Research Institute in a study (Johnson et al., 1981) for the Maritime Administration. Of more practical interest to the operator, however, is whether a device is active (requires external power) or passive (can stand alone).

Active devices most commonly use electric or pneumatic power, and have the ability to actuate visual and audible alarms and to provide remote indication. The most common electric instruments measure the liquid level by means of magnetic floats sequentially operating reed switches, radar or sonar impulses bounced off the liquid surface, or hydrostatic pressure transducers located in the tank. Alarm indication may be centralized or distributed, and remote readouts may be single or multiple. At least two manufacturers offer hand-held radio receivers that allow an operator on deck to monitor levels and receive alarms from all tanks regardless of location.

Since an external source of electricity is needed, this type of monitoring instrument is suited mainly to ship installations. Several manufacturers do offer instruments that are solar powered and could be installed on unpowered barges. The solar-powered devices cannot, however, provide an alarm, owing to the low power available from their photovoltaic collectors.

Pneumatically operated level detection systems have found only limited application aboard ships and barges. In most cases, the reasons have been the limitations on supplies of clean, dry air and the potential for creating an explosive mixture by admitting oxygen into an otherwise safe atmosphere in the tank.

The most common passive level monitors found on barges are simple visual, mechanical/magnetic, or purely mechanical types that require monitoring by the operator. The simplest of these monitors is a glass viewing port that can be mounted either in the deck or in the expansion trunk hatch cover. More elaborate versions of this device can have a hand-operated wiper for clearing condensation from the underside of the glass, a stepped and calibrated scale that can be viewed through the glass, and a second port to allow a light to be directed into the tank.

Another simple but effective device for monitoring the top 4-6 ft of the tank consists of a nonmagnetic tube that penetrates the tank with a float and magnet outside the tube (Figure 3-2). The float magnet interlocks with a magnet at the bottom of the lightweight stick inside the tube. As the float rises, the coupling of the magnets causes the stick

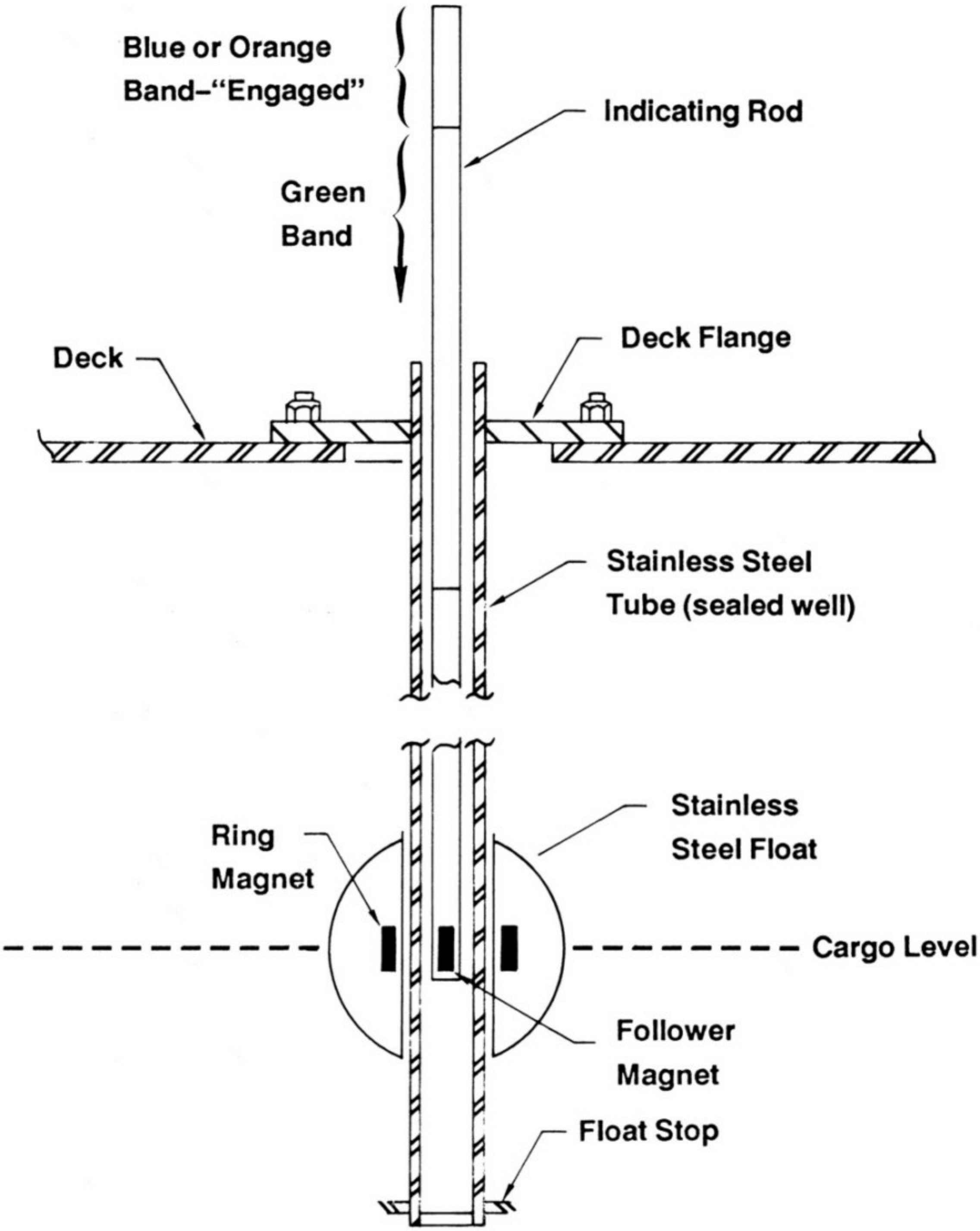


FIGURE 3-2 Indicating stick.

to rise with the liquid level, providing a reliable and reasonably accurate indication of tank level. With green, yellow, and red bands on the stick, the tanks can be monitored at reasonable distances if the deck is not too cluttered.

A variation on this principle has the stick attached to the float and rising in a tube that projects above the deck. A magnet at the top of the stick causes magnetic flags to flip over as the top magnet passes them, changing the visible color of the column from white to red. The range of indication on each of these types is limited by the weight of the stick and the vertical clearance above the barge deck.

A more complicated but effective full-length gauging instrument uses a wire-guided float, which unreels and retracts a calibrated tape from a spring-loaded drum as the float falls or rises with the tank level. This instrument may be supplied either unpowered or powered to drive a remote gauge and alarms.

Independent, power-operated, high-level alarms should be considered for tank vessels that have neither redundant cargo level monitoring systems nor level monitors with built-in alarm capability. Any alarm system should have a means of checking the complete alarm operation before loading and, if electrically powered, should have intrinsically safe circuitry. The most common type of alarm in marine use has a magnetic float that holds a reed switch closed. When increasing cargo level lifts the float above the switch, the switch opens, breaking the circuit and sounding the alarm. A mechanical or magnetic link is normally included to lift the float to check for float freedom or proper electrical function. In addition to the float-actuated type, several manufacturers offer capacitance or optical alarm devices that might be adapted to marine use. Functional testing of these types, however, might be more difficult.

While each operator will have ideas about acceptable risk, the possible consequences of a cargo overfill incident are severe enough to require very careful consideration of the vessel's need for additional equipment prior to converting to closed loading. As a minimum, a full-depth level monitor with an alarm, an independent high-level alarm, and a closed gauging and sampling connection should be fitted on ships with IG systems. Unpowered barges should have at least a means of monitoring the top few feet of the tank, a restricted standpipe, and, because of their lower design pressure rating, a rupture disk, spill valve, or high-capacity relief valve with intertank overflow capability.

The logical next step for barges is to provide a system that reads level warning and alarm signals aboard the barge and actuates alarm and control devices at the terminal. A practical method of doing this can be realized by installing currently available sensors aboard the barge, explosion-proof alarm and control enclosures routinely fabricated for refineries, and intrinsically safe circuitry, also currently available, between dock and barge. The configuration of the connection between the barge and the dock cable, presumably a plug and socket arrangement, would need to be accepted as an industrywide standard to ensure that any barge can connect to the alarm system at any marine terminal.

Hydrocarbon Vapor Recovery and Disposal Systems

Several established processes can be used to reduce the hydrocarbon vapor emissions from crude oil and gasoline loading. The control processes fall into two broad categories: combustion and recovery. Combustion processes include flares and incinerators. Recovery processes include lean oil absorbers, refrigeration systems, and carbon-bed adsorbers.

The optimal process for one vapor control application may not be optimal for another. In selecting a process for a given situation, the most important decision is whether or not to recover the hydrocarbon. This decision depends primarily on

- the nature of the vapor stream, specifically, its expected variability in flow rate and hydrocarbon content; and
- locational factors, such as the availability of utilities and the distance from the tankship or barge to the vapor control facility.

To prevent flame flashbacks, each hydrocarbon-containing line that feeds the flare needs to pass through at least one detonation arrestor. This is especially important for the line between the cargo compartments and the combustion or recovery equipment.

When Combustion Is Preferable to Recovery

Compared to hydrocarbon recovery systems, flares and incinerators are inexpensive to install and easy to operate. They will probably be more economic at low-volume terminals that are located far from existing utility hookups. This is especially true if the vapor vented from tankships and tank barges is lean, and the potential value of the recovered hydrocarbon is low.

When Recovery Is Preferable to Combustion

It may be economic to recover hydrocarbon from large, relatively rich streams at high-volume terminals that have adequate space and easily accessible utilities. Recovery equipment costs more to install and operate, but the value of the recovered hydrocarbon makes recovery cost-effective, especially at terminals with adequate space and easily accessible utilities.

Recovery Followed by Combustion

Most recovery processes can recover 80-95 percent of the hydrocarbon with moderate installation and operating costs. However, it becomes prohibitively expensive to remove much more because the operating conditions become too severe (e.g., temperatures below −200°F, pressures above 250 psia).

If further reduction is needed, a small flare or incinerator should follow the recovery unit to polish the outlet stream. A polishing combustor can be designed small, since it will see a lean, steady feed.

Combustion Processes

Flares and incinerators combust hydrocarbon-containing vapors as they arrive from the vessel or from intermediate vapor recovery equipment. The combustion products are mainly CO_2 and H_2O; small amounts of NO_x and CO are also produced.

Both flares and incinerators are more than 98 percent efficient if operated properly. They can perform reliably as the sole hydrocarbon control process; and even more reliably as polishing units.

The primary drawback is that they do not recover the hydrocarbon. The value of unrecovered hydrocarbon can be significant when crude or gasoline is being shipped.

Another potential drawback is that combustion devices can be relatively unsafe, simply because they are potential ignition sources. This concern is especially important if the displaced vapors are not inerted.

Vapors from vessels with inert gas systems will have oxygen contents below 11 percent--too low to support combustion. The lack of oxygen will greatly reduce the risk of explosion. It will also require the combustion system to draw in additional air (to raise oxygen levels to the point where the mixture will burn). Diluting the vapors will increase the size of the combustor and the amount of supplemental fuel needed to maintain minimum combustion temperatures.

Open Flares

Open flares have been used by refineries and chemical plants for decades. Almost all were installed as plant protection and safety devices. However, during the past 5 to 10 years, an increasing number have been installed specifically to reduce hydrocarbon emissions.

The vapors ignite as they pass through one or more burners. Several different burner head designs are available to maximize combustion. They vary in size and shape depending on the design flow rate, the design hydrocarbon content, and turndown requirements. To maintain a flame at all times, every flare needs a pilot burner in case the main flame goes out. The pilot burner is much smaller than the primary burners.

Advantages Open flares are the least expensive control option. They require little operator attention and will sustain burning on their own as long as the incoming vapors contain enough hydrocarbon. As long as the combustion zone stays properly lighted, they are usually more than 98 percent efficient.

Disadvantages If the hydrocarbon content drops too low, supplemental fuel will be needed to prevent significant drops in efficiency (potentially to zero if the flame goes out). In shipping applications, supplemental fuel will probably be needed until the end of the loading cycle, unless the cargo is exceptionally volatile.

Although flares are effective hydrocarbon removal devices, it is difficult to demonstrate whether or not they achieve the commonly believed 98 percent efficiency level. Industry and the EPA have conducted numerous tests and have agreed that efficiency of more than 98 percent is typical. Nonetheless, lack of demonstrability may limit applications in areas where state and local regulators want proof in the form of rigorous field tests.

The radiative heat given off by flares is a concern, but not a major one. Flares, especially open ones, need to be located away from people and equipment. By comparison, location of an incinerator is somewhat less of a concern, since its combustion zone is enclosed.

Noise and visual impact are other minor disadvantages of flares, particularly open flares. These factors do not affect performance or safety, but may affect an operator's chances of getting permits for equipment.

Enclosed Flares

An enclosed flare is essentially an open flare with a protective cylindrical shroud around the burners. The shroud helps increase natural draft and aerate the combustion zone. The shroud also helps minimize the impact of wind and other disturbances.

Enclosed flares are open to the atmosphere on top. On the bottom they have louvers to help control the inflow of combustion air. The louvers increase the efficiency somewhat by reducing the excess air. However, louver adjustment is usually performed manually and is not very accurate. On some enclosed flares the louvers are not adjustable.

Advantages Enclosed flares are somewhat easier to test for compliance than open flares. Flue gas samples can be drawn from within the stack. Thus, even though it is difficult to determine how much air enters through the louvers, measurements are more likely to be accurate than those around open flares. Enclosed flares also radiate less heat and are less noisy than open flares, especially when designed large enough to contain the combustion zone within the stack.

Disadvantages Enclosed flares are more expensive than open flares. They are also subject to capacity limitations.

Incineration

Incinerators, when properly run, are at least as efficient as flares. Combustion is carried out in a confined chamber under controlled conditions (Figure 3-3). Vapors enter the reaction chamber, ignite, then exit through the stack. Supplemental combustion air and fuel are added to the reaction mixture to maximize combustion efficiency.

Combustion air is added to maintain a slight excess of oxygen. Supplemental fuel is added to maintain the desired operating temperature. Process control for both systems is achieved through use of temperature sensors in the stack.

The inside of the incinerator's reaction chamber is lined with refractory material, to help seal in the heat and maintain the operating temperature. This minimizes use of supplemental fuel. To further increase combustion efficiency, the reaction chamber is sized so the vapors spend at least 1 second in the chamber under all operating conditions.

The operating-temperature window is chosen to destroy the maximum amount of the hydrocarbon without forming unacceptable amounts of NO_x. (The incinerator hardware can usually tolerate temperatures well above the desired operating temperature.)

Incinerators have quench air supplies to control high-temperature excursions. If the temperature of the flue gas rises too high, a high-temperature alarm will warn the operators and a quench air fan will blow air through the reaction chamber.

Advantages Incinerators are easier than flares to test for compliance, since both the inlet and outlet flow rates and compositions can be measured. This fact will be increasingly important in the future if state and local regulators insist on compliance demonstrations.

Incinerators may be slightly more efficient than flares. If operated properly they can achieve more than 98 percent hydrocarbon destruction over larger ranges of flow rates and hydrocarbon contents.

Incinerators can be designed to recover heat. The heat can be used to generate steam and heat tanks at the loading facility, thus partially offsetting energy costs. (It may or may not be economic to do so.)

Disadvantages Compared to flares, incinerators are more costly and complex to install and operate.

Recovery Processes

Compared to combustion processes, recovery processes are complex to design and operate. Nonetheless, in some cases the value of the recovered product may be worth the extra expense.

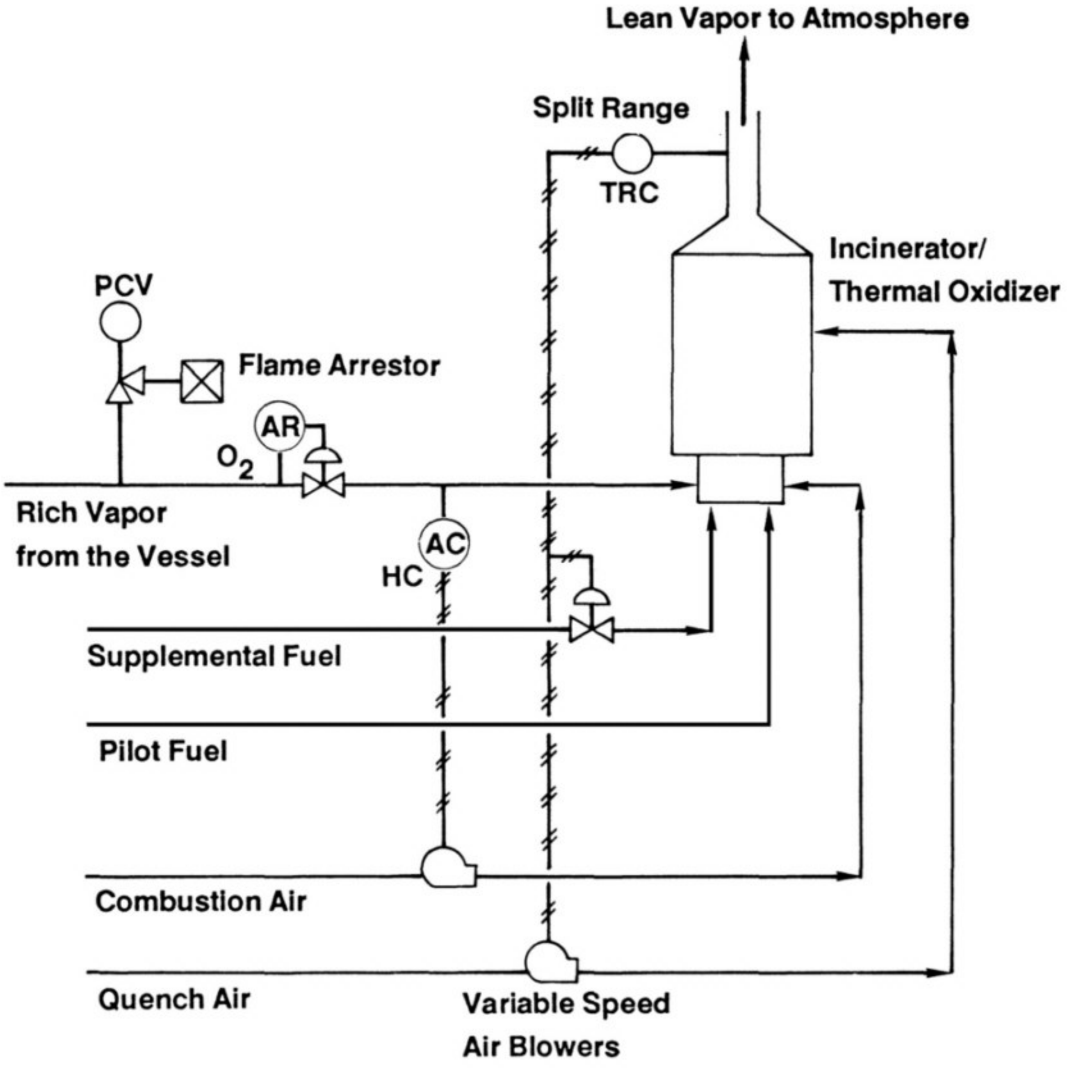


FIGURE 3-3 Hydrocarbon combustion by incineration. The controls shown are for normal operation. Additional controls may be needed for startup, shutdown, and emergency operation.

Several commercially proven vapor recovery processes are used in a variety of marketing and refining applications, and would lend themselves to tankship- and barge-loading applications:

- lean oil absorption,
- refrigeration, and
- carbon bed adsorption.

Lean Oil Absorption

Lean oil absorbers use condensation and cooling under pressure to transfer hydrocarbons from a rich vapor into a lean oil (Figure 3-4). Lean oil absorption processes are very efficient at recovering hydrocarbon from rich streams, but much less efficient at removing hydrocarbon from streams that contain little hydrocarbon.

Lean oil absorbers usually operate at pressures of 100 to 200 psia. To further reduce the exiting vapor's hydrocarbon content, some absorption units also cool the lean oil. Typically, an absorber can remove 80-90 percent of a vapor's hydrocarbon by pressure increase alone. Efficiencies up to about 95 percent can be achieved by also lowering the operating temperature.

At temperatures much below 60°F hydrate formation may cause freezeup problems. If the system is under pressure, water can also freeze, even at temperatures above 32°F. Antifreeze (e.g., ethylene glycol) can be used to lower the liquid hydrocarbon's freezing point.

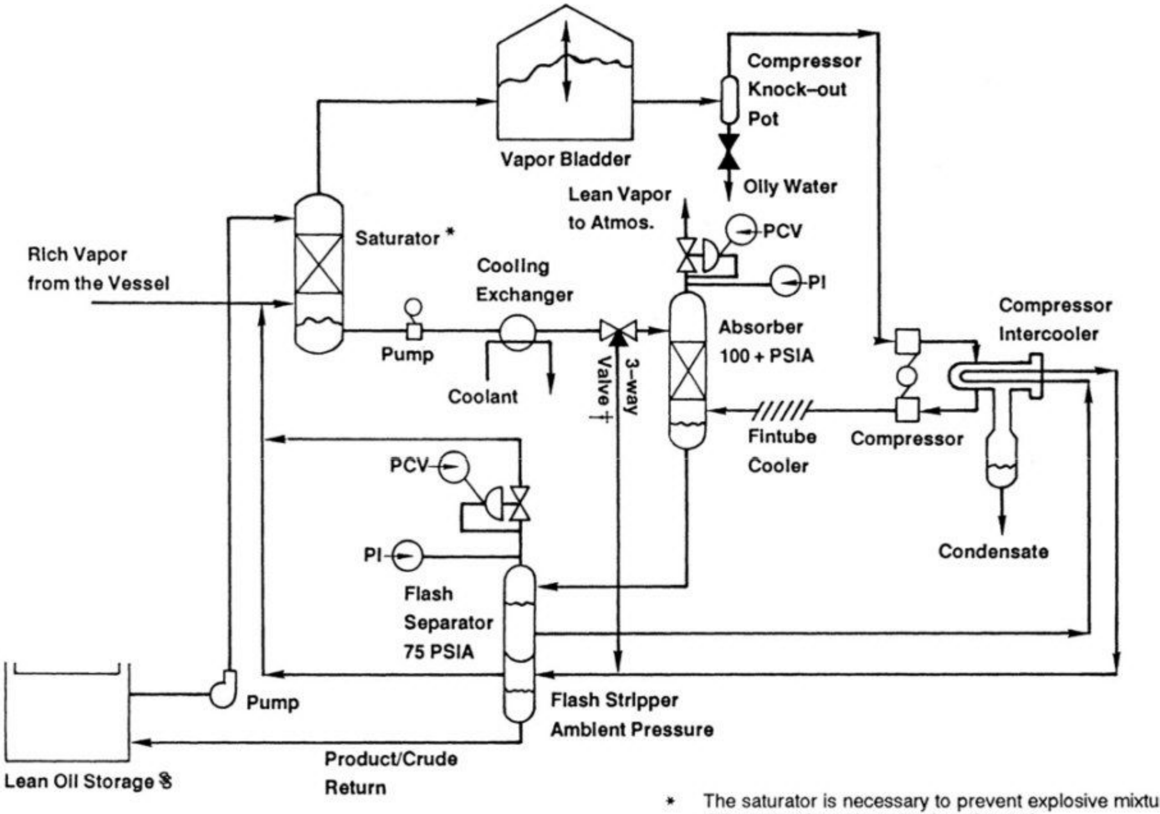
Unless they are inerted, the vapors vented during loading are often explosive. Since potential spark sources exist in the compressor, absorber, and other processing equipment, it is important to overenrich the vapors. Overenriching can be accomplished by sending the vapors through a saturator. (Inerting of noninerted vapor at the dockside is an undesirable alternative. All nonhydrocarbon gases will leave the absorber saturated. Hydrocarbon emissions will increase if additional inert gas flows through the absorber carrying equilibrium amounts of hydrocarbon with it.)

A vapor bladder should be installed upstream of the compressor. The bladder will help dampen variations in vapor flow rate and hydrocarbon content and thus allow a smaller absorber to run for longer, lined-out periods, yielding vapor with a low, predictable hydrocarbon content.

Any hydrocarbon liquid with sufficiently low vapor pressure can be used as the lean oil; the decision is an economic one. Marketing terminals use gasoline. Tankship- and barge-loading facilities could use crude, product, or another specially designated lean oil supply. The recovered hydrocarbon could either be incorporated and sold as part of the lean oil or stripped from it and dealt with separately.

When possible, it is less expensive to use the stock being loaded, then return it to a storage tank or to the vessel being loaded. The limitations on this alternative are as follows:

- The recovered light ends may cause the stock to become off-specification, owing to an increase in vapor pressure or air content.



* The saturator is necessary to prevent explosive mixtures unless the rich vapors from the vessel are inerted.

† While the vapor bladder is filling, the saturator needs to run to enrich the incoming vapors. In this case, the 3-way valve bypasses to the flash stripper (to remove air and light ends) before the storage stock is returned to storage. During normal operation, the 3-way valve sends stock on to the absorber.

$ Could be product, crude or a designated lean oil supply.

FIGURE 3-4 Hydrocarbon recovery by lean oil absorption.

(This is often a problem if refined oil is used, but is rarely a concern if crude is used.)

- The recovered light ends may increase the lean oil's vapor pressure, thus limiting its ability to absorb additional light ends.

Advantages Absorption units are effective at recovering 80-95 percent of a vapor stream's hydrocarbon, if significant amounts are present.

Disadvantages Absorption processes can only reduce a vapor's hydrocarbon content to 1-3 percent (volume) economically. Lower emissions would require excessively high pressures and/or excessively low temperatures. This performance limitation could limit the usefulness of lean oil absorbers in shipping applications, since vented vapors are likely to be lean during most of the loading cycle. (If the incoming vapors contain less than the absorber's equilibrium hydrocarbon content, say 2 percent, then the absorber will actually enrich them.)

These problems can be solved in two ways. First, if lower emissions are needed, one can route the absorber off-gas to a small polishing flare or incinerator. Second, to avoid enriching the vapors, one can use an on-line hydrocarbon analyzer upstream of the absorber to bypass vapors if they contain unrecoverable amounts of hydrocarbon.

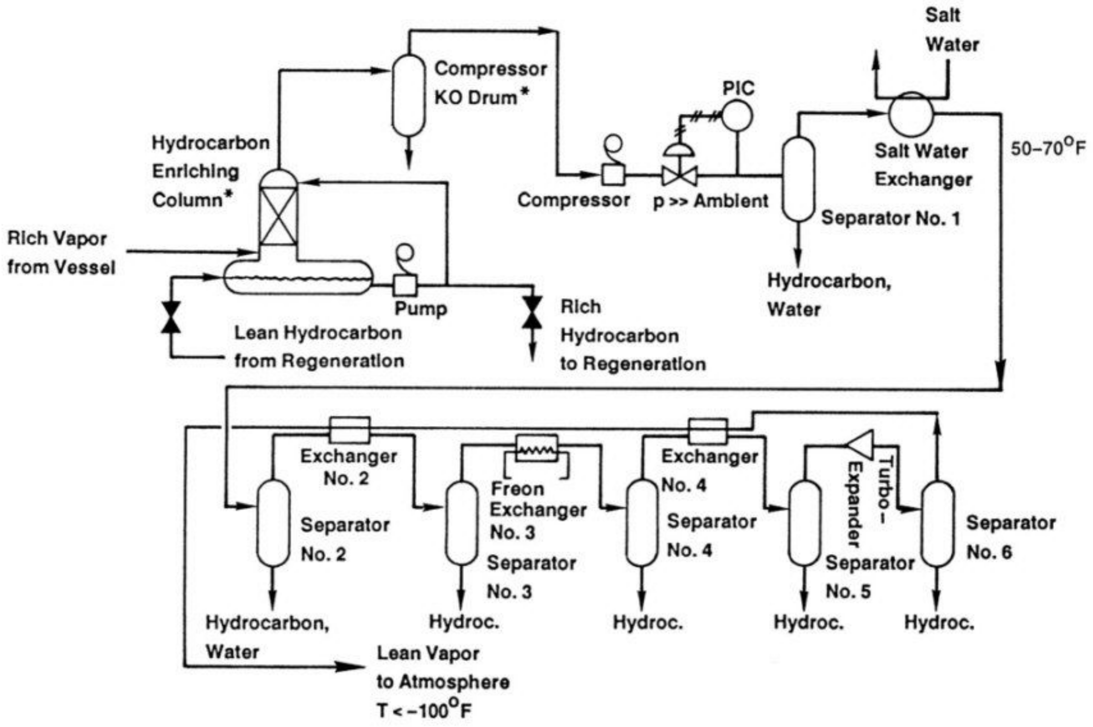
Direct Refrigeration

Direct refrigeration systems remove hydrocarbon by cooling the vapors through a series of low-temperature heat exchangers. No lean oil is used (Figure 3-5). These systems are best suited to vapors from non-inerted product carriers--vapors that do not contain as much CO_2, light ends, or corrosion-causing contaminants, such as H_2S.

Most direct refrigeration systems use sea or river water to cool the vapors to around 60°F. This step removes most of the water (humidity) and heavy hydrocarbons. Next, as many as four refrigeration loops cool the remaining vapor to somewhere in the −100°F to −150°F range. The number of loops needed and the intermediate operating temperatures depend on the hydrocarbon species present and the percentage recovery desired. Usually the first exchanger drops out water at around 32°F, the second cools to below 0°F for intermediate-weight hydrocarbons, and so on.

To further improve hydrocarbon reduction, it is useful to compress the vapors, thus further reducing the equilibrium hydrocarbon content. Compression is usually done after the first or second exchanger, when most of the easy-to-recover water and heavy hydrocarbons have been removed.

After the vapor has passed through the low-temperature exchangers, it is expanded down to ambient pressure as it is vented to the atmosphere. This expansion lowers temperature further and drops out additional hydrocarbon. If the expansion is done through an ordinary control valve (i.e., isenthalpically), the vapor's outlet temperature



* This equipment may not be needed if the rich vapors are inerted.

FIGURE 3-5 Hydrocarbon recovery by direct refrigeration.

will drop 5-15°F. However, if the expansion is done through a turboexpander (i.e., isentropically), the temperature will drop 50-70°F. Thus, outlet temperatures below −200°F are achievable.

Advantages Since very low temperatures are possible, direct refrigeration can sometimes remove more than 99 percent of a stream's hydrocarbon.

Disadvantages Below 60°F hydrates may form and plug heat exchange surfaces and lines. One way to avoid this is to inject ethylene glycol or other antifreeze, but this gets very expensive at low operating temperatures. Another solution is to operate the unit intermittently to allow periodic thawing. This approach, however, requires overdesign and may impose limited loading rates on tankships and barges.

Inerted vapors contain about 15 percent CO_2 by volume. Therefore, as a practical limitation, refrigeration systems that handle inerted vapors should not be operated below −150°F (the freezing point of CO_2).

Refrigeration systems also tend to corrode if they contain species such as H_2S. To minimize corrosion, crude vapors should be pretreated with caustic before they enter the refrigeration unit.

Carbon Bed Adsorption

Carbon bed adsorbers use activated carbon or a similar adsorptive medium to adsorb hydrocarbon selectively. Air and very light hydrocarbons pass through the medium, while heavier hydrocarbons are adsorbed to the medium's surface (Figure 3-6).

After the capacity of the medium is used up, that is, after most of the adsorptive sites are already holding hydrocarbon, hydrocarbon will “break through” and appear in increasing amounts in the exiting vapor. At this time, the medium needs to be recharged, or the existing vapor will eventually contain as much hydrocarbon as the untreated vapor, and the pressure drop may become unacceptable.

Although disposal of spent carbon is an option, most shipping applications are large enough for regeneration to be cost-effective. The best approach is to use a vacuum pump to desorb hydrocarbon (Figure 3-6). The alternative, steam stripping, generates an oily wastewater stream that needs to be disposed of. In addition, a source of steam is needed.

Carbon beds are sometimes used as polishing units downstream of absorption or refrigeration units. They do this very effectively as long as the hydrocarbons are not too light (e.g., ethane or propane). Such light species tend not to adsorb, and even if they do, the adsorption is not very strong; slight temperature increases may drive them off. Alternatively, when heavier, more strongly attracted species pass through the bed, they will simply displace the lighter species from the active sites.

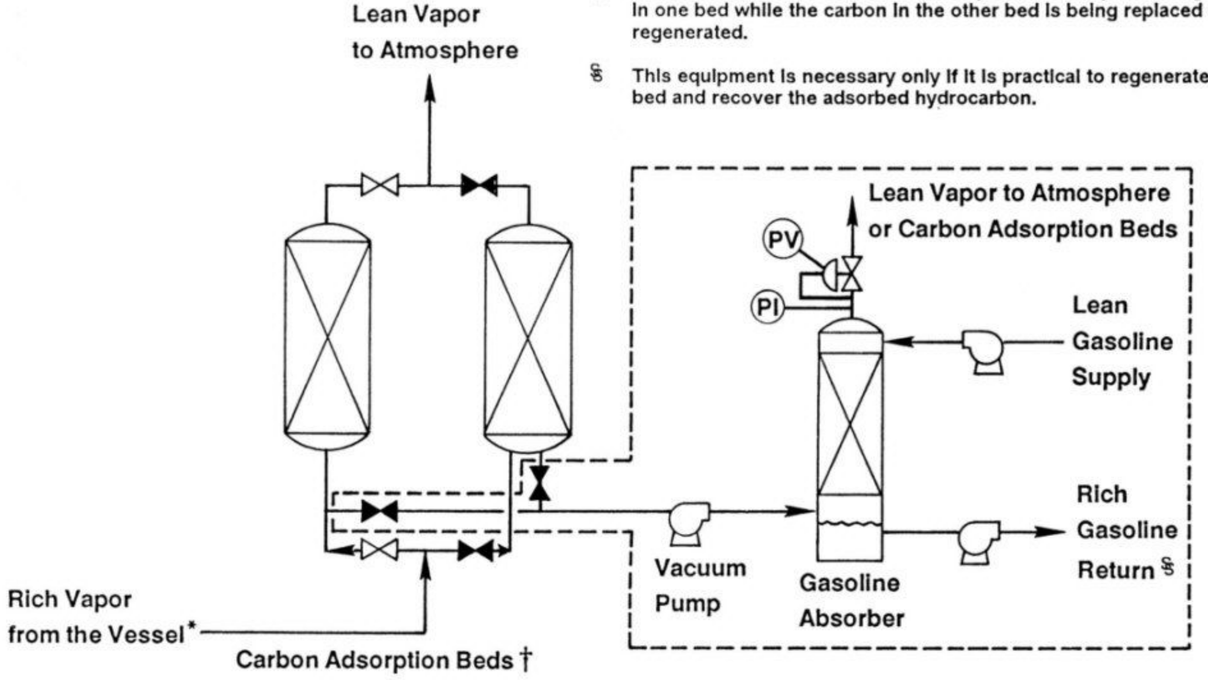


FIGURE 3-6 Hydrocarbon recovery by carbon bed adsorption.

* Alternatively, the relatively rich vapors may come from an upstream absorber or refrigeration unit if the carbon adsorption beds are used for polishing.

† Two beds are needed if it is necessary to continue processing vapors in one bed while the carbon in the other bed is being replaced or regenerated.

§ This equipment is necessary only if it is practical to regenerate the carbon bed and recover the adsorbed hydrocarbon.

Carbon beds may also be used upstream of absorption units. In such systems, hydrocarbon-rich vapors are first passed through the carbon bed. Then, when regeneration becomes necessary, a vacuum pump sucks the hydrocarbons from the bed and sends them to a high-pressure absorber for recovery (Figure 3-6).

Carbon beds operate effectively whether or not the vapors have been inerted.

Advantages Carbon bed adsorbers can be more than 99 percent effective at removing hydrocarbon.

Disadvantages Carbon beds do a poor job of recovering light ends, such as ethane and propane.

H_2S and other contaminants permanently poison activated carbon. Therefore, in crude and other dirty services regeneration becomes impossible and carbon replacement costs become prohibitive. The poisoning problem can be avoided by upstream treatment with caustic, but this adds to cost. H_2S contamination is not a concern for vessels that transport gasoline.

Vacuum desorption requires an absorber to recover the desorbed vapors. This makes them more complex than absorption by itself because the two processes are interwoven. (The only reason for combining the two is to achieve very high efficiencies without the use of a flare or incinerator.)

Carbon beds would need to be very large to handle the high flow rates and hydrocarbon loadings generated by most shipping applications. To be practical, each bed would need to be large enough to handle at least one full-loading cycle before regenerating.

Alternative and Emerging Technologies

Several alternative technologies have been suggested as ways to help reduce vapor emissions. Catalytic combustion, it has been proposed, could substitute for flares and incinerators now used to burn vapors. Evaporation-retardant chemicals could be used to blanket cargoes, reducing evaporation and thus lowering the amount of hydrocarbon in vapor. Biofiltration and semipermeable membranes also may offer promise in decomposing or recovering vapors in the future.

Catalytic Combustion

Catalytic combustors are an alternative to thermal combustors. Their main applications include combustion of vapors from solvent and paint dryers. Such vapors are dilute, relatively stable in flow rate and composition, and contain few, if any, contaminants.

Catalytic combustion does not, however, appear to be a practical process for controlling hydrocarbon emissions from crude and gasoline loading; the vapors are far too rich and contain too many contaminants. Recovery or thermal combustion (using a flare or an incinerator) is much more practical. This is true even if the displaced vapors pass through a vapor recovery unit first. Vapors displaced from vessels will contain 0-30 percent or more hydrocarbon. After recovery they will contain 0-3 percent hydrocarbon. In either case, the hydrocarbon concentration will often be several times the 0.1-0.5 percent level that is optimal for catalytic combustion. In addition, crude and heavy product vapors invariably contain H_2S and many other contaminants. These species will quickly reduce the catalyst's activity, often irreversibly.

Catalytic combustors rely on an active catalytic surface (usually noble metals on a silica or alumina base) to lower the activation energy and time needed for combustion. For this reason, they can combust low-hydrocarbon-content vapors with more than 95 percent efficiency at low temperatures, typically only 600-900°F. Ideally, the feed vapors contain between 0.05 and 0.75 percent hydrocarbon, corresponding to hydrocarbon concentrations between 5 and 75 percent of the lower explosive limit (typically around 1 percent hydrocarbon in air).

Thermal combustors rely on a homogeneous gas-phase reaction. They need to operate in the 1,200-1,800°F range to achieve more than 95 percent efficiency since they do not have the benefit of a catalyst. As long as vapors contain enough hydrocarbon they will sustain combustion on their own without catalyst, but at lower concentrations, supplemental fuel may be needed to keep the reaction going. This is very expensive for large, dilute streams, and makes catalytic combustion attractive for such streams.

If the hydrocarbon content rises over 1 percent, the catalytic combustor's temperature will rise above 1,000° F. This accelerates sintering (also referred to as thermal aging); the finely dispersed noble metals become liquid, migrate within the catalyst pores, and meld together into much larger droplets. This melding reduces the active catalytic surface area, in extreme cases by orders of magnitude.

Catalytic combustors are very sensitive to contaminants. Particulates and char foul the catalyst surface and plug the bed. Heavy hydrocarbons, silicone compounds, and some oxides mask the catalyst by forming a filmy deposit on the surface. Still other contaminants, expecially H_2S, chlorides, and most metals, inhibit combustion by poisoning the catalytic sites.

Gross fouling can be reversed by physical cleaning. Masking can be reversed by washing with an aqueous solvent or, sometimes, by controlled overheating. These regenerative processes degrade the catalyst slightly each time, but usually restore it adequately the first few times.

Poisoning is a greater problem. With some poisons it may not be possible to regenerate the catalyst. Many manufacturers recommend keeping the concentration of poisons in the feed stream below about 0.25 parts per million (ppm).

Vapor-Suppressing Foams

Vapor-suppressing foams may be an attractive alternative to onshore vapor control (Canevari and Cooper, 1974). Companies that market these foams believe they could be used to seal in the light hydrocarbons that normally vaporize during both loading and unloading.

The foams are aqueous-based and biodegradable. After about 24 hours they collapse, form a waterlike solution, and sink to the bottom. For the foams to achieve a high degree of vapor control, vessel operators would need to generate them on board, then spread and maintain a 2- to 6-in. layer on the liquid hydrocarbon's surface throughout the off-loading and loading cycle.

Refiners have used vapor-suppressing foams for many years. They retard fires and inhibit evaporation of most hydrocarbons on which they are sprayed. To date, however, they have been demonstrated only in firefighting and spill-control applications. As a result, the following issues need to be resolved before the use of foams can be considered a viable control measure:

- What hydrocarbon control efficiency can the foam offer? The foam layer would need to be maintained at all times. This could rule out crude oil washing (COW) and similar tank cleaning, since these operations would tend to collapse the foam and saturate the vapor space. Some foam manufacturers have discussed the feasibility of using foams during loading to control emissions and to maintain tanks in gas-free condition. However, much of the vapor emitted is generated by volatilization during offloading, and further saturation during compartment washing. Unless the foam is also maintained during off-loading and compartment washing is discontinued, overall efficiency would be low.
- How can one make sure the foam is spread deeply enough in every part of each compartment? If any cargo is exposed to the vapor space, the efficiency of the overall system will drop.
- Would spray nozzle systems be needed on each ship? COW nozzles could be used, but they might need to be resized and aimed properly.
- Will the flow of fluid through the foam sprayer cause static electricity generation and buildup, and thus increase the risk of an explosion? Sprayers should probably be used only on inerted vessels.
- Is the foam corrosive? It will be necessary to check compatibility of the foam with PV relief valves, control valves, deck undercoatings, and so on.
- Will the foam affect product specifications, form emulsions downstream, or cause operating problems in downstream processing equipment? Such hidden costs would need to be quantified. (The emulsion problem may be avoided by using protein-based foams instead of surfactant-based foams.)
- Will the collapsed foam cause cargo measurement problems?

Molecular Layer Vapor Barrier

A patent granted to the Exxon Corporation (Canevari, 1980) describes a method of lowering vapor losses by spraying a thin (350 monolayer) film of evaporation-inhibiting material on the cargo. The patent states that a field test was conducted during the unloading of light Arabian crude from a commercial tankship, and that 2 hours after discharge the tank so treated contained 44 percent less vapor than a similar untreated tank.

If this material were sprayed on a crude or gasoline cargo shortly after the start of loading in a gas-free tank, and the surface of the cargo were quiet, it might reduce the normal evaporative loss substantially. The patent says that only about 3.5 gallons of the material would be needed to treat the cargo in a 90,000-dwt tankship.

The use of this material shows promise, but further shipboard testing will be necessary before it can be considered safe and effective.

Biofiltration

Biofiltration requires cultivation of bacteria that can oxidize hydrocarbons from contaminated air. The bacteria needs to be grown on a moist medium (e.g., on the wet surface of a gravel bed). Then the contaminated air passes through the medium, the hydrocarbon will diffuse into the liquid film and oxidize to CO_2 and water. These products will then diffuse back into the gas stream.

Membrane Separation

Membrane separation relies on a semipermeable membrane to screen out hydrocarbon selectively. Oxygen, nitrogen, and other gaseous species normally present in air will pass through. Hydrocarbon, H_2S, and other undesirable species will be held back.

VAPOR BALANCING AS AN ADJUNCT TO VAPOR CONTROL

The technique known as vapor balancing can be used as an adjunct to vapor control to reduce instantaneous processing rates, or for other reasons. For example, at Exxon's offshore Hondo Field in California, loading emissions are pumped into a large tank vessel where they are retained for subsequent burning. The vessel acts as a buffer, permitting loading rates higher than could otherwise be accommodated by the vapor treatment facilities at the site. Vapors are drawn from the holding tanks at a constant rate, not dependent on instantaneous loading rates.

But vapor balancing should not be regarded as a standard procedure. The roofs of many modern storage tanks are designed to float on the surface of the liquid, leaving no space for vapors. There may be applications for vapor balancing at specific sites.

OPERATING PROCEDURES TO REDUCE EMISSIONS FROM TANKSHIPS

Hydrocarbon vapors are heavier than air, hence tend to lay in a concentrated layer just above the liquid surface. By short-filling compartments, vessels that load crude oil or gasoline can retain most of the hydrocarbon vapors onboard while in port, and then later release them to the atmosphere at sea. This approach will reduce in-port emissions from tankships substantially, but its economic application and environmental acceptability would be highly site-specific.

Ballasting Emissions

Ballasting emissions of volatile organic compounds (VOCs) already have been significantly reduced by regulations requiring most tankships of 20,000 dwt or more to use segregated ballast tanks (SBTs) or clean ballast tanks (CBTs) and to retain ballast vapors from cargo tanks aboard the tanker, where feasible. In the future all new crude tankships over 20,000 dwt (30,000 dwt for product carriers) in U.S. waters will eliminate all VOC ballasting emissions, because they will be equipped with SBTs.

Existing crude oil tankers, if fitted with COW facilities, may not have sufficient SBT or CBT. However, U.S. Coast Guard regulations now require that “each tank vessel having a COW system--without sufficient SBT or CBT--must have a means to discharge hydrocarbon vapors from each cargo tank that is ballasted to a cargo tank that is discharging crude oil.” This transfer of vapors is accomplished using IG vent lines. Using this arrangement, VOC emissions from ballasting are eliminated.

Loading Emissions

Hydrocarbon vapors are denser than air. Recent safety guidelines for the tankship and marine terminal industry (International Chamber of Shipping et al., 1984) state that

> As . . . cargo enters an empty gas free tank there is a rapid evolution of gas. Because of its high density the gas forms a layer at the bottom of the tank which rises with the oil surface as the tank is filled. Once it has been formed the depth of the layer increases only slowly over the period of time normally required to fill a tank, although ultimately an equilibrium gas mixture is established throughout the ullage space.
>
> Above this layer the atmosphere originally present in the tank persists almost unchanged and it is this gas which in the early stages of loading enters the venting system. In an initially gas free tank, therefore, the gas vented at first is mainly air (or inert gas) with a hydrocarbon concentration below the Lower

> Explosive Limit (1 percent HC). As loading proceeds, the hydrocarbon content of the vented gas rises. . . . [T]he gas layer depth will be taken as the distance from the liquid surface to the level above it where the gas concentration is 50 percent by volume. . . . [G]as will be detectable at heights above the liquid surface several times the layer depth defined in this way.
>
> Most high vapor pressure cargoes give rise to a gas layer with a depth in these terms of less than 1 meter.

The 83 tons of emissions that result, on average, from loading a 100 percent crude-oil-washed VLCC have been analyzed as shown in Table 3-1 (Uhlin, 1984).

Atmospheric emissions while loading cargo are minimized by filling each compartment as rapidly as possible, to reduce the amount of evaporation into the ullage space (an exception to this is at the start of loading when rapid rates may cause splashing, which increases evaporation).

Loading into Gas-Free Cargo Tanks

Table 3-1 shows that gas-freeing of cargo tanks on the ballast passage combined with loading into the gas-freed tanks would reduce VOC vapor emissions by about one-third.

TABLE 3-1 Atmospheric Emissions Loading 250,000-dwt Crude Carrier (all tanks COW)

Vapor Emissions	Tons
Vapor in empty tanks before loading	35
Evaporative loss during loading and gauging	58
Subtotal	93
In ullage space after loading and gauging[a]	7
Atmospheric emissions during loading and gauging	86
Initial gauging	3
Emissions during loading and final gauging	83

[a] The ullage space after loading eventually reached equilibrium and registered 50 percent hydrocarbon equal to 15 tons on arrival at the discharge port.

Gas-freeing all the cargo tanks on the ballast passage would increase bunker fuel costs. In addition, it might delay crude oil washed tankships at the discharge port.

Loading to 70 Percent of Capacity

Loading each gas-freed cargo tank only 70 percent would retain most of the vapors in the ullage space. To minimize sloshing at sea, the cargo could later be transferred to fill most of the tanks to capacity. This technique could reduce carrying capacity by 30 percent; thus its economic acceptability would need to be evaluated.

HYDROCARBON VAPOR CONTROL SYSTEMS: ASSUMPTIONS FOR PURPOSES OF ASSESSMENT

Since vapor control systems are not widely used in maritime applications, the committee found it necessary to set some ground rules for analyzing cost estimates. The resulting hypothetical system is intended to meet all likely regulatory requirements and incorporate all safety features. It uses available technology and would be capable of reducing loading and ballasting emissions at terminals by more than 99 percent. The assumptions that underlie the system are:

- Vapors will be inert or overrich prior to being treated or transferred any significant distance.
- Incineration is the control process in all estimates. It has low capital cost and universal application.
- Detonation arrestors will be placed in vapor pipelines near the treatment system, at the dock manifold, and at the tank vessel's manifold. Flame arrestors are not considered to be an acceptable substitute.
- Redundant tank gauging and alarm systems will be used for closed loadings.
- Shoreside loading facilities will have provisions for automatic shutdown (using contact signals from the alarm systems).
- Loading at terminals will remain at current loading rates.
- Tank vessels loading at docks that serve only tankships and large inerted tank barges will have onboard systems for closed loading with redundant gauging and alarm capability and an inert gas system designed for less than 7 percent O_2.
- All tank vessels will be outfitted with vapor collection headers sufficient to accept vapors at full-loading rates.
- All cargo tanks that are inerted will be fitted with vapor locks for use with sonic gauging tapes. If not inerted (as with most tank barges), cargo tanks will be fitted with restricted standpipes extending to just above the tank bottoms.
- Docks at terminals serving only tankships and large inerted tank barges will be designed to accept inerted vapors coming from the vessels.

- Except as noted above, docks at terminals serving smaller, non-inerted tank vessels will provide a means for inerting vapors coming from the vessels as they enter the vapor transfer system.*
- For smaller tank vessels without onboard inerting equipment, the vapor stream may be inerted during loading.

Vapor Collection Headers

For most tankships fitted with IG systems, the installed inert gas headers can, with a few modifications, be used as vapor collection headers. Noninerted tankships and tank barges will require the installation of one or more deck headers to collect vapors from the tanks and carry them to the vapor hose connections located in way of the cargoloading manifold. Figure 3-7 shows a typical vapor connection header for a tank barge.

The vapor collection header will be of steel construction. Internal coating must be compatible with the products to be carried.

Tank PV valves should be set for the highest pressure consistent with tank design. If tanks are fitted with individual PV valves, one additional PV valve should be installed on the vapor collection header. This valve and its header should be sized for the maximum loading rate to all tanks served by the header. A rupture disk or spill valve should be installed in the vapor header to limit tank pressure to the hydrostatic test pressure of the tanks in case of overfill. Such a device should relieve liquid to a cargo tank or another enclosure. The vapor collection header should be designed to allow for 1.0 psi (0.5 psi for barges) back pressure at the vapor hose flange during maximum-rate loading with tank pressures below the PV valve setpoint. If multiproduct loading of cargoes susceptible to cross-contamination is expected, tanks should have individual PV valves. Line blinds or valves should be provided at the vapor connections to the tanks.

A detonation arrestor should be located as near as possible to each vapor hose connection and installed to be easily removed for cleaning and maintenance. A shipboard pressure control system should be considered to allow the ship to control the cargo tank pressure independent of the shore facility.

A drip pan, wide enough to accept a reducer, should be located under each vapor hose connection to catch any condensate during hose removal.

The vapor hose connection may be of either bolted or cam lock type and should accept both standard 125 pound or 150 pound flanges from the hose.

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*An alternative method of rendering the vapors nonexplosive would be to enrich them. Enriching would minimize the quantity of vapors to be processed.

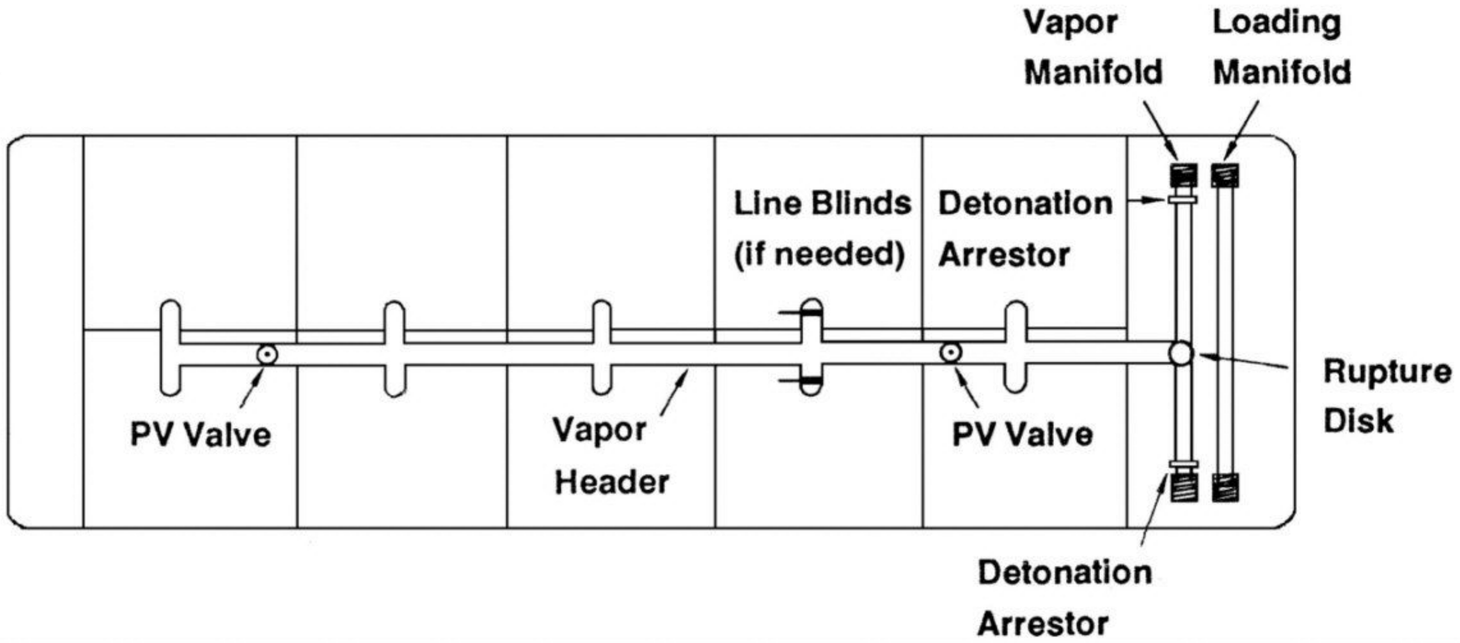

FIGURE 3-7 Typical barge vapor-collection header. The vapor header is sized to allow no more than 0.25 psi pressure drop at maximum loading rate. PV valves are redundant, sized for full-load rate and set just below barge design pressure. The rupture disk is sized for maximum flow rate and designed to rupture at barge hydro test pressure.

Tank Gauging and Alarms for Inerted Tank Vessels

Inerted tank vessels are assumed to have two independent tank gauging and alarm systems, one to measure the full tank depth, the other to measure the top 6-10 ft below deck. A single gauging system may be used if it is inherently redundant by design. In this case, however, a separate and redundant alarm system should be installed.

The gauging and alarm systems are assumed to have an accuracy of better than 0.5 in., and two alarm setpoints, each redundant. The system includes a high-level warning at about 12 in. below the top of the tank and a high-level alarm at 4-6 in. below the top of the tank. If loading is conducted from a cargo control room, level indication and alarms are displayed in the room with audible and visual alarm indications on deck. If cargo operations are carried out on deck, level indicators are located at the tanks, with audible and visual warning and alarm indications placed where they will be heard and seen from anywhere on deck. The alarm system provides a means for supplying pump shutdown contacts at the tankship's rail for use by the terminal's emergency shutdown system (where available).

Special Considerations for Tank Vessel Inert Gas Systems

Either flue gas or independent IG systems are acceptable if the vapor mixture leaving the tank vessel has an oxygen content of less than 8 percent at all times. The system should therefore be designed to produce inert gas with as low an oxygen content as possible, but no greater than 7 percent. The tank vessel's IG system must have sufficient instrumentation and a recorder to allow the terminal to verify the proper inerting of the tanks during the prior discharge.

Dockside Tank Level and Alarm System for Tank Barge Loading

Each cargo tank is assumed to be fitted with a reliable high-level alarm and shutdown sensor. Each has a fail-safe method for checking the instrument and circuit prior to each loading. Each instrument provides two separate, normally closed contacts to initiate the high-level warning and high-level shutdown independently.

Each instrument has two setpoints: a high-level warning at 12 in. below the top of tank and a high-level alarm at 4-6 in. below the top of tank. Warning and alarm/shutdown signals are both audible and visual and easily detected from both the loading manifolds and the barge dock.

Instruments are connected through intrinsically safe cable to weathertight nine-pin connectors near the loading manifolds. Each connection serves the instruments of four tanks. All instruments and cables outside the dockside enclosure are intrinsically safe. The dockside enclosure may be either explosion-proof or intrinsically safe. The main connecting cables from the dock to the tank barge allow connections for the maximum number of tanks expected in barges that utilize the dock.

Two lights for each tank are located on the dockside enclosure. Large (4-6 in.) lenses with dimmer controls, arranged to represent the layout of the tank barge deck and visible from the barge manifold, are preferred.

The system sounds alarms of distinctly different pitch for the high-level warning and high-level alarm/ shutdown. Contacts will be provided in the dockside enclosure to activate the dock's emergency shutdown on a high-level alarm. The system has the capability to perform continuity and function checks prior to the start of each loading.

To facilitate accurate loading, the barge operator may also wish to provide an unpowered or intrinsically safe solar- or battery-powered gauging system that does not require an external electric source. If no gauging system is provided, a second set of high-level warning/alarm devices must be provided with their contacts wired in series with the other warning/alarm devices such that the signals will be activated if either contact opens.

Figure 3-8 is a schematic illustration of a dockside gauging and alarm system for tank barge loading. Figure 3-9 shows the dockside enclosure panel for the system.

Vapor-Handling System for Terminals

At terminals loading large, inerted tank vessels, the incinerator or other vapor control process and the vapor transfer piping system are sized to receive the maximum loading rate expected for gasoline and crude oil, with a suitable safety margin. At tank barge terminals, the systems are sized for the maximum loading rate plus sufficient additional inerting gas to lower the oxygen content of the vapor stream to less than 8 percent. This may take four or more volumes of inert gas for each volume of barge-emitted vapor, depending on the oxygen content of the inerting gas. As tankship loading rates are frequently five or more times the tank barge loading rates, terminals serving both may find that the required size of the system will be nearly the same, owing to the large volume of inert gas added to the barge vapor stream.

Figure 3-10 is a schematic drawing of a simple vapor control system for a tank barge and tankship terminal. Figure 3-11 shows an incinerator system for a barge dock.

Since the oxygen content of the incinerator exhaust gas can be controlled to less than 5 percent with some incinerator designs, operators may consider using this gas as inert gas for tank barge loadings. Other sources of inert gas include fuel-fired inert gas generators, nitrogen, natural gas, and refinery flue gas.

To prevent oxygen being drawn into the system, all piping carrying inerted vapors should be under a positive pressure, but not present more than 0.5 psi back pressure at a tank barge flange or 1.0 psi at a tankship flange. Underwater pipelines may be at negative pressure only if any extension above water is of all-welded construction.

The inlet for inerting gas at barge docks should be as close as practical to the terminal flange. An oxygen analyzer (explosimeter for enriched systems) should be located as close as possible to the terminal

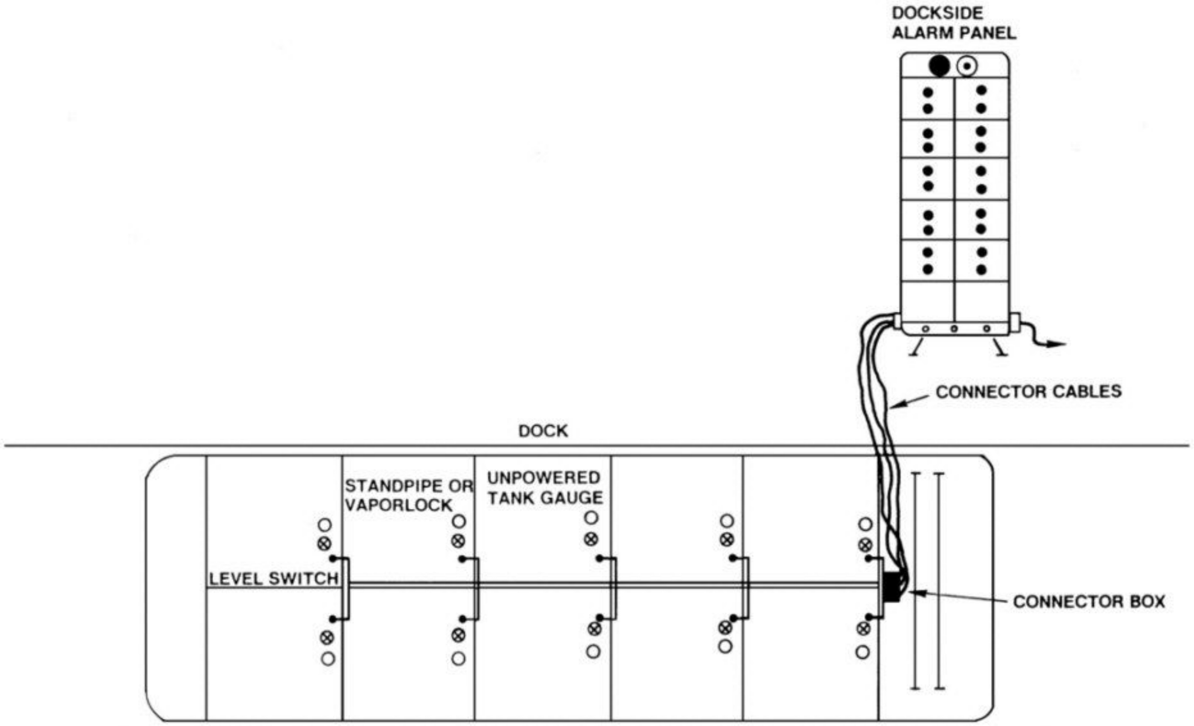

FIGURE 3-8 Dockside warning and alarm system. The following applies: (1) All electrical equipment outside of dockside panel must be intrinsically safe. (2) Dockside panel and connector cables are supplied by terminal. (3) One panel is required for each barge loading position. (4) Each nine-conductor cable serves four tanks. (5) Each tank has high-level warning and high-level shutdown. (6) Warning and shutdown switches are nor-mally closed and open to activate warning or shutdown. (7) Switches on barge must have a means to perform a continuity and functional test following hookup. (8) Redundant level and alarm switches with contacts wired in series with the primary set may be installed in lieu of the unpowered gauges.

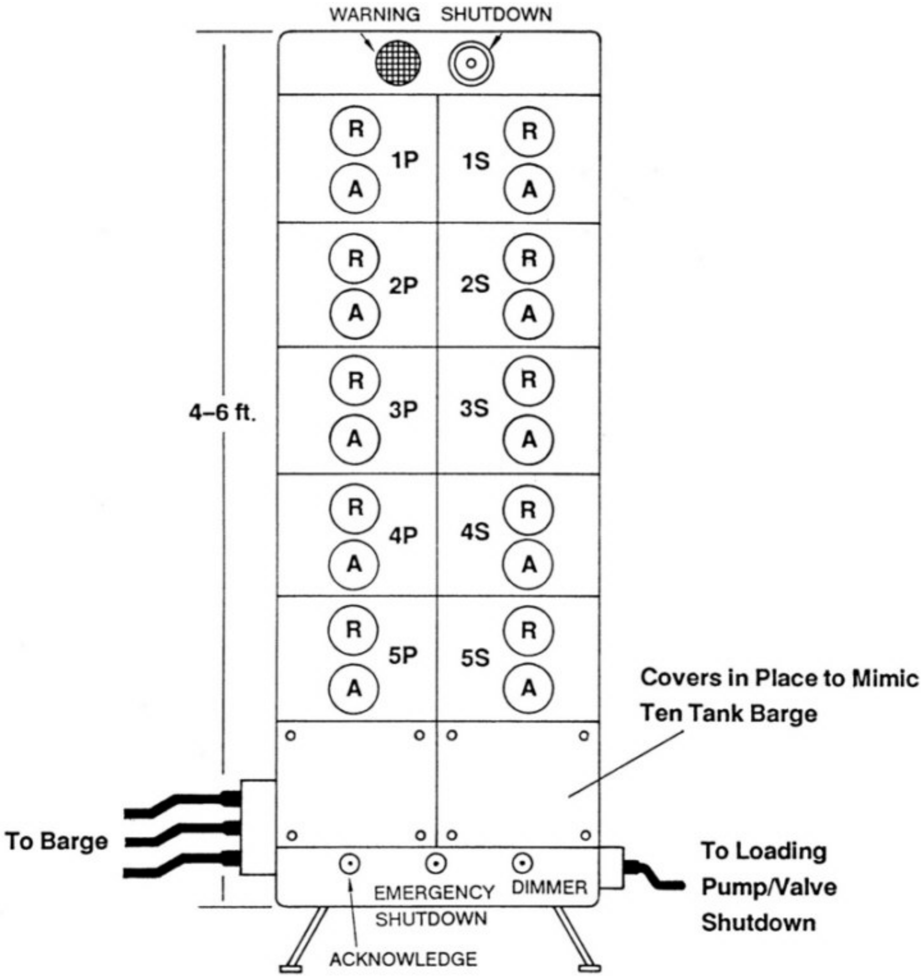

FIGURE 3-9 Dockside warning and alarm panel. The following applies: (1) Warning lights are amber and alarm lights are red. (2) The enclosure is explosion-proof. (3) Wiring to the barge is intrinsically safe. (4) Warning/alarm circuits are open to actuate. (5) High-level alarm actuates siren and shutdown. (6) High-level warning actuates 3-second horn. (7) Warning lights flash for 3 seconds then are on steady. (8) Alarm lights and siren must be acknowledged. (9) Each nine-conductor cable serves four tanks.

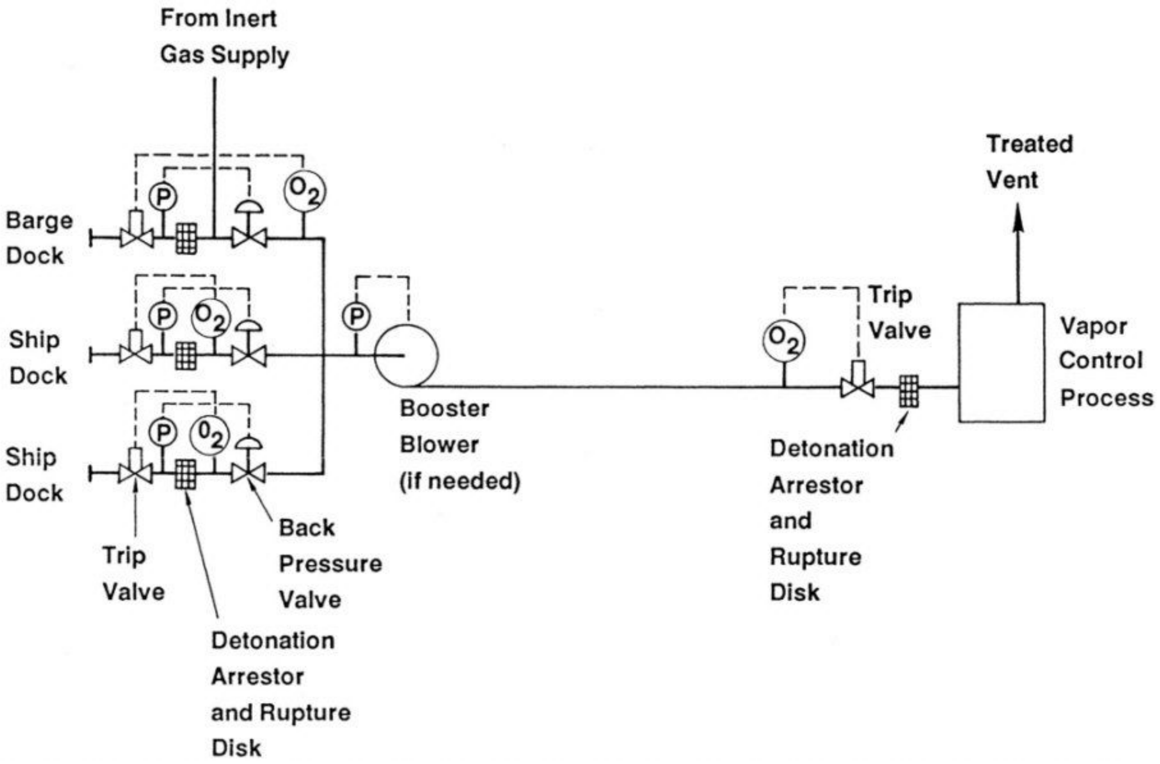

FIGURE 3-10 Simple shoreside vapor control system for a ship and barge terminal. The following applies: (1) Dock manifold trip valve should trip if an oxygen level of 8 percent or more is measured. (2) Back pressure at dock flange should be 0.25-0.5 psi. (3) Booster suction pressure should be ≥ 0.2 psi. (4) Valve immediately before vapor control process should trip if oxygen level is 8 percent or more. (5) All piping should be at positive pressure to prevent oxygen ingress. (6) Underwater piping to offshore terminals may be at negative pressure, however any portion that may be above water should be of all-welded construction.

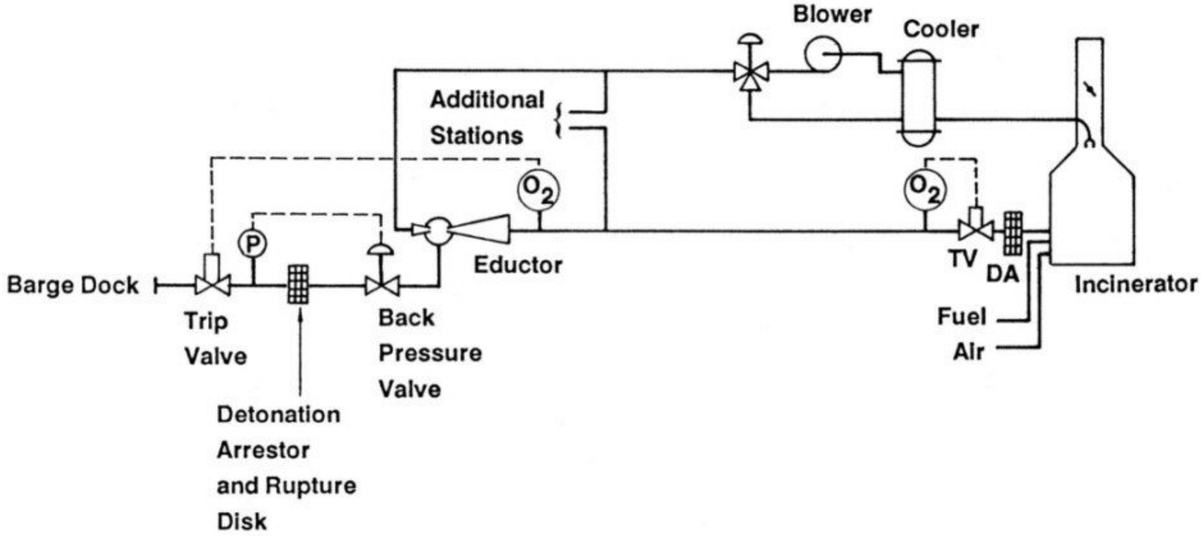

FIGURE 3-11 Incinerator system for a barge dock to obtain inert gas with an eductor. The following applies: (1) Only safety-related control loops shown. (2) Combustion and inert gas flow control requires a programmable controller. (3) Inert gas oxygen concentration ≤ 1.0 percent. (4) Vapor/inert gas mixture ≤ 7 percent. (5) Oxygen trips set at 8 percent. (6) Back pressure valve maintains 0.25-0.5 psi at dock flange. (7) Minimize piping between dock flange and eductor. (8) Piping between back pressure valve and eductor should be all welded and short. (9) Incinerator, eductor, and piping should be sized for maximum expected flow rate.

flange, but downstream of any inert gas inlet. A trip valve at the terminal flange should be designed to close if an oxygen concentration of 8 percent or more is detected. If a booster is required because of a pressure drop through vapor transfer piping, a recirculation loop with a cooler or other type of capacity control should be used to maintain a positive pressure at the booster suction.

Care must be taken in the design and operation of the vapor transfer system to eliminate any ignition sources. Temperatures in piping and other components of the vapor transfer system should be kept well below the vapor ignition temperature, whether vapors are inerted or not. At a minimum, detonation arrestors and rupture disks should be located at the terminal flange(s) and at the inlet to the vapor control process. A final oxygen analyzer (explosimeter) should be located near the vapor control process, but far enough upstream to ensure closure of the trip valve before the potentially explosive vapors reach that point.

4

SAFETY CONCERNS

The committee was asked to address the safety concerns that could arise during the marine application and operation of hydrocarbon vapor control and recovery systems. In this chapter, the potential hazards attributable to the installation and operation of these systems are identified and evaluated. Historical performance data, the European experience with vapor control and recovery systems, and potential accident scenarios are discussed. Various approaches to minimize the risk of accidents at such facilities are suggested.

ACCIDENT SCENARIOS

Three main types of undesirable events may occur during marine transfer of liquid hydrocarbons or during ballasting:

1. a fire resulting from the ignition of a liquid spill or an unconfined flammable vapor cloud;
2. an explosion resulting from the ignition of a flammable vapor/air mixture in a partially or totally confined area; and
3. water pollution as a result of an accidental liquid release.

Fires and explosions require the presence of ignition sources having an adequate level of energy. These sources include static discharge, lightning, the use of improper electrical equipment, smoking, open flames, and unguarded combustion systems. Human error is the major contributing factor to the presence of practically all ignition sources, except for lightning. Static buildup can, for example, be minimized by loading tanks at velocities consistent with accepted industry guidelines (International Chamber of Shipping et al., 1986) and by minimizing splashing.

Failure to adhere to standard operating procedures, such as allowing an adequate time period for static charge dissipation before dipping, sampling, and ullaging, has been cited as a major contributing factor to static charge ignition. Similarly, failure to adhere to nonsmoking requirements, failure to use explosion-proof motors and other electrical components, and the absence of flame and detonation arrestors, or the presence of inadequately maintained units, can all be traced to operator error and failure to follow standard operating procedures.

Water pollution during transfer operations occurs when a tank or transfer pipe ruptures or leaks or when the tank is overfilled. Tank rupture may occur as a result of overpressurization, an internal explosion, or an implosion due to fast liquid withdrawal. The transfer hose/piping may rupture because of mechanical damage or sudden vessel movement, such as during inclement weather. Corrosion could also contribute to tank and pipe failures.

A small explosion in a vapor transfer pipe could rupture the pipe or result in the propagation of a detonation wave to both vessel and shore tanks; either of these losses of integrity could result in the release and ignition of the contents. The extent of the hazard is obviously a function of the preventive measures employed to minimize the frequency of such occurrences and the measures taken once the accident occurs to minimize its consequences.

These types of accidents may occur regardless of whether vapor control and recovery systems are in use. They may be related, in that the occurrence of any one may lead to another. An accidental spill may, for example, be ignited and result in a fire which may engulf pressurized containers and result in explosions.

For accidents during marine transfer of hydrocarbon fuels, the details of each accident scenario will depend on several factors, including:

- type of delivery or receiving vessel, such as inland barge, ocean barge, or self-propelled tankship;
- type and quantity of liquid cargo being transferred, for example, crude oil, gasoline, liquefied natural gas, or liquefied petroleum gas;
- presence, if any, and types of vapor control and recovery systems used, such as adsorption, absorption, incineration, vapor balance, refrigeration, and inerting, or any combination;
- location of the initial event, for example, above deck, below deck, in transfer lines, or in shore facilities;
- operations underway, such as ballasting or loading;
- presence or absence of adequate, well-maintained and tested automatic detection, alarm, and hazard control equipment; and
- presence or absence of properly trained operating and response personnel.

HISTORICAL ACCIDENT DATA

Historical accident data are a valuable tool for determining potential failure modes and future accident scenarios. Although the data base for vapor control and recovery system accidents is not large, it can be examined together with general marine accident causes to visualize potential accidents involving vapor control and recovery systems and to suggest preventive approaches.

General Marine Liquid Transfer Accident Data

Marine accident data on fires, explosions, and water pollution during the transfer of liquid hydrocarbon fuels were extracted from U.S. Coast Guard computerized files. The data were limited to accidents occurring in U.S. ports during loading, discharging, and ballasting of barges and tankers.

In the period from 1980 to September 1986, there were 18 fires/explosions involving barges. Three of the barges were total losses, while seven were rendered unseaworthy. The accidents resulted in six deaths and an equal number of injuries. Twelve of the fires/explosions occurred in the cargo tanks, five in the pump room and machinery space, and one was of unknown location. Ten accidents of known origin involved human error as the major contributing factor. Eight of the accidents were directly attributable to personnel disregarding proper safety precautions and regulations, improper securing or rigging, and carelessness. The remaining two incidents were caused by static electricity and a mechanical material failure.

Two of the barges (*Hollywood 1015* and *Hollywood 1016*) were involved in the same explosion and fire (U.S. Department of Transportation, 1986). Ignition was attributed to a flashback from an acrylonitrile vapor flare system. This explosion is discussed in more detail later in this chapter.

For the same period, there were 22 fire/explosion accidents in tankships, in which 6 deaths and 8 injuries occurred. Two of the vessels were total losses, while 11 were rendered unseaworthy. The locations of the fires/explosions were:

- Machinery space--9
- Cargo tanks--5
- Pump room--3
- Boiler--3
- Electrical equipment--1
- Unknown--1

The contributing factors were known in 19 cases. Six were directly attributed to personnel error, while 13 were due to vessel equipment failure (i.e., mechanical, electrical, fatigue), most of which could have been prevented through proper maintenance and inspection. None of these tanker accidents involved any type of vapor control and recovery system, since none were employed at the time. The data do illustrate, however, the high frequency of accidents due to human error.

Data from Lloyd's List (Table 4-1) provided information on 26 explosions that took place over a 12-year period on vessels equipped with inert gas systems (see Chapter 2). These accidents are not restricted to marine transfer operations. However, the table confirms that an inert gas (IG) system is not a panacea for tanker fires and explosions. It must be well maintained and operated to minimize the probability of fire or explosion. Operating under the false assumption that the mere presence of an IG system ensures that the tanks are inerted may lead to fires or explosions.

TABLE 4-1 Explosions in Tanks Equipped with Inert Gas Systems

Date	Vessel Name	Tonnage (MDWT)	Flag[a]	Year	System On?	Comments
0287	*Theonymphos*	98	GR	1968	Yes	Exploded while tank washing at sea in ballast
0686	*Southern Cross*	32	BS	1977		Exploded while loading; 3 missing
0586	*Alexandros F*	100	GR	1978		Exploded, loaded with iron ore; sunk
0386	*Paloma Del Mar*	117	SP	1973		Explosion in slop tank
0386	*Galini*	125	GR	1973		Exploded at sea in ballast
0585	*Petragen One*	29	PA	1982		Exploded discharging naphtha; 32 killed
0883	*Castillo De Bellver*	263	SP	1978		Exploded at sea, loaded; sunk
0483	*Hoegh Falcon*	81	NOR	1981		Tank explosion in ballast at anchor
0582	*Thorodland*	7	PA	1974		Explosion while tank cleaning at Haifa
0382	*Golden Dolphin*	92	USA	1974	No	Explosion while tank cleaning at sea; sunk
0281	*Harmony Venture*	228	LIB	1973	No	Exploded while tank cleaning at sea
0480	*Amoco Cremona*	74	LIB	1968	Yes	Collision in ballast; holed and afire
0480	*Mycene*	235	LIB	1976	No	Explosion while tank cleaning; sunk
0380	*Yemanja*	158	LIB	1973	No	Explosion while tank cleaning
0380	*Maria Alejandra*	232	SP	1977		May have been inerting; sunk in 40 seconds
1279	*Energy Determin.*	316	LIB	1976	No	In ballast, slop tank exploded; sunk
1279	*Primarosa*	250	IT	1973	No	Cargo vapor back flow to inert gas system blowers; exploded
1179	*Independent a*	150	RM	1978		Hit at anchor, loaded; explosion and fire
1079	*Berge Vanga*	224	LIB	1974		Apparently exploded and sunk; ore cargo
0879	*I. Angelicoussis*	66	GR	1964		Explosion while loading
0779	*Aegean Captain*	207	LIB	1968	Yes	Collision at sea
0579	*Atlas Titan*	209	LIB	1969	No	Tank cleaning with portable pumps in port
0479	*Seatiger*	122	LIB	1974	No	Vent riser hit by lightning; no cargo aboard
0877	*Manhattan Duke*	81	SG	1976		Hit dock berthing; exploded
1275	*Berge Istra*	224	LIB	1972		Explosion in slop tank/double bottom; sunk
1075	*Kriti Sun*	122	GR	1974		Hit by lightning

[a] GR = Greece; BS = Bahamas; SP = Spain; PA = Panama; NOR = Norway; USA = United States; LIB = Liberia; IT = Italy; RM = Romania; and SG = Singapore.

Source: Compiled from data published in Lloyd's List, revised August 8, 1986.

The latest edition of the *International Safety Guide for Oil Tankers and Terminals* (International Chamber of Shipping et al., 1986) acknowledges the possibility of explosions aboard tankers equipped with IG systems and warns of hazards due to static electricity and pyrophoric iron sulfides in case of a failure in the system during discharge.

Marine Liquid Transfer Accidents with Vapor Control and Recovery Systems

Very few vapor control and recovery systems are in operation today. Their use is limited mainly to vessels transporting highly toxic, flammable, and malodorous materials. Thus, the number of accidents involving these systems has been relatively small, and the data are not statistically significant to allow the prediction of accident frequencies. However, available historical data allow one to anticipate the kinds of accidents that might involve vapor control and recovery systems should they become more widely used.

As far as could be determined, only one accident occurred in the United States involving a vapor control and recovery system during the period from 1980 to September 1986. This accident occurred at 21:30 on November 1, 1983, when the tank barges *Hollywood 1015* and *Hollywood 1016* exploded, burned, and sank while transferring acrylonitrile at the barge dock of the Sohio Chemical Company, Vistron Green Lake, Texas (U.S. Department of Transportation, 1986). All the cargo tank lids were blown off both barges. Two operators received minor injuries, and a tug in attendance was slightly damaged. The barges were receiving acrylonitrile from the storage area through about 10,000 ft of 10-in. pipe. The vapors created during the loading operation were transported through the tank barges' vapor recovery system piping and burned in a flare at the dock.

A combination of events led to a flame flashing back from the flare to the barges. The Coast Guard investigation showed that the flashback occurred when the vapor flow rate in the recovery system fell below that of the flashback velocity of acrylonitrile. The flame propagated through the flame arrestor, which was useless because it had three holes ranging in size between 0.5 in. and 1.5 in. Plates were deformed, nearly doubling the 1-mm minimum required distance between plates. The damage had apparently been caused by thermal expansion before the accident. In addition, a water seal pot located ashore was not filled to the appropriate level (attributed to operator error and dirtiness of the sight glass). The seal-pot level alarms were also disconnected (due to operator error).

Anecdotal information on European casualties involving vapor control systems used in loading self-propelled river barges* was given to the

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*On European waterways, cargo is carried on “barges” that often contain living quarters and propulsion machinery. There is no American equivalent of these vessels, which in this country would be classed as small tankships.

committee (personal communication, Robert Conn, Shell Oil Co., Houston, Texas, fall, 1986). This information is incomplete and in some cases vague as to the precise circumstances of the accidents, but it does point to some potential problem areas. Fires and explosions can result from over- and underpressurization of cargo tanks during closed loading or discharge, owing to defective or improperly used tank level gauging and alarms or to excessive cargo transfer rates. Static discharges from a variety of causes can bring about ignition of vapors, especially if vessels and transfer equipment are not properly grounded or if cargoloading rates are excessive (NTSB, 1987). Detonation arrestors installed in vapor lines to stop detonation waves can fail to prevent fires, especially if the lines have bends in them. (In at least one case, a detonation wave burst every right-angle bend in a vapor line, passing through several detonation arrestors.)

Vapor Control and Recovery Systems in the Petrochemical Industry

Vapor control and recovery systems are employed in the petrochemical industry at numerous locations. They do not appear to present any particular or additional hazards to the industry. However, these systems are operated continuously and are maintained and checked regularly as part of the overall process. In general, vapor control and recovery systems at petrochemical facilities are operated from central control rooms that are continuously manned, and where malfunctions are quickly noted and corrected. Generally, each system is dedicated to one vapor stream of relatively well-known composition and physical condition.

It would be unreasonable to expect vapor control and recovery systems operated by smaller, less sophisticated operations to receive the same care and attention they would in larger units of the industry. Differences in operating conditions include:

- lack of personnel trained in vapor control and recovery system maintenance, operation, and repair;
- sporadic nature of marine transfer operations, so that systems may sit idle for long periods of time;
- variety of products that may be transferred, which require greater system flexibility; and
- assortment of connecting hoses and pipe diameters that must be dealt with.

POTENTIAL HAZARDS OF VAPOR CONTROL AND RECOVERY SYSTEMS

General Hazards

Before examining the potential hazards associated with the operation of specific systems, it would be appropriate to identify common features that may contribute to an increase in risk due to the installation and use of the systems.

Vapor control and recovery systems are inherently more complex processes than the simple pumping and vapor venting operations employed today. Complex add-on systems do not necessarily and automatically increase the hazards of an existing operation. Vapor control and recovery systems *can* be designed to operate as safely as existing systems by using appropriate detection, alarm, and control devices and redundant safety components, but at an increased cost. Such highly sophisticated chemical processing systems will require that they be operated by well-trained personnel and maintained and inspected regularly. Presently, tankermen and shore crews have minimal technical training and educational background. Barge tankermen, for example, may be transient and may not have substantial technical education. Most have U.S. Coast Guard tankerman certificates, for which they are not retested on a regular basis. In addition, any licensed master, mate, pilot, or engineer is automatically certificated as a tankerman, with no requirement for experience in loading and unloading barges.

It is a recognized fact that human error is the major cause of industrial accidents. Unless well-trained, technically educated, dedicated personnel are assigned to the operation and maintenance of such systems, errors in judgment and improper procedures will be the major causes of accidents.

Vapor control and recovery systems require the use of closed vapor collection systems with relatively long transfer lines. To allow for the high rate of loading and discharging of the liquid product, vapor lines are designed to have the largest practicable diameter. The accidental introduction of air into such a pipeline system is an invitation to a major disaster. Ignition in a long duct results in an accelerating wavefront and possibly a detonation. The effectiveness of commercially available detonation arrestors in stopping the fast, propagating flames of all potential fuel vapors is questionable. Bends in the vapor line tend to shorten the time to and increase the likelihood of detonation (but do not increase the maximum pressure). Since the shore facility and vessel are connected via the vapor line, an explosion at either location or within the vapor line may propagate to and damage all interconnected storage tanks.

Since vapor control and recovery systems are closed operations, special precautions must be taken to prevent overfilling and spillage during loading. Overloading may result in liquid entering the vapor lines and rupturing them. High-level alarms and automatic shutoff valves are not totally reliable. Electronic and mechanical level indicators have problems with solidifying and polymerizing products and corrosive cargoes. Redundant gauging systems, operating on different principles, may be required to ensure reliable operation.

Because of the care that must be taken during loading and discharging of cargoes at terminals equipped with vapor control and recovery systems and because of the limitations on pumping rates imposed by the size of the vapor return lines, the duration of a typical transfer operation will be increased.* Not only will this increase the period

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*Where small diameter vapor return lines limit pumping rates, a significant risk of tank overpressure exists.

during which the facilities are at risk, but operators will tend to take shortcuts to speed the process and reduce costs without realizing the potential hazard.

The nonuniformity of vessels and their connections and the wide variety of cargoes that may be handled by one vessel in separate transfer lines present a potential problem of incompatibility between vessels and shore facilities. Jury-rigged connections for the purpose of expediting the transfer process will increase the risk of accidents.

Another operational concern is the need for adequate documentation of barges. Barges are often “tramped” along their routes, passing from hand to hand as they move toward their destinations. They are required to carry documentation so that tankermen and towing personnel know about the materials and cargo systems they are handling. These requirements must be conscientiously carried out. The hazards of poor documentation would be magnified by closed loading and vapor handling.

Specific Hazards of Vapor Control and Recovery Systems

Vapor Balancing

Loading and venting rates must be carefully balanced to avoid rupturing or imploding cargo tanks. Present barge designs allow permanent deformation of the tanks at pressures as low as 3 psig and rupture at 4-7 psig. The tanks could distort or implode at a vacuum of only 1 psig.

Pressure/vacuum (PV) valves have been known to stick shut or open owing to the accumulation of dirt, corrosion, and solidified or polymerized products. Thus, PV valves cannot be relied on completely for over- or under-pressure protection.

The blowing or pigging of lines has also been cited as a major cause of tank failure in Europe. A vapor flow rate that exceeds the venting capacity of the line can lead to a sharp increase in pressure and line or tank rupture.

Carbon Adsorption

The major problem associated with carbon adsorption vapor control and recovery systems is the potential for spontaneous heating and ignition of the carbon bed, especially after shutdown (Naujokas, 1985). Vacuum stripping of the carbon bed is preferable to steam stripping, since it avoids subjecting the bed to high temperatures. At oxygen concentrations as low as 10 percent, the bed can gradually heat up to the ignition temperature. Fires in carbon beds are difficult to extinguish.

Combustion Systems

Incineration and flare systems are both susceptible to compressor failure and flame flashbacks, particularly during startup and shutdown. If a flare is accidentally extinguished (e.g., by wind), an explosion may occur on reignition. Several accidents have been reported during or after taking flare systems out of service for maintenance (Kilby, 1968).

Absorption

High-pressure absorption systems require the use of a compressor that would raise the pressure of the hydrocarbon-rich air to 100-200 psi. Gasket failure in the compressor may lead to a leak and subsequent ignition of the released vapor. A failure in the hydrocarbon supply line or a reduction in the vapor introduction rate may bring its concentration to within the flammable range, leading to a compressor explosion.

Refrigeration

Refrigeration systems operate at temperatures below −100°F. Several problems arise at low temperature. Changes in the properties of containment materials may render them brittle, for example. Freezing and accumulation of such components as water vapor, carbon dioxide, and hydrocarbon hydrates can also clog the system. Compressors used in conjunction with refrigeration systems also introduce additional possible ignition sources.

TECHNOLOGIES TO REDUCE THE RISK OF FIRE AND EXPLOSION

Hydrocarbon vapor control at marine terminals will require careful design and risk analysis of the design to identify weaknesses in the system. Vapors being returned from a tankship or tank barge may frequently be in the explosive range (about 1-10 percent hydrocarbon in oxygen, with variations depending on hydrocarbon type, moisture, and other factors).* Handling these vapors will add some degree of risk to cargo transfer operations. However, the terminal and marine transportation industries have much experience in dealing with these risks safely, and a range of technologies can be applied to prevent or limit the effects of fires and explosions.

Inerting or Enrichment of Vapors

The terminal operator must generally require that the vapors are either inert (owing to the addition of nonreactive gas) or overrich (with the addition of a reactive gas) to ensure that the vapors are either above or below the explosive range. For some terminals that

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*An independent survey found that more than 70 percent of barges engaged in the carriage of gasoline or diesel cargoes routinely contained vapors in the flammable range (NTSB, 1987).

serve only tankships, which are generally inerted, this decision may be irrelevant. For terminals that load tank barges and smaller, noninerted tankships, however, it will be very important.

If the vapor control system will have any flame or mechanical source of ignition such as a compressor or blower, inerting is very highly recommended. Likewise, inerting should be considered if the vapors are to be transferred any appreciable distance or at high velocity, since electrostatic charges can be generated by hydrocarbon vapors flowing in a pipe.

Vapors may be inerted or enriched as they enter the system by injecting inert gas or light hydrocarbon gas into the vapor line at the dock. This operation, of course, requires careful monitoring and control and significantly increases the load on process equipment associated with the vapor control system. However, these costs may be necessary to ensure safety if a convenient and safe location for the process equipment is not available on the dock, immediately adjacent to the vessel.

Inerted or enriched systems should include reliable and well-maintained oxygen or hydrocarbon concentration sensors with associated alarms, process shutdowns, and quick-closing valves to stop the flow of vapors to possible ignition sources if an explosive vapor mixture is detected.

Regardless of whether vapors are inerted, ignition sources should be avoided wherever possible in designing recovery systems. Designs should be scrutinized to eliminate unnecessary flames, mechanical friction, compression, exothermic chemical reactions, and sources of electrostatic discharge. Obviously, all potential ignition sources cannot be eliminated in systems where vapors must be transferred over long distances or where flaring or incineration is the control process chosen.

Passive Safety Devices

Since active safety systems are subject to mechanical failure and human error, passive safety devices should be included in the system design. One such passive device is the detonation arrestor, which is similar to many flame arrestors in that it provides a large heat-conducting surface to cool and quench flames.

Detonation arrestors differ significantly from flame arrestors, however, in their rugged construction, which permits them to remain effective when the flame front is accompanied by the extreme pressure front that results from a fully developed detonation traveling through the pipe. Common end-of-line flame arrestors are totally ineffective in handling such fast-moving flame fronts and should be used only at openings into the system, to prevent flames from entering. Flame arrestors for use at openings to the atmosphere should have U.S. Coast Guard approval.

In-line detonation arrestors, in the large sizes suitable for use in tank vessel vapor control, are relatively new and should be installed according to carefully worked out designs. Research and development in detonation arrestor design at the necessary large sizes and vapor capacities are desirable. Each installation will require testing, conducted in accordance with a procedure that tests the device against more severe conditions (such as longer pipeline run-up distances and more pipeline bends) than the specific application may call for. An example of such a test can be found in the International Maritime Organization document known as MSC Circular 373 (International Maritime Organization, 1984). Additional assurance may be gained by having this test performed in a mock-up of that part of the system protected by the detonation arrestor.

Flame arrestors should be located at every opening from the system to the atmosphere. Detonation arrestors should be installed in-line, upstream of the vapor control process, and at each possible ignition source. Additionally, a detonation arrestor should be located near the dock vapor connection and on the tank vessel at its vapor flange. Since very high pressures are associated with a detonation flame front, a rupture disk should be installed downstream near the detonation arrestor, oriented to allow the pressure front and flame to blow into a safe area should a detonation occur. In long or complex vapor piping, additional rupture disks should be located at all 90° bends.

Another technology that should be considered as a backup safety measure on shoreside installations is the explosion suppression system. This is a simple device that detects the sudden pressure rise that accompanies the ignition of the vapor and, within milliseconds, inhibits the flame front with a blast of the fire suppression chemicals halon 1301 or 1211. Pressurized halon cylinders and sensitive pressure detectors are connected to the piping at as many points as necessary to ensure complete flooding and early detection of an explosion. For the system to be effective, cylinders and sensors must be spaced closely enough to prevent the combustion from having the time to develop into a high-speed detonation. The unit costs of the cylinders and sensors are relatively low, and these devices should be considered for any location in the piping where an ignition is likely to occur.

MITIGATION MEASURES

To ensure the safe operation of vapor control and recovery systems, the following measures must be considered:

1. Minimum requirements should be developed for the scheduled maintenance and inspection of all vapor control and recovery system components and control and alarm devices, including IG systems, PV valves, flame and detonation arrestors, level gauges, compressors and blowers, pilot flames, and oxygen monitors.
2. Training programs and minimum educational requirements should be developed for both shore and vessel operators of vapor control and recovery systems.
3. Except in special cases, where the probability of encountering ignition sources can be shown to be exceptionally low, vapors should be required to be inerted before being treated or transferred any significant distance. Minimal considerations for such noninerted cases would include (a) process equipment free of ignition sources, (b) no blowers or other flow-assist devices in vapor lines, and (c) theoretical calcula

tions and test data showing that the proposed vapor piping is short enough, and the flow velocity low enough, to minimize the likelihood of an electrostatic charge being generated in the pipe.

4. Data on the reliability of detonation arrestors should be developed by testing under realistic field conditions (e.g., long vapor pipeline runs, 90° bends).
5. Installation of a secondary explosion suppression or control system should be considered. One approach is to use halon suppression systems; another is to install blowout panels or rupture discs at intermittent locations along the vapor line to prevent pressure buildup as a result of an internal explosion, minimizing the probability of shock generation and propagation through the arrestor. (See the discussion of these technologies in Chapter 3.) Another desirable alternative, especially in instances where the vessel operator has little control over the procedure used in the shore facility, is to install a shipboard pressure control system to allow the ship to control the cargo tank pressure independent from the shore facility.
6. From a safety standpoint, it is important to standardize operations and transfer and communication equipment to ensure compatibility between different types of vessels and all shore facilities they serve. Vessels that visit ports in different states should not be confronted with requirements for different procedures and equipment. Connecting flanges must be of the same size. System pressures must be similar. Detonation arrestors and other safety equipment must be compatible with corresponding items aboard vessels. Procedures at all facilities must be consistent.
7. Redundant, reliable level gauging systems need to be employed on marine tankships, with high-level alarms at 95 percent and an automatic pump shutdown at a higher level (such as 98 percent), with manual override. In addition, an improved communications system between vessel and shore facilities needs to be established to ensure that the tanks will not be overfilled.
8. New hazard mitigation technologies need to be evaluated. Research is needed to investigate the effectiveness of monomolecular layers and vapor suppression foams that may be used to minimize vapor generation in marine tanks. Methods for the application and replenishment of these additives in the tanks should be developed. Their effect on the quality of the product and their compatibility with tank materials should also be investigated.

RISK ANALYSIS

One of the questions addressed by the committee was whether or not vapor control and recovery systems would increase the risk of fire and explosion accidents should they be installed and operated at marine transfer facilities. To answer this question properly requires the calculation of risk. Such a calculation is also necessary to compare the costs and benefits of these systems to society. The expected annual losses due to accidents involving vapor control and recovery systems should be added to the annual cost of operating these facilities and include: capital investment; regulatory costs associated with the administration, enforcement, and inspection of vapor control and recovery systems; and operating costs, including additional specialized labor, maintenance, and training.

The risk of an accident may be defined as the potential loss over a specified period of time. It is equal to the product of the expected frequency or probability of occurrence and the potential severity or consequence of the accident:

$$\text{Risk} = \text{Frequency} \times \text{Severity}.$$

Frequency is usually measured in terms of the probable number of accident occurrences per unit time, while severity is measured in terms of the potential number of fatalities or injuries and the dollar loss due to property damage and downtime with each occurrence.

Because of the limited number of vapor control and recovery systems used today and the relative short history of their use, both in the United States and Europe, there are not enough historical data to quantify the potential increase or decrease in risks associated with their use. Furthermore, the risks of accidents involving these systems are highly dependent on such factors as the geographic location of the marine terminal, the size of the exposed population, the value of the terminal and adjacent property that might be affected in case of an accident, the frequency with which the system is operated at the site, and the preventive and protective measures deployed at the site.

Since the assessment of the risks associated with vapor control and recovery system operations is highly site-specific, it will be necessary to carry out risk calculations for each type of system at various “typical” terminal locations. Such calculations require that the potential frequency of a postulated accident (such as the historical accidents described and those postulated for specific systems earlier in this chapter) be-estimated using a fault tree analysis. This is a systematic procedure in which all immediate and alternative steps that could have led to the undesirable event are identified and displayed in the form of an upside-down tree. These steps, in turn, are traced back through the system until one arrives at the ultimate causes that initiated the sequence of smaller events that led to the undesired event. These causes may be failures of individual hardware components, materials, or control instruments, human error, or other factors which either singly or in combination could have led to the hazardous event.

The fault tree is then quantified by entering the probabilities of occurrence of the basic failures. Probabilities of material and equipment failure and of human error are available from various sources. If not, they may be estimated using engineering judgment and historical data. It is possible then to calculate the probability of occurrence of the undesired event and to identify those basic failures and paths that are most critical (i.e., those with the highest probabilities of occurrence). Priorities can then be established for taking corrective action. The quantitative fault tree may also be used to gauge the contribution of a specific mitigation measure toward reducing the overall frequency of the undesired event.

The severity of an accident may be estimated by using injury and damage criteria and analytical or empirical models that can predict the extent of the hazardous zone or accident footprint (e.g., distribution of thermal radiation distribution from a fire in a storage tank or from a flammable cargo spilled on water, contours of overpressures from an explosion, and vapor concentration profiles from a toxic gas release). The hazardous zone is superimposed upon a detailed map of the affected area to estimate the potential for public exposure and property damage.

There are two major drawbacks to risk analysis. First, in developing the fault tree, the analyst may unknowingly omit certain sequences of events that could lead to accidents, or he may omit events he judges to be highly unlikely. Such an oversight is particularly more likely to occur when analyzing complex systems with little historical background.

The work of Wagenaar (1986), which uses a data base of 100 shipping accidents, provides some evidence that increased system complexity adds risk. Wagenaar states that complexity makes it impossible for humans to comprehend cause-effect relationships and therefore they cannot make judgments about the riskiness of their actions or inactions.

The other problem with risk analysis concerns uncertainty. There are uncertainties associated with the probabilities of occurrence of events, particularly as they apply to human-related events. In addition, some uncertainties are associated with the models used to predict the consequences of accidents. Thus, it is important to assign uncertainty bands to all values assumed in the risk analysis.

Secondary Impacts

The increased cost of operating marine transfer terminals and vessels due to the regulation of vapor emissions may induce firms to leave the shipping business completely, or to transfer their business to unregulated terminals, if available. The increased costs may also displace some water shipping to other modes of transport that are less safe, as outlined below.

On a ton-mile basis, most of the hazardous materials transported annually in the United States are moved in domestic waterborne commerce by bulk containers, such as tankships or barges (see Table 4-2). U.S. tankers and barges contributed 636.5 billion ton miles of the hazardous transport service in 1982. This constitutes 81 percent of all hazardous material transport on a ton-mile basis.

Although substantial underreporting exists in all sectors, marine accident rates are extremely low relative to other modes of shipping. Abkowitz and List (1986) have shown that marine transport on a ton-mile basis is the safest mode of shipping, followed by rail and truck. The overall incident rate for marine transport is 0.76 incident (involving hazardous material spill, injury, or death) per billion ton-miles, while the incident rate for rail is 67 and for truck 150. Furthermore, the two classes, flammable and combustible liquids, have the lowest incident rate of all classes of hazardous materials transported on water (0.59 and 0.12 accident per billion ton-miles, respectively).

TABLE 4-2 Estimated Transportation of Hazardous Materials in the United States, by Mode in 1982

Mode	Number of Vehicles/Vessels Used for Hazardous Materials	Tons Transported (million)	Ton-Miles (billion)
Truck	337,000 dry freight or flat bed 130,000 cargo tanks	927.0	93.6
Rail	115,600 tank cars	73.0	53.0[a]
Waterborne	4,909 tanker barges	549.0	636.5
Air	3,772 commercial planes	0.285	0.459
Total		1,500.0	784.0

[a] 1983 data; 1982 data had too many errors to allow calculations.

Source: Adapted from U.S. Congress, Office of Technology Assessment (1986). Reproduced in Abkowitz and List (1986).

Not included in this analysis is pipeline transport. There are no reliable data on the total amount of intra- and interstate flammable and combustible liquids transported by pipeline. An analysis carried out by the American Petroleum Institute (Rusin, 1979) estimated that the total throughput of all combustible and flammable liquids in the United States in 1977 was 1.896 billion barrel-miles per day. During the same year, 237 accidents were reported to the Materials Transportation Bureau of the U.S. Department of Transportation (1984). These data suggest that the accident rate for liquid pipeline transport is about 2 accidents per billion ton-miles, more than twice the rate of water transport.

Data indicate that regulatory strategy analysts should include an estimate of the displacement of water transport into less safe transportation modes. Reduced hydrocarbon emissions at marine transfer facilities may be attained at the expense of more fires and explosions during railroad, truck, or pipeline transport.

Russo (1987) has argued that the cost to society of displacement or loss of jobs is an important benefit-cost parameter. Not only is there lost income but there are emotional costs manifested in disease, divorce, and domestic violence. Although this microperspective has been challenged, policy analysts may have to weigh these costs in their decisions.

5

COST-EFFECTIVENESS

The cost of emission control is a central issue. On a gross level, as a proportion of the industry's throughput, it appears manageable. According to estimates prepared for the committee, the annualized cost would be less than 1 percent of the value of cargoes handled.

However, these costs may be more burdensome on some parts of the industry than on others. Case studies conducted at the direction of the committee suggest, for example, that installing an operating vapor control facility at a small terminal in Texas would add $0.008 per gallon of gasoline loaded, while the cost at a larger terminal would rise only $0.0036 per gallon. Some smaller companies, especially in the inland barge industry, may have problems financing the necessary investments.

On the basis of dollars per metric ton of emissions prevented, the case studies show costs of $5,206 per metric ton and $2,944 per metric ton, respectively, for the small and large terminals. Additional calculations confirm the strong dependence of cost-effectiveness on terminal throughput.

To obtain realistic and consistent estimates of the costs of complying with possible requirements for hydrocarbon vapor control, the committee developed hypothetical design assumptions (see Chapter 3, “Hydrocarbon Vapor Control Systems: Assumptions for Purposes of Assessment.”) For consistency and comprehensiveness, the committee established seven cases for estimation purposes, covering a range of vessel and terminal types. These assumptions were used in two independent cost studies (one commissioned by the committee) to estimate the capital, operating, and maintenance costs of vapor control systems (Booz-Allen & Hamilton, 1987; United Technical Design, Inc., 1987).

THE COST OF CONTROL

Capital Cost Estimates

The committee commissioned an independent study by United Technical Design (UTD, 1987) to estimate the capital investments in vessels and terminals necessary to meet the standards now under consideration. The UTD study--using seven detailed design cases developed by the committee that specified four different vessel types and three terminals--estimated the cost of installing the necessary equipment*:

Case 1

Crude Oil Carrier (70,000 dwt) Vessel characteristics are: 800 ft long by 125 ft wide by 55 ft high; draft, 42 ft; 15 cargo tanks with a single gauging and alarm system; boiler flue gas providing inert gas at 5-7 percent oxygen content; normal loading rate 35,000 bbl/hour; 2 pressure/vacuum (PV) valves on the inert gas (IG) system main set at 2 psi, each sized for full flow; loading manifold midship without header from IG system main. Design assumptions are:

- IG system and supply header to be used as the hydrocarbon vapor header. The addition of detonation arrestors is the only modification required.
- Installation of an additional gauging and alarm system is necessary to provide redundant tank gauging capability.

The estimated capital costs of these retrofits total $168,000 (Table 5-1).

Case 2

Product Carrier (35,000 dwt) Vessel characteristics are: 700 ft long by 90 ft wide by 50 ft high; draft, 39 ft; 24 cargo tanks with no automatic gauging or alarms; no IG system; normally carries several grades of motor and aviation gasolines as well as distillate diesel and jet fuels (distributed in tanks based on the sizes of cargo parcels on each voyage); loading rate up to 25,000 bbl/hour; individual PV valves on each tank, set at 1.5 psi; loading manifold midships. Design assumptions are:

- Installation of complete inert gas system.

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*Recent purchasing experience (by a major oil company) suggests that the UTD study's estimated costs for detonation arrestors (which account for one-third of the total estimated cost of the system on barges) may be substantially higher than realistic. Nor are gas-freeing costs and out-of-service time included in the estimates. In its terminal estimates, the study assumes the use of incinerator flue gas as a source of inert gas. It does not include the cost of auxiliary fuel supplies for the incinerators. The report also does not address operating costs of the cooling systems for inert gas scrubbers (which can be substantial).

TABLE 5-1 Case 1 Cost Estimate Summary: Crude Oil Carrier (70,000 dwt)

Category	Cost ($)
Vapor header hardware (detonation arrestors and installation)	63,120
Instrumentation (hardware and installation)	71,400
Subtotal	134,520
Engineering and design (assume 10 percent of subtotal)	13,452
Startup and testing (assume 10 percent of subtotal)	13,452
Contingency allowance (assume 5 percent of subtotal)	6,726
Total job cost estimate	168,150
Rounded-off	168,000

- Inert gas system to be used as the hydrocarbon vapor header with addition of detonation arrestors and deck connections.
- Installation of a redundant tank gauging and alarm system.

The estimated capital cost of these retrofits is $831,000 (Table 5-2).

Case 3

Ocean Barge (19,000 dwt) Vessel characteristics are: 450 ft long by 75 ft wide by 30 ft high; draft, 24 ft; 12 cargo tanks with no automatic gauging or alarms; no IG system; cargo similar to case 2; loading rate up to 15,000 bbl/hour; individual PV valve on each tank, set at 1 psi; loading manifold midship; diesel-driven pumps aft, with no electric generator. Design assumptions are:

- Installation of complete vapor header.
- Installation of a redundant tank gauging and alarm system.

The estimated capital cost of these retrofits is $266,000 (Table 5-3).

TABLE 5-2 Case 2 Cost Estimate Summary: Product Carrier (35,000 dwt)

Category	Cost ($)
Major equipment (hardware and installation)	364,000
Piping (material and installation)	140,000
Instrumentation (hardware and installation)	161,000
Subtotal	665,000
Engineering and design (assume 10 percent of subtotal)	66,500
Startup and testing (assume 10 percent of subtotal)	66,500
Contingency allowance (assume 5 percent of subtotal)	33,250
Total job cost estimate	831,250
Rounded-off	831,000

Case 4

Inland River Barge Vessel characteristics are: 265 ft long by 54 ft wide by 12 ft high; draft, 9 ft; 10 cargo tanks with no automatic gauging or alarms; no IG system; cargo similar to case 2; loading rate 4,000 bbl/hour; individual PV valves at each tank set at 1 psi; loading manifold aft; diesel driven cargo pump aft, with no electric generator. Design assumptions are:

- Installation of complete vapor header.
- Installation of a redundant tank gauging and alarm system.

The estimated capital cost of these retrofits is $168,000 (Table 5-4).

Case 5

Product Terminal for Barges Terminal characteristics are: two docks designed to load two barges at each side from two loading stations at each dock; loads one product at a time to each barge at 4,000 bbl/hour; space available for incinerator one-quarter mile away; all gasoline storage tanks have floating roofs; transfer pumps located 300 yd from

TABLE 5-3 Case 3 Cost Estimate Summary: Ocean Barge (19,000 dwt)

Category	Cost ($)
Vapor header hardware (including PV valves and installation)[a]	67,000
Piping (material and installation)	65,000
Instrumentation (hardware and installation)	81,000
Subtotal	213,000
Engineering and design (assume 10 percent of subtotal)	21,300
Startup and testing (assume 10 percent of subtotal)	21,300
Contingency allowance (assume 5 percent of subtotal)	10,650
Total job cost estimate	266,250
Rounded-off	266,000

[a] Does not include detonation arrestors.

dock; loadings handled by one person at waterfront and one at tank farm. Design assumptions are:

- Installation of four complete hydrocarbon vapor transfer lines and associated incinerator feed headers.
- Incinerator one-quarter mile away supplies inert gas to the dock area.
- Installation of two full-capacity booster fans arranged in parallel.
- Installation of terminal alarm system and vapor control system instrumentation.

The estimated capital cost of these retrofits is $1.23 million (Table 5-5).

Case 6

Crude Oil Terminal for Ships Terminal characteristics are: single dock designed to load one ship of up to 75,000 dwt at a time; loads only one type of crude oil at 35,000 bbl/hour; tank farm with space for incinerator located 1 mile from dock; 220-volt alternating current (AC) elec

TABLE 5-4 Case 4 Cost Estimate Summary: Inland River Barge

Category	Cost ($)
Vapor header hardware (PV valves/detonation arrestors and installation)	50,000
Piping (material and installation)	17,000
Instrumentation (hardware and installation)	67,200
Subtotal	134,200
Engineering and design (assume 10 percent of subtotal)	13,420
Startup and testing (assume 10 percent of subtotal)	13,420
Contingency allowance (assume 5 percent of subtotal)	6,710
Total job cost estimate	167,750
Rounded-off	168,000

tricity available at tank farm; nearest natural gas service 6 miles away; storage tanks have floating roofs; terminal operated by one person at tank farm and one at dock; only minimal 110-volt AC electric power available at dock. Design assumptions are:

- Installation of one complete hydrocarbon vapor transfer line and incinerator feed header.
- Incinerator does not supply gas to the dock area, since vessels are assumed to have own inerting capability.
- Incinerator located 1 mile from dock area.
- Natural gas service available 6 miles from the incinerator.

The estimated capital cost of making these retrofits is $2.57 million (Table 5-6).

Case 7

Product Terminal Serving Ships and Barges Terminal characteristics are: one pier for loading two ships of up to 55,000 dwt and two docks for loading four inland barges at each dock; each of two tankship loading stations can provide 25,000 bbl/hour, each of eight barge loading stations can load 4,000 bbl/hour; closest available space for

TABLE 5-5 Case 5 Cost Estimate Summary: Product Terminal Serving Barges

Category	Cost ($)
Major equipment (hardware and installation)	659,000
Piping (material and installation)	271,300
Instrumentation (hardware and installation)	49,800
Subtotal	980,100
Engineering and design (assume 10 percent of subtotal)	98,000
Startup and testing (assume 10 percent of subtotal)	98,000
Contingency allowance (assume 5 percent of subtotal)	49,000
Total job cost estimate	1,225,100
Rounded-off	1,225,000

incinerator is 1 mile from docks; 220-volt AC electricity and natural gas service available 100 yd from space; all gasoline tanks have floating roofs; terminal operated by one person at each dock or pier and two at the tank farm. Design assumptions are:

- Installation of eight complete barge hydrocarbon vapor transfer lines.
- Installation of two complete hydrocarbon vapor transfer lines.
- Incinerator supplies inert gas to ship and dock areas.
- Natural gas service available 900 ft from the incinerator.
- Installation of terminal alarm system and vapor control system instrumentation.
- Installation of two parallel sets of full-capacity booster fans for incinerator feed and inert gas feed to the dock area.

The estimated capital cost of these retrofits is $7.50 million (Table 5-7).

These estimates suggest that the owners of tank vessels approaching the ends of their useful lives, a significant proportion of the barge fleet, for example, will need to make investments that are large compared to the salvage values of the vessels. The estimates also imply rather substantial costs for low-volume barge terminals.

In the long run, of course, shippers will pay these costs. In the present slack market for inland barge services, however, the costs will

TABLE 5-6 Case 6 Cost Estimate Summary: Crude Oil Terminal for Ships

Category	Cost ($)
Major equipment (hardware and installation)	471,200
Piping (material and installation, gas service included)	1,551,600
Instrumentation (hardware and installation)	33,700
Subtotal	2,056,500
Engineering and design (assume 10 percent of subtotal)	205,650
Startup and testing (assume 10 percent of subtotal)	205,650
Contingency allowance (assume 5 percent of subtotal)	102,825
Total job cost estimate	2,570,625
Rounded-off	2,571,000

not readily be passed through to shippers, unless traffic rises or a substantial number of barges are scrapped.

Operating and Maintenance Cost Estimates

The UTD study included estimates of the operating and maintenance costs attendant on the seven retrofit cases. These estimates are low, for two reasons. First, the study limited its evaluation of operating costs to basic utilities such as natural gas and electricity, and ascribed all operating costs to the terminals. Second, it omitted from consideration the operating and maintenance costs of cooling water systems for the inert gas scrubbers in cases 5 and 7; in fact, these cooling systems can account for substantial proportions of operating and maintenance costs at marine terminals. The estimated annual operating and maintenance costs for the seven cases are presented in Table 5-8.

OPERATING COST ESTIMATES FOR INLAND BARGES

The barge industry, already plagued by overcapacity and a stagnant market, would bear some of a vapor control requirement's greatest costs. The prospect of installing $160,000 vapor control systems on

TABLE 5-7 Case 7 Cost Estimate Summary: Product Terminal Serving Ships and Barges

Category	Cost ($)
Major equipment (hardware and installation)	2,519,200
Piping (material and installation)	3,359,000
Instrumentation (hardware and installation)	123,800
Subtotal	6,001,800
Engineering and design (assume 10 percent of subtotal)	600,180
Startup and testing (assume 10 percent of subtotal)	600,180
Contingency allowance (assume 5 percent of subtotal)	300,000
Total job cost estimate	7,502,160
Rounded-off	7,502,000

TABLE 5-8 Estimated Annual Operating and Maintenance Costs for the Seven Case Studies

Case	Operating Cost ($/year)	Maintenance Cost ($/year)
1. Crude oil carrier (70,000 dwt)	N/A	4,800
2. Product carrier (35,000 dwt)	1,500	78,000
3. Ocean barge (19,000 dwt)	N/A	12,800
4. Inland river barge	N/A	9,600
5. Product terminal/barges	14,000	41,000
6. Crude oil terminal/ships	14,000	28,000
7. Product terminal/ships and barges	32,000	79,000

$250,000 barges prompted the American Waterways Operators, an industry group, to request an independent study of the operating and maintenance costs associated with hydrocarbon vapor control in barges (Booz-Allen & Hamilton, 1987).

Using design assumptions developed by the committee (see Chapter 3, “Hydrocarbon Vapor Control Systems: Assumptions for Purposes of Assessment”), the Booz-Allen study developed capital cost estimates that agree with the UTD study as a basis for estimating operating and maintenance costs.

Based on the UTD (1987) report and engineering cost estimates obtained from barge operators, the Booz-Allen study estimated capital costs for retrofitting a variety of inland tank barges, from small vessels in “clean” service (carrying gasoline, middle distillates, or other light products) to large ones engaged in “dirty” service (crude oil, residual fuel oil, and similar cargoes).

The cost of retrofitting the 20,000-bbl barge specified in case 4 of the UTD report, the Booz-Allen study estimates, is $160,000 (reasonably close to the UTD estimate of $168,000). A 5-year-old, 10,000-bbl barge would cost $96,000 to retrofit, according to the Booz-Allen study. The cost could reach $250,000, the study found, in a 50,000-bbl barge in dirty service. Figure 5-1 displays the study's range of estimated costs for retrofitting inland barges of various ages, sizes, and tank arrangements.

Installing vapor control equipment on barges would raise operating costs for maintenance and repair, crew training, tank cleaning, and insurance, according to the Booz-Allen study. On the representative 10,000-bbl barge, maintenance costs would rise from $19,000 annually to $25,000 or more, depending on the durability of automated gauging and alarm systems. Training tankermen to operate vapor control systems would cost $4,000 initially, per barge, with a recurring cost of $2,000 per year. Annual tank cleaning costs are estimated to rise by $5,000 on the representative barge, which is assumed to operate in clean service, and thus to need frequent cleaning. Insurance costs would rise by somewhat less than $1,000 per year.

In addition, according to the study, each barge would lose revenue owing to the imposition of vapor controls. The representative 10,000-bbl barge would need to be taken out of service for 4 days, at a loss in revenue of $1,000, while the necessary hardware was installed. Barges also would spend more time at docks during loading, while the vapor control systems were being connected, inspected, and disconnected, at an annual cost estimated at $2,000 for the representative barge.*

In all, the study concludes, the representative barge's costs would rise by approximately $19,000 per year, and its revenues would decline by $2,000 (not counting the revenue lost during installation). Table 5-9 compares the pro forma income statement of the representative barge before and after the imposition of vapor controls.

Because of its limited scope, the Booz-Allen & Hamilton study does not elucidate factors influencing demand. To analyze completely the potential economic impacts of a regulation, the industry being regulated needs to be characterized with respect to its market structure.

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*The lost revenue is applicable only if the barge could have found work during this period of time. In addition, note that revenue lost to a particular barge would be obtained by another barge. Therefore, the entire industry would not lose any revenue.

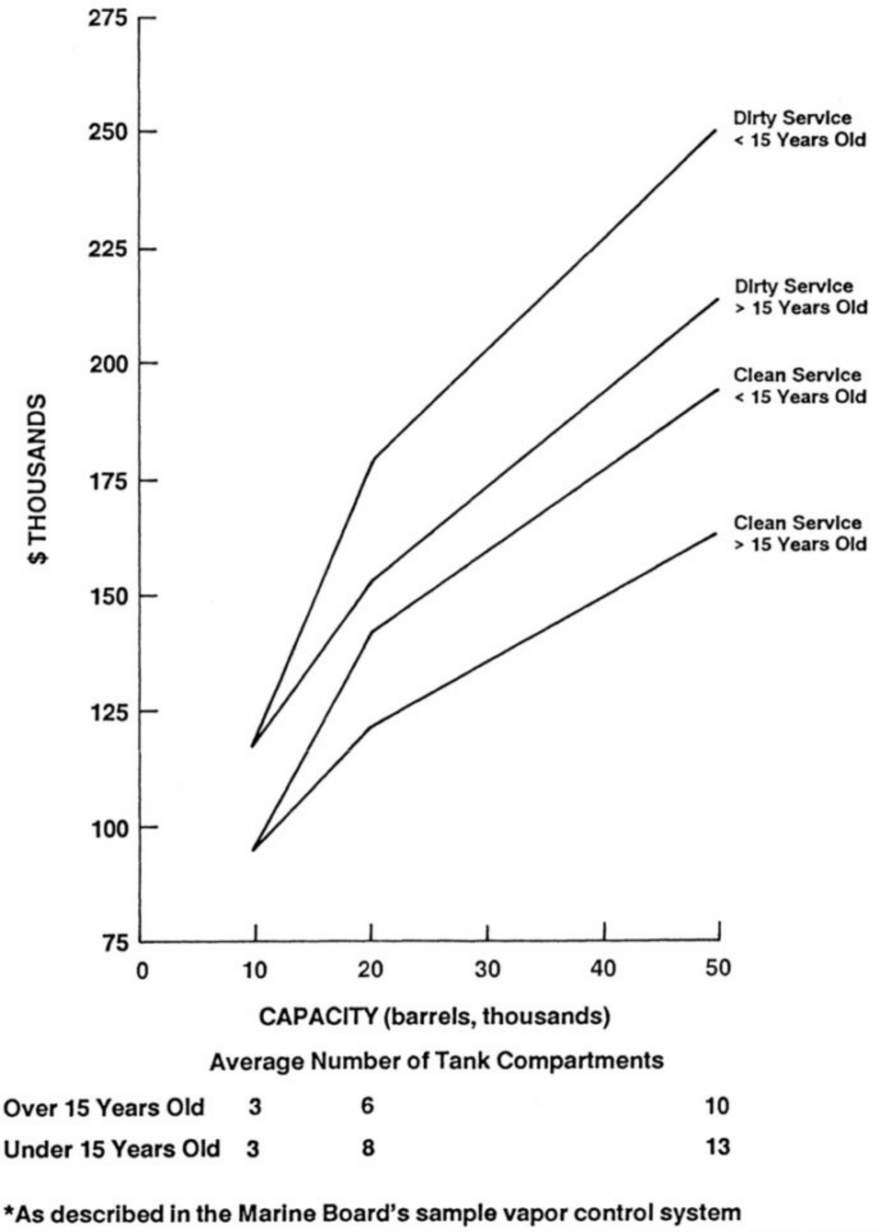

FIGURE 5-1 Installed capital costs for vapor control system on an inland barge. Source: Booz-Allen & Hamilton (1987).

TABLE 5-9 Impact of Vapor Control Requirement on Pro Forma Income Statement of Representative Inland Barge

	Thousands of Dollars per Year		
Category	Before Controls	Impact of Controls	After Controls
Revenue	270	(2)[a]	268
Costs			
Tug cost	135		135
Fuel	32		32
Barge depreciation	19	5	24
Barge maintenance and repair	19	6	25
Other voyage costs	13	5	18
Barge insurance	13	1	14
Overhead	40	2[b]	42
Total costs	271		290
Loss before interest and taxes	(1)		(22)
Transportation cost index	100		107.8

[a] Does not include $1,000 revenue lost during installation.

[b] Training cost for replacement personnel. It excludes $4,000 for the cost of training current crew.

Source: Booz-Allen & Hamilton (1987).

COST-EFFECTIVENESS OF HYDROCARBON VAPOR EMISSION CONTROLS AT MARINE LOADING TERMINALS IN TEXAS

The cost-effectiveness of an air quality regulation is often measured by the cost of abating a given amount of a particular kind of emission (e.g., dollars per metric ton of hydrocarbon vapors). Since the cost is borne ultimately by consumers, it also makes sense to calculate the cost per physical unit of throughput (e.g., the amount added to the cost of a gallon of gasoline or fuel oil).

Instituting the same controls at different sites can yield varying costs by either of these measures. The volumes and types of traffic at marine terminals vary widely, for example, so that a low-volume terminal will experience higher costs than a higher-volume terminal, all other things being equal. The layout of the terminal and vapor control facilities can affect costs substantially by determining the distances that vapor and inert gas must be piped.

TABLE 5-10 Cost of Control at Marine Terminals in Texas

Factor	Small Terminal	Large Terminal
Gasoline loaded (bbl/year)	1,373,000	14,900,000
Total fixed capital		
Terminal	$745,000	$1,945,000
Vessel retrofit	$672,000	$6,141,000
Annual operating costs	$461,800	$2,288,600
Volatile organic compound reduction (metric ton/year)	88.7	777.2
Cost of control (dollars/metric ton)		
Terminal	$ 3,258	$ 736
Vessel retrofit	$ 1,948	$ 2,208
Combined total	$ 5,206	$ 2,944

The staff of the Texas Air Control Board, at the committee's request, prepared case studies of two marine terminals in Texas (Figure 5-2 and Figure 5-3). The study chose a large terminal (annual throughput of 15 million bbl/year, instantaneous loading rate of 14,000 bbl/hour), and a small terminal (1.4 million bbl/year throughput, maximum instantaneous loading rate of 5,000 bbl/hour for gasoline, 2,500 bbl/hour for fuel oil). This represents a reasonable case, since both terminals load mainly gasoline.

The results of this study are summarized in Table 5-10. More details are presented in Table 5-11, Table 5-12, Table 5-13, Table 5-14 and Table 5-15.

The large gasoline terminal selected for study is actually small compared with the loading rate of 82,000 bbl/hour and, by extension, the annual throughput of 430 million bbl/year (assuming a 60 percent utilization) of the hypothetical product terminal serving both ships and barges used in the UTD report (United Technical Design, Inc., 1987).

Nevertheless, the large terminal is apparently a typical large Texas terminal. A survey of the industry revealed that volumes and loading rates for gasoline were much larger several years ago, but market forces have shifted gasoline transport to pipelines at the expense of marine vessels.

Methodology for Selecting Terminals

A search through state emissions inventory records and other information yielded 44 terminals. Nearly 60 percent were at refineries, 30 percent were public or privately owned bulk terminals, and the rest were pipeline or other marine-related companies. About 30 percent were in the Houston area, 25 percent in the Corpus Christi area, 25 percent in the Beaumont/Port Arthur region, 10 percent in the Galveston/Texas City

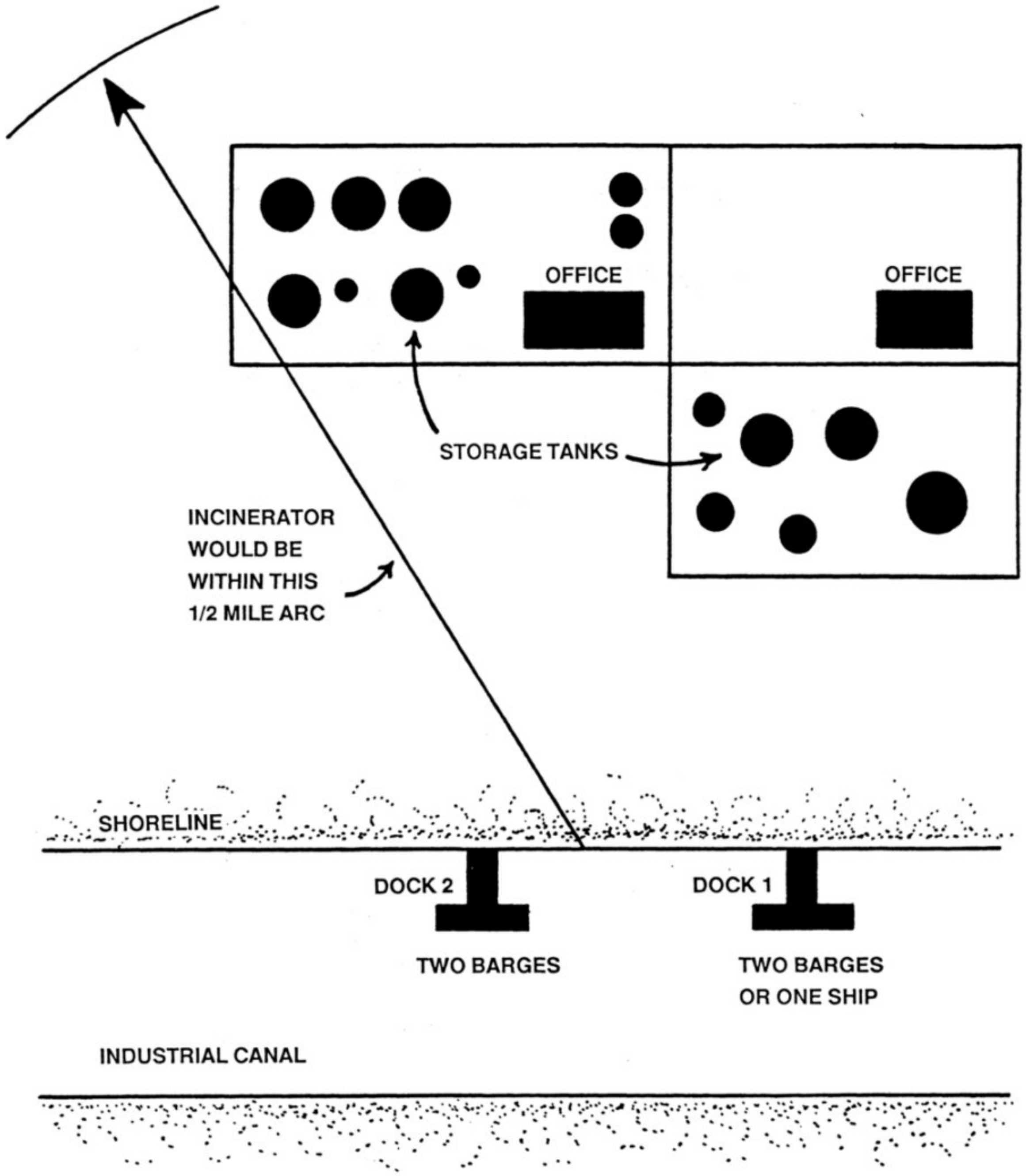

FIGURE 5-2 Small Texas terminal.

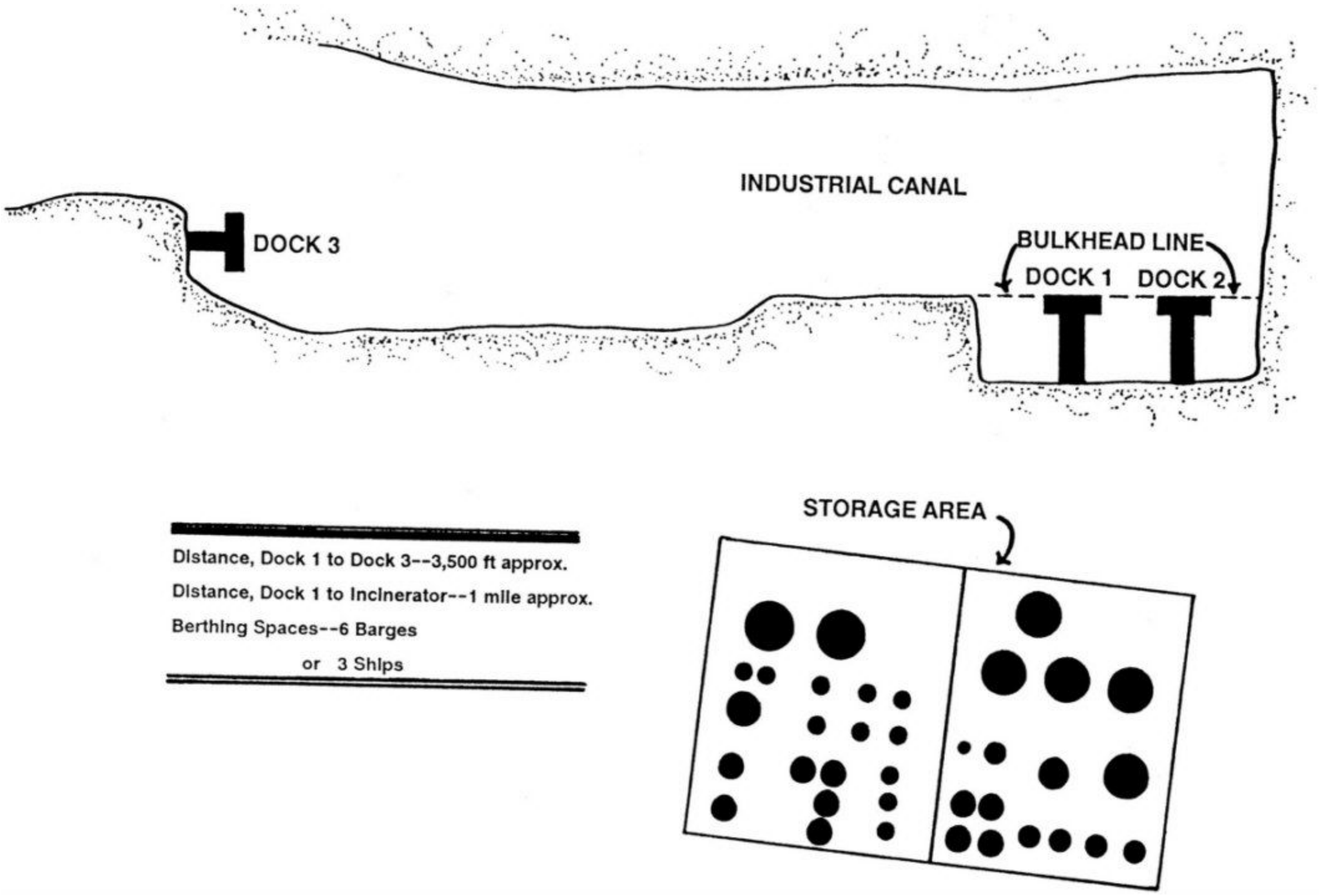

FIGURE 5-3 Large Texas terminal.

TABLE 5-11 Small Terminal Physical Characteristics

Item	UTD Case 5: Terminal for Barges	Small Texas Terminal
Total annual gasoline throughput (bbl)	NA	1,373,000 actual
Maximum instantaneous loading rate (bbl/hour)	16,000, gasoline	5,000, gasoline 2,500, fuel oil
Number of docks	2	2
Number of loading spots	4	4 barges or 1 ship and 2 barges
Distance[a] to incinerator	1/4 mile	1/2 mile[b]
Distance to fuel gas	1/2 mile	6-in. main in immediate area
Distance to 220-volt AC	1/2 mile	Immediate area
All gasoline tanks have floating roofs	Yes	Yes
Distance to loading pumps	300 yd	600 yd approx.
Manning, direct operations		
Tank farm	1	1
Dock	1	2
Tankermen	0	2
Ship-loading capability	None	One dock takes 150,000 dwt ships[c] and barges; second dock for barges only
24-hour operation	NA	Yes
7-day operation	NA	Yes

[a] Distance from dock.

[b] Includes minimum distance of 250 ft from other equipment (storage tanks) recommended by Industrial Risk Insurers.

[c] Ships are rarely loaded at this terminal.

area, and the rest elsewhere on the Gulf Coast. Companies were surveyed to ascertain annual loading throughputs of crude oil and gasoline, maximum pumping rates, and other operational information. An important element in selecting specific sites to study involved the companies' willingness and availability to participate.

The two sites selected should not be considered to represent the average small and large terminals in the industry. They represent specific small and large operations in Texas that provide a reasonable basis for this study. At their request, the operators of the sites selected are not identified.

TABLE 5-12 Large Terminal Physical Characteristics

Item	UTD Case 7: Terminal for Ships/Barges	Large Texas Terminal
Annual gasoline throughput (bbl)	NA	14,900,000
Maximum instantaneous loading rate (bbl/hour)	82,000	14,000
Number of docks	3	3 (2 barges, 1 ship)
Number of loading spots		
Barges	8	6 or
Ships	2	3 ships
Dock to incinerator	1 mile	1 mile
Dock to 220-volt AC	100 yd	NA
Dock to fuel gas main	100 yd	NA
All gasoline tanks have floating roofs	Yes	Yes
Dock to loading pump	?	NA
Manning, direct operators		
Tank farm	2	9
Dock	3	1/dock
Tankermen	?	1/dock

Cost of Control at Terminals

Fixed capital costs at terminals for the study were based entirely on the UTD study (United Technical Design, Inc., 1987) commissioned by the committee. Where loading volumes of the Texas terminals differ from the UTD cases, fixed capital was factored by methods traditionally used in preparing preliminary capital estimates (Peters and Timmerhaus, 1968).

Operating costs, except as noted, were also taken from the UTD study and adjusted to match the specifics of the Texas terminals. Time constraints prevented the gathering of unit cost data (e.g., $/kwh), so that variable costs such as utilities and labor are not adjusted. This simplification should not significantly affect the results.

It should be noted that most, if not all, terminals surveyed load products other than gasoline. Some of these products may also need vapor control systems. Also, the two terminals selected for this report are used by more than one operating company. These complications were not considered in this study, however, due to a lack of information. A thorough evaluation of these complicating factors could be conducted, but the impacts thus identified probably would not change the conclusions of the study. Gasoline loading by the terminal operators is important at both Texas terminals.

TABLE 5-13 Vessel Retrofit Costs--Small Texas Terminal

						Annual Maintenance	
Barge Capacity (bbl)	Fleet Factor[a] (bbl/ day/vessel)	Annual Throughput (bbl)	Number of Vessels	Retrofit[b] ($000/ vessel)	Total Retrofit ($000)	Per Vessel[b] ($000)	Total ($000)
25,000	1,000	1,373,000	4	168	672	9.6	38.4

[a] Derivation of fleet factors is discussed in Appendix G.

[b] From UTD study.

TABLE 5-14 Vessel Retrofit Costs--Large Texas Terminal

							Annual Maintenance	
Vessel	Capacity (bbl)	Fleet Factor[a] (bbl/day/vessel)	Annual Throughput (bbl)	Number of Vessels	Retrofit[b] ($000/ vessel)	Total Retrofit ($000)	Per Vessel[b] ($000)	Total ($000)
Barges	10,000	400	2,930,000	20	97	1,940	9.6	192
	20,000	800	5,860,000	20	147	2,940	9.6	192
Ocean barge	100,000	7,000	3,300,000	2	215	430	12.8	26
35 kdwt “ship”	262,500	10,000	2,810,000	1	831	831	78.0	78
Total			14,900,000			6,141		488

[a] Derivation of fleet factors is explained in Appendix G.

[b] From UTD study.

TABLE 5-15 Cost-Effectiveness Summary

	Small Texas Terminal		Large Texas Terminal	
Item	Terminal Facilities	Vessel Retrofit	Terminal Facilities	Vessel Retrofit
Gasoline loaded (bbl/year)	1,373,000	--	14,900,000	--
Loading rate (bbl/hour)	5,000	--	14,000	--
Total fixed capital	$745,000	$672,000	$1,945,000[a]	$6,141,000
Annual operating costs				
Fuel and electrical	$ 9,000	--	$ 12,400	--
Maintenance	25,000	$ 38,400	65,000	$ 488,000
Capital				
Depreciation, 10 percent	74,500	67,200	194,500	614,100
Interest on borrowed money, 10 percent	74,500	67,200	194,500	614, 100
Net added labor	106,000[b]	--	106,000[b]	--
Total	$289,000	$172,800	$572,400	$1,716,200
Cost (dollars/gallon)	$0.0050	$0.0030	$0.0009	$0.0027
Cost of control (dollars/metric ton)	$3,258	$1,948	$736	$2,208
Reduction (metric tons/year)	--88.7--		--777.2--	

[a] UTD case 5 was also used as the basis for estimating capital and operating costs for the large Texas terminal since case 5 is more similar than case 7 to the Texas terminal.

[b] One man per shift--net added labor over existing staff for operating control system. (Actually this is probably a “worst” case approach. The terminals visited by the Texas Air Control Board probably could operate a control device with their existing staff.)

A limit to the accuracy of this case study is in the siting of the incinerators. As shown by the UTD study, piping costs can be a major part of a control system. Thus, the distance from the incinerator to the vessel being loaded will materially influence the capital cost. Useful guidelines were obtained from terminal operators, but none could be considered as firm or final; since such siting decisions are made by different functional groups and management levels in the companies and could take several months to complete. A final site plan would not necessarily be the same as one proposed for a hypothetical study such as this one. Thus, it is not possible to represent the site selected at each terminal as anything but a fairly realistic assessment of what might be chosen if the facility were actually built. The site selections do meet recommended incinerator and dock spacings guidelines (Industrial Risk Insurers, 1984).

The operator of the larger terminal stated that an existing flare would probably be used as the necessary control device instead of installing a new flare or incinerator. However, in this report the cost of a new incinerator is included in the capital costs. Use of an existing flare would probably not be typical of the industry, and such an assumption is too optimistic for general conclusions (although in Texas 60 percent of marine terminals are at refineries, where existing systems might be used).

The estimated operating costs here do not include indirect charges for corporate overhead, sales, and administrative costs, for example. These costs were not available, vary considerably from company to company, and would add only 10-30 percent to the final annualized operating costs.

Cost of Control on Vessels

Existing vessels would be retrofitted to operate with a terminal vapor control system. Retrofitting costs were estimated by the UTD study (United Technical Design, Inc., 1987). To estimate the vessel retrofit costs associated with vapor control at each terminal, it is necessary to determine a mix of vessels sufficient to serve the terminal, considered as a dedicated fleet. The committee developed “fleet factors” representing the number of barrels per day different vessels can load on a daily basis in normal operations, taking into account transit times. Appendix G explains the derivation of the following fleet factors.

- 70,000 dwt crude carrier (capacity 490,000 bbl): 25,000 bbl/day/vessel
- 35,000 dwt product carrier (capacity 262,500 bbl): 20,000 bbl/day/vessel
- 19,000 dwt ocean barge (capacity 142,500 bbl): 10,000 bbl/day/vessel
- River barge (capacity 25,000 bbl): 1,000 bbl/day/vessel

Many of the inland river barges in Texas are only 10,000-20,000 bbl in capacity. Fleet factors for these smaller vessels were obtained by direct, linear ratio of capacity to fleet factor.

Control Effectiveness

The incinerator control device chosen by the committee for use in its analysis has a removal efficiency of 99.8 percent (U.S. Environmental Protection Agency, 1985). If it were used at the two Texas terminals studied, 88.7 and 777.2 metric tons per year of VOC emissions would be prevented at the small and large terminal, respectively. VOC emissions factors were estimated using the EPA AP-42 method (U.S. Environmental Protection Agency, 1985). These factors of 3.4 pounds per 1,000 gallons loaded for barges, and 1.8 pounds per 1,000 gallons loaded for ocean barges and 35 kdwt product carriers were applied to the Texas terminals' throughputs to calculate VOC emission in metric tons per year.

Cost-Effectiveness at Selected Texas Terminals

Table 5-11, Table 5-12, Table 5-13 through Table 5-14 give details of costs and physical characteristics of the Texas terminals. Fixed capital costs, including vessel retrofit costs, for the small terminal are predicted to be $1,417,000. Annual operating costs (not including supplemental fuel) of $461,800, including capital charges and direct operating costs, equate to $0.008 per gallon of annual throughput on gasoline. Cost of control is calculated to be $5,206 per metric ton of VOC emissions reduced at the small terminal.

Fixed capital costs for the larger terminal are likewise predicted to be $8,086,000. Annual operating costs (not including supplemental fuel) of $2,288,600 at the larger terminal results in a throughput charge of $0.0036 per gallon. This equates to $2,944 per metric ton of VOC emissions reduced as the cost of control at the large terminal.

Other Costs Not Accounted For

Permits, insurance, liability questions, capital generation problems, operating manpower, and other such areas were not addressed.

COST-EFFECTIVENESS AS A FUNCTION OF TERMINAL THROUGHPUT

The cost-effectiveness of an emission control system is measured by the dollars spent per metric ton of pollutant abated. Cost-effectiveness is generally a function of the capital and operating costs of the control system and the capacity utilization of the control unit. For a particular control unit the cost per ton will generally decrease as the

TABLE 5-16 Fleet Assumptions for Cost-Effectiveness Analysis

Vessel Capacity (1,000 bbl)	Fleet Factor (bbl/day/vessel)	Vessel Type
25	1,000	Inland river barge
40-50	5,000	
130-150	10,000	19 kdwt ocean barge
	20,000	35 kdwt product carrier
400-600	25,000	70 kdwt crude carrier

control unit use increases. For marine terminals, control unit use is directly proportional to product throughput because displaced vapors are a function of product loaded.

Capital and Operating Costs for Control System at Terminal

Capital and operating costs of the incinerator system were obtained from the United Technical Design, Inc. (1987) study. The UTD costs are based on 2,000 hours of incineration operation for this cost-effectiveness analysis. Throughput was varied for this cost-effectiveness analysis, and operating costs were recalculated for various throughputs (see Appendix G).

Vessel Retrofit Costs

Vessel retrofit costs were obtained from the UTD study. The basis for determining the total amount of vessel retrofit costs attributed to the model facility was to assume a dedicated fleet. To enable this, assumptions were made about the number of barrels per day of terminal throughput that can be handled by vessels of different types (Table 5-16). The number of vessels needed is determined by dividing annual throughput by 365 and dividing by the appropriate factor(s) in the table. For example, a terminal with an annual throughput of 356,000 bbl using inland river barges would have an average daily throughput of 1,000 bbl/day. The terminal's fleet would be calculated for inland barges as follows:

(1,000 bbl/day)/(1,000 bbl/day/vessel) = 1 vessel.

The fleet factors in Table 5-16 include allowances for time it takes a vessel to make a voyage (of an assumed length), deliver product, and return to the loading terminal.

Because fleet factors are rough estimates, an attempt was made to provide an upper-bound or worst-case cost-effectiveness number by arbitrarily doubling the fleet size based on the fleet factors. It is possible that the fleet factors as provided already yield a worst-case cost-effectiveness estimate by assuming dedicated service. The retrofit cost in many cases will be shared by more than one facility. However, it is beyond the scope of the analysis to make those estimates.

Emission Factors

Because cost-effectiveness is a function of both the annualized cost and the emission reduction estimates, emission estimates for loading operation were based on factors obtained from EPA's AP-42 document (U.S. Environmental Protection Agency, 1985). Emission factors are available by both vessel type and product carried.

This analysis assumes that only crude oil and gasoline are being loaded. The emission factors used for the 70 kdwt oil carrier, 35 kdwt product carrier, 19 kdwt ocean barge, and inland river barge are 0.61, 1.8, 1.8, and 3.4 pounds per 1,000 gallons loaded, respectively. These factors are the same as those used to estimate nationwide marine vessel emissions in Chapter 1. These emission factors represent typical or average conditions on a vessel; actual emissions are a function of both vessel conditions and product carried.

Cost-effectiveness would obviously increase or decrease if different assumptions affecting emissions are made with respect to vessel condition. For example, the emission factors for a gas-freed tank barge in gasoline service and a dirty vessel in the same service would be 2.0 and 3.9 pounds per 1,000 gallons, respectively. The cost per ton of emissions abated would almost double for gas-freed vessels, because there are less emissions.

Cost-Effectiveness Curves

Figure 5-4, Figure 5-5 through Figure 5-6 are graphs of cost-effectiveness as a function of throughput for UTD cases 5, 6, and 7. The actual numbers plotted are presented in Appendix G.

COST-EFFECTIVENESS COMPARED TO CONTROL OF OTHER VOC SOURCES

The cost of controlling VOC emissions from tank vessels has been estimated by the committee as $2,944 per metric ton (of VOCs controlled) for large throughput terminals, and $5,206 per metric ton for small throughput terminals. Table 5-17 compares these costs with several other sources of VOCs, whose control is under consideration. The

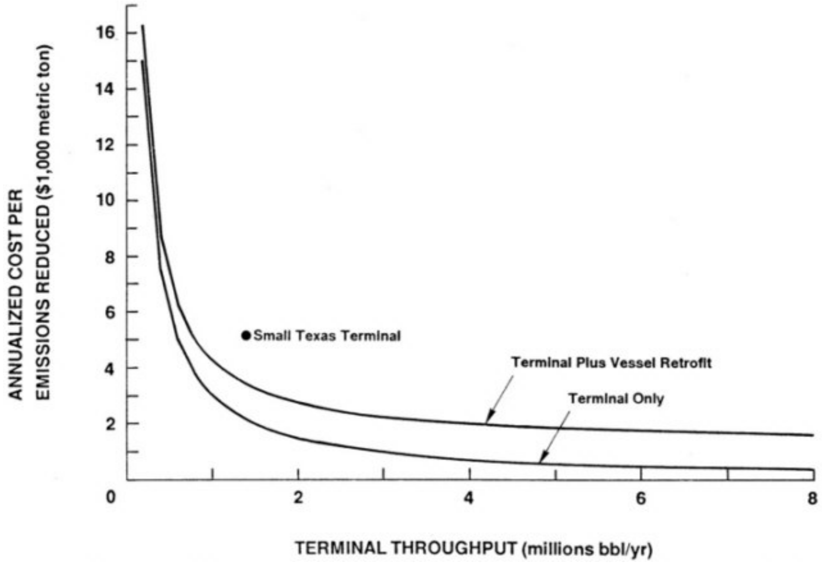

FIGURE 5-4 Cost-effectiveness as a function of throughput--inland terminal serving barges. Source: United Technical Design, Inc. (1987).

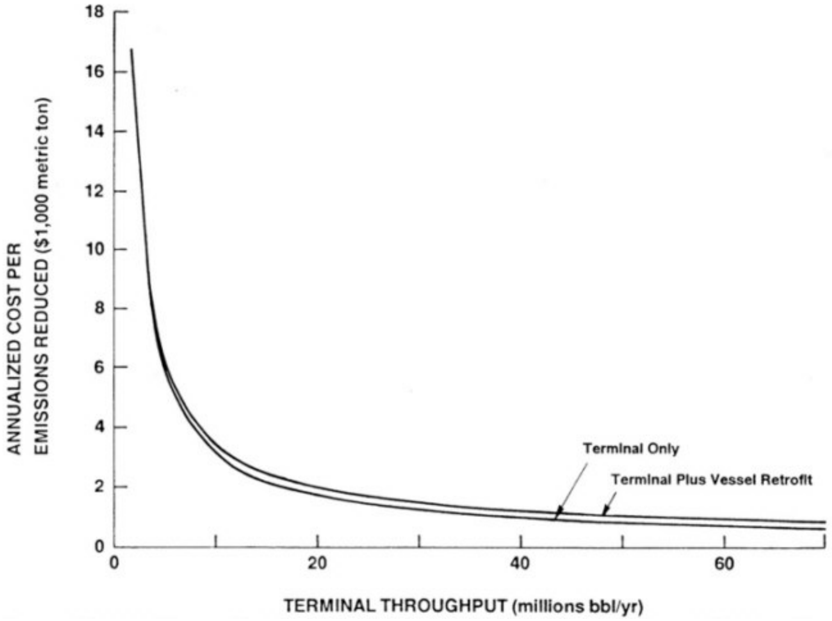

FIGURE 5-5 Cost-effectiveness--crude oil terminal for ships. Source: United Technical Design, Inc. (1987).

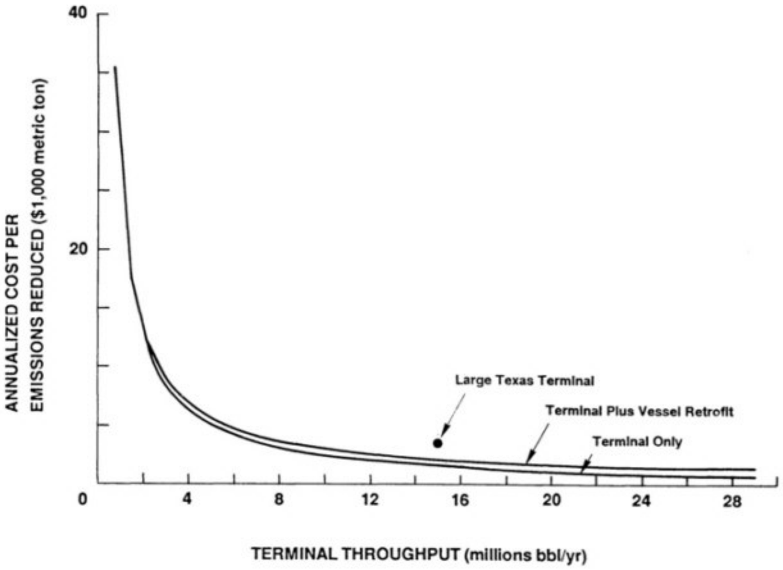

FIGURE 5-6 Cost-effectiveness--product terminal serving ships and barges. Source: United Technical Design, Inc. (1987).

TABLE 5-17 Comparison of Costs to Control Volatile Organic Compounds

Source	Control Technique	Cost ($/metric ton of VOC controlled)
Large marine terminal	(See UTD case 7)	$2,944
Small marine terminal	(See UTD case 5)	$5,206
Automobile gas tanks	Stage II control at service stations	$850-$1,080[a]
Automobile gas tanks	Onboard canisters	$850[a]
Gasoline	Gasoline volatility control	$1,500-$2,500

[a] 1984 dollars.

Source: U.S. Environmental Protection Agency. examples in the table represent broad EPA strategies for reduction of VOC. A more interesting comparison would be with the highest cost of control being required at the state level in areas not attaining the national standards. These data were not available to the committee.

6

CONSIDERATIONS IN DEVELOPING NEW POLICY

Specific impacts at the local level would be associated with any regulations to control hydrocarbon vapor emissions from marine loadings. More than 98 percent of tank vessels' vapor emissions occur at loading ports (Figure 6-1). Hydrocarbon emission abatement is intended to reduce ozone levels near these ports. At the same time, the vessel operators will be faced with substantial costs, falling particularly heavily on smaller inland tank barge companies and low-volume terminals. Cargoes carried by tank vessels might be diverted to other modes of transportation. The impacts of an accident--a fire or explosion--would be site-specific.

The responsibility for regulatory coordination, however, cannot be undertaken at the local level. Handling potentially explosive vapors carries a risk. The industry, states, and locales involved need to be sure their activities do not unduly raise this risk. Varying state controls could have this result, if they were implemented in a patchwork of control requirements tailored to local circumstances.

The regulatory challenge is heightened by the diversity in the populations of vessels and terminals. A large product carrier, equipped with multiple tanks and an inert gas (IG) system, has a great deal more flexibility in limiting its loading emission than a simple river barge. A small terminal with a low throughput is likely to install less elaborate vapor recovery or disposal systems than a larger, busier terminal. One locale's ozone problem may be less severe than another's. Varying approaches to control would be natural.

But uniformity is vital. Flanges and connections must be standardized and operating pressures and loading rates compatible, as tank vessels travel from port to port, state to state, and nation to nation. Operating procedures and training standards should be uniform, to the extent possible, to reduce opportunities for human error. Gauging systems, safety equipment, and safety procedures must offer the same high degree of protection everywhere.

The U.S. Coast Guard is the agency charged with the responsibility for regulating vessel safety. This agency ultimately must judge the safety of systems for vapor control. It must inspect and certificate each vessel periodically for safety and pollution-control reasons. Coast Guard inspectors have the power to refuse or revoke certification of vessels and their equipment that present safety hazards. The Coast

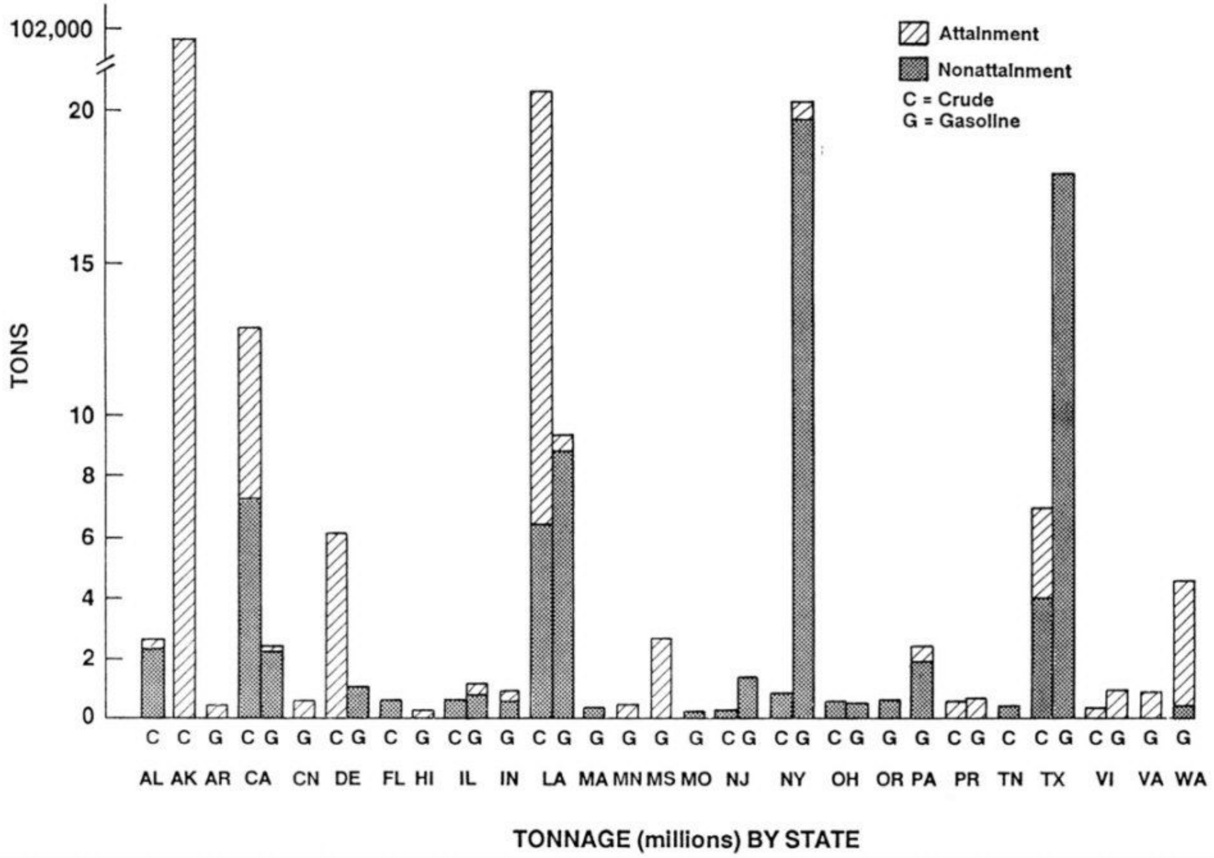

FIGURE 6-1 Crude oil and gasoline loaded in ozone attainment/nonattainment areas, by state, 1985.

Guard may review the safety of terminal systems that may affect the safety of vessels; it also has the authority to close terminals for cause, in the interest of safety.

Neither the Coast Guard nor the U.S. Environmental Protection Agency (EPA) has taken a major initiative to coordinate or standardize state or other local marine hydrocarbon vapor control activities to ensure safety. EPA's National Ambient Air Quality Standards (NAAQS) system, under which the State Implementation Plans for ozone are to be submitted, offers no obvious mechanism for coordinating these initatives, beyond assessing their effectiveness in reducing emissions.

FEDERAL AIR POLLUTION CONTROL AUTHORITY: THE CLEAN AIR ACT

The NAAQS established by EPA under the Clean Air Act (CAA), require each state with nonattainment areas for ozone to submit a SIP to reduce hydrocarbon emissions. Among the sources being considered for control are marine terminals serving tank barges and tankships.

The standards being considered in several states (see Appendix B) would, in effect, require loading terminals to install and operate systems for piping hydrocarbon vapors to recovery or disposal equipment. Vessels, too, would be retrofitted. Most tankships in use today have IG piping systems that would need relatively little modification (only detonation arrestors and a redundant gauging system) to serve as vapor headers. Inland barges and smaller, older tankships would face substantially larger costs, probably enough to justify scrapping some older barges.

Marine vessels, unlike other mobile emissions sources, such as automobiles, are not expressly regulated by federal air quality legislation. It is unclear whether EPA may require states to regulate marine vessel emissions. However, the CAA does not preclude states from voluntarily doing so in the SIP. (Appendix C discusses the CAA and related legal and policy issues as they apply to the control of hydrocarbon vapor emissions from tankships and barges.) Emissions from tank vessels are currently regulated indirectly, by attributing them to their stationary gathering points (in this case, marine terminals).

The CAA (section 116) recognizes the primary responsibility of the states for air pollution control (with narrow exceptions such as automobile and aircraft emissions and certain hazardous emissions). The CAA requires states to institute whatever controls are necessary to attain the NAAQS, without regard to cost. Where tank vessel hydrocarbon vapor emissions are significant, and other areas of abatement have been exploited, a state must turn its attention to these emissions in its plan for compliance with the NAAQS.

FEDERAL MARINE SAFETY REGULATORY AUTHORITY

The U.S. Coast Guard, under the Port and Tanker Safety Act (PTSA) of 1978 (33 USC section 1221-31 and 46 USC chapter 37), has clear and comprehensive responsibility for marine safety and for preventing the pollution of water by tank vessels. Under this authority, the Coast Guard regulates the design, construction, repair, maintenance, operation, and manning of vessels.

Except to a limited degree, the Coast Guard has no specific regulations in place to address the safety of vapor control devices onboard tank vessels, although it does approve and inspect vapor recovery equipment under its general inspection authority. The Coast Guard has general authority to review and approve the safety aspects of shoreside facilities at terminals. It may shut down terminals whose operations are identified as unsafe.

Some Coast Guard regulations, such as those that address water pollution, implement the terms of international agreements. Vapor control regulations might apply equally to both domestic and foreign vessels visiting a port in which controls were in force, so that issues of national uniformity and deference to international regulation require careful consideration. For example, the marine pollution convention known as MARPOL 73/78 governs discharges of polluting materials from ships, and several other agreements concern the handling of potentially hazardous or polluting cargoes. The International Maritime Organization (IMO) is the body under whose auspices most international agreements regarding vessel safety and vessel-related water pollution are developed. (Appendix C outlines the pertinent international agreements.)

SAFETY AND OPERATIONAL COMPLEXITY

The requirement for vapor control systems, it has been suggested, could increase the risks of cargo spills, fires, and explosions by adding to the operational complexity of loading operations, and in particular by requiring additional handling of potentially explosive vapors. Experience to date is too limited to justify conclusions on this score, although it does suggest that proper training and management can keep the risks of vapor control within the bounds of normal risks in the industry.

Operating vapor control systems would entail standards of precision and care, for example, well above those considered normal in the industries. Hydrocarbon cargoes might have to be handled using a level of care similar to that applied in handling hazardous cargoes under subchapter O of Title 46 of the Code of Federal Regulations.

Most tank barges and some tankships generally are loaded with hatches and vents open, to allow visual inspection of cargo levels. Most tankships are closed loaded. Containing vapors will require loading closed, with remote tank gauging systems and vapor handling systems to carry vapors to disposal or recovery facilities ashore or retain them aboard for subsequent disposal. Experience with closed loading of tank barges is limited, but suggests that, while training and supervision would need to be upgraded, the necessary operations could be carried out with little or no increase in spills or other accidents. The Coast Guard would have to proceed on the basis of risk analysis while it and the industries involved gather the experience necessary to quantify the risks. Such a risk analysis has not yet been made.

ENERGY CONSERVATION AND THE CHOICE OF CONTROL TECHNOLOGIES

A possible concern is that those implementing regulations might interpret the requirements of Lowest Achievable Emission Rate (LAER) and Best Available Control Technology (BACT), as provided by EPA regulations, to require the use of hydrocarbon destruction technologies (flares or incinerators) in cases where recovery (absorption, adsorption, or refrigeration) could provide very good, but slightly less, control. While destruction technologies do, in fact, offer marginally higher control efficiencies, consideration should be given to the energy conservation attributes of recovery.

If terminals loading only 25 percent of the crude and gasoline found it economical to use recovery technologies with a 95 percent recovery efficiency, there would be a conservation of almost 100,000 bbl/year of valuable hydrocarbons. Were systems required that destroyed these hydrocarbons to achieve 99 percent efficiency, there would only be an additional reduction of about 500 tons of volatile organic compounds (VOC), nationwide, and none would be conserved. Considering the current prospect for decreasing oil reserves and increasing dependence on foreign oil supplies in this country, such a policy, if implemented, would seem to be in conflict with national energy conservation policy.

INTERNATIONAL CONSIDERATIONS

Few foreign vessels load gasoline or crude oil at U.S. ports (see Table 1-3). Thus, the impact of regulations on foreign-flag shipping at this time would be very modest. Nevertheless, because domestic regulations would apply (however marginally) to foreign-flag ships, coordination at the international level is desirable to ensure uniformity and other forms of equity. The IMO is the international body in which most maritime pollution-control and safety agreements are developed. Domestic actions to control vessel emissions that affect foreign-flag shipping should be coordinated with other maritime nations through the IMO.

IMPACTS ON COMMERCE

State and local environmental requirements may be invalidated by federal courts if they are judged to impose unconstitutional burdens on interstate or international commerce. The permissible extent of the burden depends on the nature of the local interest and on whether there are alternatives with less impact on interstate commerce (*Huron Portland Cement Co. v. City of Detroit*, 36 U.S. 440 [1960]). A challenge to state or local regulation of vessel emissions would have to show that the burden is excessive in relation to the benefit the regulation serves

(*Pike v. Bruce Church,* 90 S. Ct. 844, 397 U.S. 137, 25 L. Ed. 2d 174 [1970]). Numerous judicial and administrative actions since the enactment of the CAA suggest that large impacts on trade are a matter of course in air quality programs, and that these impacts must be very harsh to result in invalidation by a court.

The impacts on commerce of state vapor control regulations could be substantial. First, vessel and terminal owners and operators would suffer the direct costs associated with installing and operating the necessary systems. The committee's assessment suggests that these costs would vary widely from vessel to vessel and terminal to terminal. For example, estimates made for the committee indicate that an inland river barge would incur the same retrofit cost--$168,000--as a 70,000-dwt crude carrier with 25 times the cargo capacity. Case studies of two actual terminals show added capital and operating costs that range from more than $5,000 per ton of emissions abated for a small terminal (loading 1.3 million bbl/year of gasoline) to less than $3,000 per ton of emissions for a larger terminal (loading 14.9 million bbl/year). This disparity in cost could put small terminals and inland barge companies at a competitive disadvantage in relation to larger units of the industry.

Second, the hydrocarbon vapor control standards under consideration for marine terminals and vessels would affect the cost-competitiveness of tank vessels in relation to other forms of transport. (Tank vessel carriage of petroleum cargoes domestically, as noted in Chapter 1, is declining as pipelines exploit considerable cost advantages.)

Third, the imposition of standards only in nonattainment areas for ozone, it has been suggested, would lead many vessel operators to limit their operations to areas where vapor control is not required, or where requirements are less stringent.

Without detailed economic study, it is impossible to gauge the sizes of these economic impacts. Appropriate regulatory coordination, with attention to safety and uniformity, can minimize them, but not avoid them altogether.

REGULATORY ALTERNATIVES

For federal regulators, the committee identified three possible approaches to the possible regulation of hydrocarbon vapor emissions from tank vessels: status quo, direct federal preemption, and a coordinated federal regulatory development program.

Status Quo

The first alternative, of course, is to do nothing. States would develop individual SIPs, with EPA guidance and coordination only in matters of air quality. Differing safety requirements, incompatible hardware, and varying levels of attention to operations and training would raise investment and operating costs and magnify the other economic impacts.

More important, this approach would raise the risks of loading hydrocarbon cargoes, because of the lack of attention to standardization. This would leave the Coast Guard with the responsibility for ensuring the safety of vapor control systems after the fact, after standards have been imposed in various ways by different states, and after EPA's regulatory approval procedures are well under way.

Direct Federal Preemption

The second alternative is legislation specifically regulating vapor emissions from tank vessels, in the same way that the emissions of automobiles are regulated--by direct federal standards.

This alternative would provide the maximum of uniformity. However, the need to reduce ozone levels is a highly localized one, and a national emission standard would affect vessels and terminals nationwide.

The Coast Guard would need to play a major role in developing legislation and regulations in this case. Safety, the Coast Guard's prime responsibility, must be the paramount consideration, and an administrative mechanism giving the Coast Guard a strong advisory voice would need to be established.

Coordinated Federal Regulatory Development Program

The third alternative is a cooperative program of regulatory development, in which the Coast Guard would establish vessel safety regulations (including personnel certification standards) and, in consultation with EPA, would develop compatible terminal safety provisions affecting the vapor control equipment on shore.

This alternative would leave states free to accept or reject vapor control requirements in their SIPs, in keeping with their own need to reduce ozone levels. At the same time, it would ensure the uniform requirements necessary for safety and operating efficiency, thus minimizing the economic impacts of vapor control requirements.

A formal coordinating framework, involving federal and state regulators, with advice from industry, would be necessary to carry out this approach. Industry especially would be urged to undertake training and education programs aimed at bringing operating and safety procedures up to standards similar to those that now prevail in the carriage of hazardous subchapter O cargoes.

Such an approach would streamline the regulatory process, bringing the desired environmental improvements sooner than the status quo approach. The uniformity and safety this approach would foster would tend to lower both the costs and the risks of vapor control requirements.

7

CONCLUSIONS AND RECOMMENDATIONS

1. Of the estimated 56,600 metric tons of hydrocarbon vapor emissions from tank vessels in 1985 (about 0.2 percent of national volatile organic compound emissions), about 95 percent, came from gasoline and crude oil loaded in tankships and tank barges. Almost all of these emissions were from vessels in domestic trade. About two-thirds were from inland tank barges and the rest from tankships.
2. Control and recovery of more than 90 percent of hydrocarbon emissions from tankships and tank barges are technically feasible with available technology. Hydrocarbon vapor emissions may be abated by any of several technologies to recover or destroy hydrocarbons. Technologies vary in their efficiency of abatement, with destruction technologies generally higher in efficiency than recovery technologies.
3. Abatement of hydrocarbon vapor emissions from tank vessels raises legitimate concerns of safety, cost, economic impact, and operational reliability. With appropriate government and industry attention, these concerns can be addressed. There is as yet too little experience to project conclusively the safety of planned operations.

   RECOMMENDATION: In the absence of historical safety experience, the U.S. Coast Guard should employ risk analysis in assessing the safety of the various hydrocarbon vapor emission control alternatives.
4. Safe handling of hydrocarbon vapors will require standardized equipment and procedures, which include redundant, automated gauging and alarm devices to prevent overfilling and over- or underpressuring, as well as in-line safety devices such as detonation arrestors.

   RECOMMENDATION: Development and testing programs should be pursued to advance the state of the art in gauging and alarm systems and also to assure and improve the reliability of large (> 6-in. diameter) detonation arrestors. The gauges and alarms program should include addressing the requirements of small, unpowered vessels, i.e., tank barges.
5. Safe hydrocarbon vapor emission abatement will require trained, experienced personnel and adequate control of operations by safety-

conscious management. The level of operational control in the tankship industry is, in general, adequate. However, that in the barge industry will need to be strengthened.

RECOMMENDATION: The U.S. Coast Guard should revise its personnel certification requirements for tankermen to ensure that responsible personnel are fully qualified and trained to maintain the safety of vapor control operations.

RECOMMENDATION: The tank barge industry should undertake a voluntary safety consciousness education campaign directed to operations. This campaign should complement any federal and state regulatory initiatives.

6. Controlling hydrocarbon vapors from vessels may be cost-effective in a particular nonattainment area for ozone if tank vessels are a significant source of hydrocarbon vapor emissions and cargo-loading throughput is sufficient to justify control measures.
7. The economic impact of vapor control regulations will be related to how the regulations are applied: their timing, the categories of vessels or terminals that may be controlled, and the geographical locations in which the regulations are imposed.
8. If emission controls are to be put in place, a coordinated national approach is essential to ensure the implementation of uniform and effective safety practices, with appropriate regard for the effects on interstate and international commerce. The necessary coordination could be achieved by amendments to the Federal Clean Air Act, or by a cooperative interagency program of regulatory development.

RECOMMENDATION: The U.S. Coast Guard should lead the development and implementation of a coordinated program to ensure the safety and standardization of maritime hydrocarbon vapor emissions controls. Such an interagency program should involve, at a minimum, the U.S. Coast Guard and the U.S. Environmental Protection Agency, operating according to appropriate federal rule-making procedures. Elements of the program should include:

- vessel safety;
- terminal safety;
- control of emissions; and
- industry safety education.

9. New vapor control, recovery, and disposal methods may hold promise as replacements for currently available methods.

RECOMMENDATION: A program of technical research, development, and testing should be directed to changes in operational procedures that may reduce emissions, to recovery and disposal technologies that may offer safer, less costly control measures, and to vapor barriers and foams that could help reduce hydrocarbon emissions by controlling vapor generation in cargo tanks.

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APPENDIX A

BIOGRAPHIES OF COMMITTEE MEMBERS

WILLIAM M. BENKERT spent more than three decades in the U.S. Coast Guard, retiring in 1978 with the rank of rear admiral. His career consisted almost entirely of extensive sea and marine safety duties. As a flag officer, he directed the office of Marine Environment and Systems and the Office of Merchant Marine Safety. From 1978-1984, RADM Benkert was president of the American Institute of Merchant Shipping, a trade organization of U.S.-flag tanker operators. From 1984-1985, he was president of Petroferm Marine, Inc., a company which sought to develop new products for marine applications. RADM Benkert has served on the Marine Board of the National Research Council for 6 years.

SAMI ATALLAH is president of Risk and Industrial Safety Consultants, Inc., a firm that conducts R&D and provides technical consulting services in areas relating to fire and explosion technology, chemical process safety, risk analysis, and the market potential for fire and safety-related equipment and products. Previously, he had served as director of the Environment, Safety, and Distribution Research Department at the Gas Research Institute, manager of the Fire Technology Unit at Arthur D. Little, Inc., senior research engineer at Factory Mutual Research Corporation, and professor of chemical engineering at Tufts University. Mr. Atallah holds B.S. and M.S. degrees in chemical engineering from Lehigh University and the degree of Chem. E. from Massachusetts Institute of Technology. He is a fellow of the American Institute of Chemical Engineers and a member of the Combustion Institute, Society of Fire Protection Engineers, Society of Risk Analysis, National Fire Protection Association, American Society of Safety Engineers, and the American Gas Association. He is a registered professional engineer in Massachusetts.

ALLEN ELI BELL has held increasingly responsible legal and management positions with the Texas Air Control Board (TACB) since graduating from the University of Texas Law School in 1972. In March 1986, he was appointed executive director. Mr. Bell holds a B.B.A. from North Texas State University in addition to his law degree. He is a member of the Texas Bar as well as the National Air Pollution Control Association.

ROBERT M. FREEMAN is the engineering manager of Exxon Shipping Co., the U.S. marine transportation operating division of Exxon Corp. In his current job, Mr. Freeman is responsible for Exxon's shipbuilding, conversion, and engineering/technical programs. In previous positions with Exxon, he has been responsible for air quality issues concerning vessel operation and has also served as an engineering project manager responsible for ship conversion and other engineering projects. His design concept for a vapor balance system resulted in the first full-time hydrocarbon vapor control system for loading marine vessels. Mr. Freeman served in the Navy for 10 years prior to joining Exxon in 1975. He holds a B.S. degree in mechanical engineering and an M.B.A. degree from the University of Pittsburgh.

ROBERT J. KLETT manages Chevron Corporation's Engineering Technology Department, Environmental Engineering Division. He is responsible for the process development, process design, and startup of refinery process plants, as well as environmental process design and project-permitting activities for refinery, chemical, and synthetic fuel projects. His career of increasingly responsible engineering and research positions at Chevron has encompassed both engineering and environmental responsibilities. His environmental activities have included the process design and trouble-shooting of plants to meet both air and water emission requirements. He has also determined cost-effective environmental compliance strategies and worked with specific projects to obtain necessary environmental permits. His engineering activities have encompassed evaluating and designing facilities to be located both on ship and on shore to process hydrocarbon gas streams. He has analyzed the cause of oxygen buildup to potentially hazardous levels in the vapor space of ships during product transport. Dr. Klett has B.Ch.E., M.S. (chemical engineering), and Ph.D. degrees from the Georgia Institute of Technology. He is a member of the American Chemical Society and the American Institute of Chemical Engineers, and is a registered professional engineer in California.

HENRY S. MARCUS has been at the Massachusetts Institute of Technology (MIT) since 1971 and currently holds the positions of associate professor of marine systems in the Ocean Engineering Department and chairman, Ocean Systems Management Program. He has also served as a transportation consultant to maritime industries and government. Dr. Marcus holds a B.S. degree in naval architecture from Webb Institute, two M.S. degrees from MIT (one in naval architecture and the other in shipping and shipbuilding management), and a D.B.A. degree from Harvard University. Dr. Marcus's research interests include how waste disposal and other externally imposed operating requirements are accommodated by marine transportation systems. Dr. Marcus was a member of the National Research Council's Committee on Maritime Innovation and also the Maritime Transportation Research Board in the late 1970s; more recently he has served as a member of the Marine Board's Committee on Productivity of Marine Terminals.

ARTHUR McKENZIE has over 50 years of experience in the tanker industry, 11 of them serving on tankers as a seaman and deck officer. He attained the rank of chief mate. He worked for 29 years ashore for Exxon, all of that time involved directly or indirectly with the operation of oil tankers. During his last 8 years with Exxon, he served as senior marine adviser. After 40 years with Exxon, Mr. McKenzie retired and established the Tanker Advisory Center, Inc. For over 25 years, Mr. McKenzie has taught a widely acclaimed 30-hour course entitled, “Petroleum Tankship Operations.” McKenzie served as a member of the group that prepared the report *Materials Aspects of Inert Gas Systems for Cargo Tank Atmosphere Control* for the National Materials Advisory Board of the National Research Council. He has also served on the U.S. Coast Guard's Rules of the Road Advisory Committee. He publishes an annual reference book, *Guide for the Selection of Tankers.*

CONSTANTINO J. SANTAVICCA is vice-president, engineering, of Ohio River Co., the largest operator of barges on the U.S. inland waterways. He has been associated with Ohio River Co. for more than 20 years and has served in increasingly responsible maintenance and engineering positions. He is currently responsible for the development, implementation, and monitoring of maintenance/repair programs and the design, construction, and capital budget functions for the company's floating and shoreside facilities. Mr. Santavicca holds a B.S. degree in marine and electrical engineering from the Massachusetts Maritime Academy, and an M.B.A. degree from Xavier University. He is a member of the Society of Naval Architects and Marine Engineers and the American Society of Mechanical Engineers, and is a U.S. Coast Guard-licensed marine engineer.

RICHARD SCHWING is a principal research engineer in the Operating Sciences Department of the General Motors Research Laboratories. He is responsible for methods development for a range of multidisciplinary research programs involving environmental impact, technological forecasting, and social change. He is editor, with W. A. Albers, Jr., of *Societal Risk Assessment: How Safe Is Safe Enough?* and author of several epidemiology, benefit/cost, cost effectiveness, and risk analysis papers. Dr. Schwing has served the International Association for Impact Assessment as president. In addition, he has served the Resources for the Future Environmental Protection Agency Benefits Research Advisory Group, the National Association of Manufacturers' Risk Analysis Task Force, the National Commission on Air Quality Benefits Panel and organized a Society of Automotive Engineers' Benefit/Cost Panel on Vehicle Emissions and a Society of Automotive Engineers' Risk Analysis Panel. In 1983, he was awarded the John M. Campbell Award by General Motors for his contributions to science. He is a member of the American Chemical Society, American Association for the Advancement of Science, Sigma Xi, and the Society for Risk Analysis. His three degrees, all in chemical engineering, are from the University of Michigan, where he specialized in thermodynamics, chemical kinetics, and nuclear engineering.

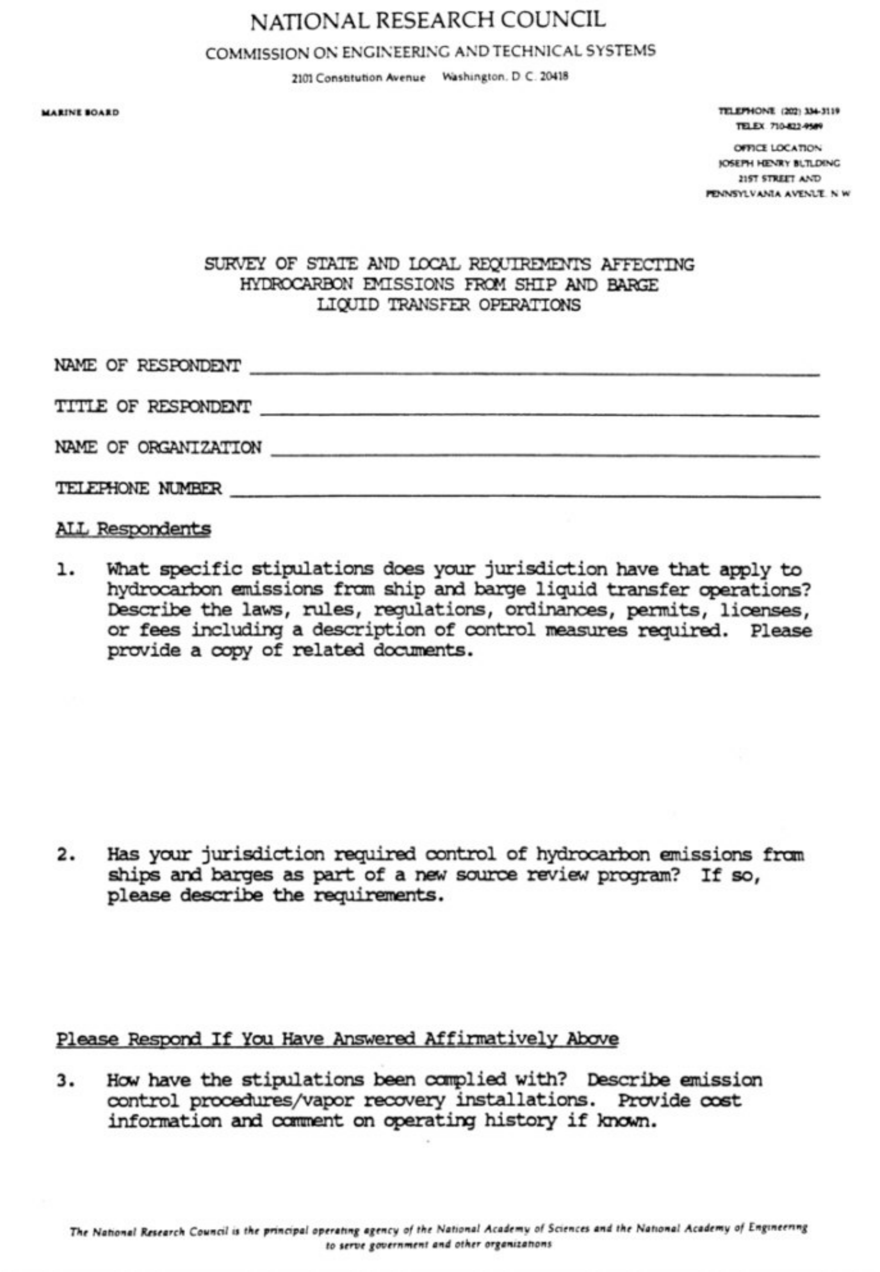
APPENDIX B

STATUS OF STATE AND LOCAL VAPOR CONTROL REQUIREMENTS AFFECTING MARITIME OPERATIONS

A survey sheet was sent to 62 state and local environmental or air pollution control agencies in an effort to assemble an inventory of stipulations that affect hydrocarbon emissions from tankships and tank barge liquid transfer operations in U.S. coastal, river, and lake ports. A copy of the survey sheet is attached as Figure B-1.

Thirty-seven responses were received including 26 from states, 7 from counties and districts, and 3 from cities. One county agency responded that its state has jurisdiction. Table B-1 summarizes the responses. Responses or summaries are also included for the key questions in the survey. Results may be summarized as follows:

1. Out of 36 agencies, only 4 have regulations that require controls: Bay Area Air Quality Management District, California; Florida Department of Environmental Regulation; State of Michigan Department of Natural Resources; and Wayne County Department of Health operating under Michigan state regulations. However, Florida and Wayne County apparently have no facilities to which the rules currently apply. Michigan has made no determination as to the applicability of their regulations to any ship and barge operations in their state. Note that responses were not received from San Diego or Santa Barbara air quality agencies in California.
2. Six authorities, Alaska, Bay Area, South Coast, Ohio, Michigan, and Puget Sound, have required or have rules that require controls under new source permitting: vapor return, incineration, submerged fill, and limit on throughput. Thirty said they have not required and have no rules to require hydrocarbon emission controls for ships and barges as part of a new source review program.
3. Compliance has not been determined by Alaska, Michigan, and Bay Area while Ohio and Puget Sound report compliance with vapor incineration and throughput limits, respectively.
4. Alaska, Michigan, Bay Area, Ohio, and Puget Sound indicate no enforcement actions have been taken.
5. Fourteen of the responding agencies said they had considered controlling hydrocarbon emissions from ships and barges while 21 said they had not. Some of the reasons given for dropping consideration are interference with interstate commerce, absence of regulations elsewhere, not cost-effective, insufficient data, safety concerns, unfair competition



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SURVEY OF STATE AND LOCAL REQUIREMENTS AFFECTING
HYDROCARBON EMISSIONS FROM SHIP AND BARGE
LIQUID TRANSFER OPERATIONS

NAME OF RESPONDENT ____________________

TITLE OF RESPONDENT ____________________

NAME OF ORGANIZATION ____________________

TELEPHONE NUMBER ____________________

ALL Respondents

1. What specific stipulations does your jurisdiction have that apply to hydrocarbon emissions from ship and barge liquid transfer operations? Describe the laws, rules, regulations, ordinances, permits, licenses, or fees including a description of control measures required. Please provide a copy of related documents.

2. Has your jurisdiction required control of hydrocarbon emissions from ships and barges as part of a new source review program? If so, please describe the requirements.

Please Respond If You Have Answered Affirmatively Above

3. How have the stipulations been complied with? Describe emission control procedures/vapor recovery installations. Provide cost information and comment on operating history if known.

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FIGURE B-1 Survey of state and local requirements affecting hydrocarbon emissions from ship and barge liquid transfer operations.

4. Have you had to enforce any of the above stipulations (contrasted with voluntary compliance)? Please list the nature of the actions, whether the actions were against vessels or terminals, and the nature of the outcome.

<u>ALL Others</u>

5. Has your jurisdiction considered controlling hydrocarbon emissions from ships and barges? Describe the proposals and their status.

<u>ALL Respondents</u>

6. Other comments.

Respond by October 31 to:

Charles A. Bookman
Committee on Control and
Recovery of Hydrocarbon Vapors
from Ships and Barges
Marine Board, Room JH 702
National Research Council
2101 Constitution Avenue
Washington, DC 20418

TABLE B-1 Survey of State and Local Requirements Affecting Hydrocarbon Emissions from Ship and Barge Liquid Transfer Operations: Sumary of Responses

Jurisdiction	Stipulations That Apply?	New Source Review?	Compliance, Controls, Cost?	Need For Enforcement	Controls Considered?
Alabama	None	No			No
Alaska	None	Yes,PSD[a]	Vapor return, not inspected	No	No
Anchorage, Alaska	None	No			No
Arkansas	None	No			No
California	None	No			Yes[b]
Bay Area Air Quality Management District, California	Yes	Yes	Under review	No	Yes
South Coast Air Quality Management District, California	None	Yes		No	Yes
Connecticut	None	No			Yes
Florida	Yes	No			No
Georgia	None	No			No
Hawaii	None	No			No
Illinois	None	No			Yes
Indiana	None	No			No
Kentucky	None	No			No

Jefferson County, Louisville, Kentucky	None	No			Yes
Louisiana	None	No			Yes
Maryland	None	No			Yes
Michigan	Yes	Yes	No information	No	No
Wayne County, Detroit, Michigan	Yes	No		No sources subject to regulation	Yes
Minnesota	None	No			No
Mississippi	None	No			No
New Hampshire	None	No			No
New York	None	No			No
North Carolina	None	No			No
Ohio	None	Yes, benzene loading	Yes, incinerator	No	Yes
Hamilton County, Southwest Ohio, Cincinnati, Ohio	None	No			No
Pennsylvania	None	No			Yes
Philadelphia, Pennsylvania	None	No			Yes
Allegheny County, Pittsburgh, Pennsylvania	None	No			No

Rhode Island	None	No			No
South Carolina	None	No			No
Texas	None	No			Yes
Houston, Texas	None	No			Yes
Virginia	None	No			No
Puget Sound, Washington	None	Yes, annual limit on gasoline loaded into barges	Yes	No	Yes
Wisconsin	None	No			No
Milwaukee County, Wisconsin	No jurisdiction				
Totals	Yes: 4 None: 32	Yes: 6 No: 30	Yes: 2 No: 2	No: 6	Yes: 15 No: 22

[a] Prevention of Significant Deterioration permit in attainment areas.

[b] See following pages for complete responses.

from unregulated terminals, need for a national standard, need for Coast Guard approval, and federal/ state concerns.

The Pennsylvania state program provided a copy of a draft regulation and support documentation. The regulation calls for displaced gasoline vapors from barge loading to be directed to a system where at least 80 percent, by weight of the organic compounds in the vapor, are recovered or destroyed.

6. Nine agencies provided comments on various aspects of ship and barge hydrocarbon controls ranging from support for federal control to willingness to comply with Environmental Protection Agency (EPA) requirements to continuing with requirements at the state level.

A vast majority of state and local agencies responding to the survey have no regulations that apply to ship and barge loading operations. Most agencies have not considered such controls and those that have appear to be waiting for action at the federal level.

SUMMARY OF AFFIRMATIVE RESPONSES TO QUESTIONS 1 AND 2

1. What specific stipulations does your jurisdiction have that apply to hydrocarbon emissions from ship and barge liquid transfer operations? Describe the laws, rules, regulations, ordinances, permits, licenses, or fees including a description of control measures required. Please provide a copy of related documents.
2. Has your jurisdiction required control of hydrocarbon emissions from ships and barges as part of a new source review program? If so, please describe the requirements.

Alaska

A Prevention of Significant Deterioration (PSD) permit was issued to Alyeska (pipeline service facilities) requiring vapor control from tanker loading using vapor return to loading station. Vapor recovery was installed but has not been inspected or enforced by the state or EPA. Copies of regulations were not provided.

South Coast Air Quality Management District

Control of hydrocarbon emissions from ships or barges has been required as part of its New Source Review (NSR) program. The district's NSR rule (regulation XIII) requires that all new sources be equipped with Best Available Control Technology (BACT). This would require hydrocarbon controls on new liquid transfer operations from ships and barges.

Bay Area Air Quality Management District

Marine operations are covered under new source review requirements in district regulation 2, rule 2-2-208 under the definition of a stationary source. The definition reads in part:

> In addition, in cases where all or part of a stationary source is a facility used to load cargo onto or unload cargo from cargo carriers, other than motor vehicles, the [Air Pollution Control Officer] shall consider such carriers to be parts of the stationary source. Accordingly, all emissions from such carriers (excluding motor vehicles) while operating within the District and within the California Coastal waters adjacent to the Air Basin shall include those that result from the purging or other method of venting vapors; and from the loading, unloading, storage, processing, and transfer of cargo. However, emissions from the operation of the carriers' engines shall be considered only while such carriers are operating within the District.

In 1987, the district granted a request by an oil refiner to control loading emissions voluntarily (banking the emissions thus abated for use in offsetting emissions from future expansions). In the same year, a major integrated oil company applied for permits to employ vapor control in a refinery and a crude oil lightering operation, also with the aim of banking the emissions-abatement credit.

Florida

State rules governing hydrocarbon emissions from these sources are described in rule 17-2.620, General Pollutant Emission Limiting Standards, as follows:

(1) Volatile organic compounds emissions or organic solvents emissions.

(a) No person shall store, pump, handle, process, load, unload, or use in any process or installation volatile organic compounds or organic solvents without applying known and existing vapor emission control devices or systems deemed necessary and ordered by the Department.

(2) Objectionable Odor Prohibited--No person shall cause, suffer, allow, or permit the discharge of air pollutants which cause or contribute to an objectionable odor.

Rule 17-2.650(1)(f) 9 and 10 apply to bulk gasoline plants and bulk gasoline terminals.

The state has not required control on ships and barges as part of its new source review program because “this situation has not come up as of this date.”

Puget Sound Air Pollution Control Agency

Although this agency has regulations that require vapor recovery at gasoline loading terminals, such controls have not been required for barge loading of gasoline. The agency says that it has limited the annual amount of gasoline loaded into barges from a modified oil refinery.

State of Michigan Department of Natural Resources

This agency has regulations governing gasoline transfer to both existing and new delivery vessels. Rule 608 requires that, for loading of gasoline into existing delivery vessels at loading facilities handling less than 5 million gallons per year, the delivery vessel must be controlled with a vapor balance system (90 percent efficiency) if the loading facility is located in a designated area, or equipped with a submerged fill pipe if it is located in any other area of the state. Rule 609 requires that, for loading of any organic compound with a true vapor pressure of more than 1.5 psia into any existing delivery vessels at loading facilities handling 5 million or more gallons per year, the delivery vessel must be controlled with a vapor recovery system (emissions not to exceed 0.7 pounds per 1,000 gallons loaded) if the loading facility is located in an ozone nonattainment area, or equipped with a submerged fill pipe if it is located in any other area of the state.

Loading of gasoline from a stationary vessel into any new delivery vessel in facilities having a throughput of less than 5 million gallons per year is regulated under rule 705. In designated areas, a vapor balance system is required that will return not less than 90 percent by weight of the displaced gasoline vapor from the delivery vessel to the stationary vessel. In other areas, submerged fill equipment is required. Rule 706 applies to loading of new delivery vessels with organic compounds having a true vapor pressure of more than 1.5 psia at loading facilities handling 5 million or more gallons per year. Emissions in this instance shall not exceed 0.7 pounds of organic vapor per 1,000 gallons of organic compounds loaded if the facility is located in an ozone nonattainment area. In other areas, submerged fill equipment is required. This latter rule would apply to gasoline transfers.

Wayne County, Detroit, Michigan

This agency enforces Michigan Air Pollution Control Commission General Rules. The agency has not required controls under these rules.

RESPONSES TO QUESTION 5

5. Has your jurisdiction considered controlling hydrocarbon emissions from ships and barges? Describe the proposals and their status.

California

In June 1984, the California Air Resources Board presented to the California Legislature the *Report to the California Legislature on Air Pollutant Emissions from Marine Vessels.* I have attached a copy of that report for your information.

Bay Area Air Quality Management District, California

Yes. Require control of gasoline and crude oil and petroleum products with a vapor pressure of greater than 1.5 psia true to a level abated by vapor recovery.

South Coast Air Quality Management District, California

Our rules development group considered controlling hydrocarbon emissions by (1) vapor balance systems, (2) carbon absorption, and (3) incineration as part of an overall revision of rule 462, which addresses land-based bulk liquid transfers. They determined that requiring such controls on ships or barges would not be cost-effective, considering the amount of emissions and the cost of installing the above controls. No such provision was added to rule 462.

Connecticut

Yes, at one time. We dropped it from consideration because of interference with interstate commerce.

Illinois

At the first hearing in this matter on October 24, 1986 [of a generic rule for hydrocarbon emission control], the Illinois Environmental Protection Agency presented a proposal which excluded barge loading from applicability. This was done in light of the absence of such regulations elsewhere and current policy, and the understanding that potentially affected parties would present factual testimony demonstrating that further control measures should not be mandated in Illinois.

Jefferson County, Louisville, Kentucky

Yes, many years ago. We had insufficient data upon which to regulate and did not. No current additional action is pending.

Louisiana

Yes. We have considered this, but these controls were thought to be too expensive and potentially dangerous unless required nationwide.

Maryland

Yes. A regulation was proposed that would have required collection of all vapors displaced in barge or ship loading operations, and recovery or destruction of those vapors. These proposals were dropped due to industry concerns regarding competition from uncontrolled terminals and safety.

Wayne County, Detroit, Michigan

If ships and/or barges handling volatile organic compounds were involved in transfer operations in Wayne County, the emissions from such operations would be regulated [by this agency under Michigan Air Pollution Control Commission General Rules].

Ohio

We are currently evaluating the feasibility of requiring hydrocarbon emission controls for a barge loading facility near Cleves, Ohio. Although the facility is currently shut down, it may be subject to Reasonably Available Control Technology requirements as a Noncontrol Techniques Guideline source should it be restarted in the near future.

Pennsylvania

The bureau drafted regulations and circulated them to affected parties. The bureau received many comments that indicated a need to resolve federal/state concerns. The bureau has suspended work on this regulation until this issue is resolved. Enclosed is a copy of the draft regulation and support documentation for your records.

Philadelphia, Pennsylvania

Not formally or specifically. The control of hydrocarbon emissions from ships and barges may be considered if the federal EPA recommends it and publishes control technology guidances.

Texas

In late 1972 and early 1973, the Texas Air Control Board proposed rules to control volatile organic compound emissions from various sources in the Gulf Coast area. These proposed rules included requirements for the control of emissions from ship and barge loading as well as the loading of trucks and railroad tank cars. Following the public participation process, the board deleted the proposed requirement for control of loading of marine vessels based on the view that the regulation of such vessels should be centralized in the U.S. Coast Guard.

A study of vessel emissions control has recently been completed by the legislatively mandated Clean Air Study Committee. The committee has recommended that the Texas legislature adopt a resolution to Congress supporting national control should the results of the current National Research Council study indicated that such control is feasible and advisable.

Houston, Texas

Yes, prefer national standard.

Puget Sound, Washington

Yes. Barge loading of gasoline is a major source of volatile organic compound emissions in our jurisdiction and we considered adopting vapor recovery requirements. However, we found that the Coast Guard has not approved vapor recovery systems for barges. Since the institutional obstacles were too great, we dropped the idea.

RESPONSES TO QUESTION 6: OTHER COMMENTS

Alabama

When a new source of volatile organic compound (VOC) emissions from barge or ship loading operations applies for an air permit, the state is required by federal regulations to determine the Best Available Control Technology or Lowest Achievable Emission Rate for that source. Control of VOC emissions at a barge dock is not impossible, just not practical. It would be easier to have a vessel built for vapor control and approved by the Coast Guard rather than retrofit existing vessels that may use the dock. It is not the state's interest to conflict with federal maritime safety, but to comply with the U.S. Environmental Protection Agency's requirements of new source review and, in cases like this, we would have to address maritime dock vapor control.

Anchorage, Alaska

The only problems have been with visible emissions.

Bay Area Air Quality Management District, California

Please keep us informed. TOSCO Oil Company at Martinez, California is proposing vapor recovery on gasoline loading onto ships and barges in order to provide emissions reduction credit. [Now in operation; see Summary of Affirmative Responses to Questions 1 and 2.]

Connecticut

Hydrocarbon emissions from barge loading is substantial and should be controlled at the federal level. Emissions from such operations in New Jersey are approximately equal to 10 percent of our entire hydrocarbon emissions from all sources in our state. Technology for controlling these emissions is either available or able to be developed. We will gladly support any efforts you make in establishing a program for the control of these emissions.

Kentucky

If the EPA issues guidance to control ship or large liquid transfer operations, then Kentucky will follow EPA guidance.

Louisiana

Programs such as offsets in urban nonattainment areas, prevention of significant deterioration, and national emission standards for hazardous air pollutants may require reductions beyond the current regulations. A company in Louisiana had to control its liquid transfer for ships and barges for acrylonitrile (a hazardous air pollutant). We have some permits where ship and barge liquid transfer controls were proposed as reductions for offsets (not sure any were actually built).

Maryland

A national regulation of barge and ship loading vapor emissions is the only viable option because the barges and ships must have standardized fittings to mate with all terminals. Furthermore, national coverage eliminates the potential competition from uncontrolled facilities with lower handling costs.

Texas

The loading of toxic, odorous, or flammable liquids is often controlled by a permit applicant due to safety or other requirements. The staff would seek to ensure that a permit transaction would not result in vessel emissions that would lead to adverse health effects or nuisance conditions prohibited by the Texas Clean Air Act as a condition of air pollution.

Puget Sound, Washington

If barge-loading vapor recovery was found to be technically feasible and safe, we would seriously consider requiring it.

APPENDIX C

LEGAL ISSUES AFFECTING REGULATION OF VESSEL CARGO VAPOR EMISSIONS

Austin P. Olney and Laurie A. Frost

Widespread failure of most of the nation's urban areas to meet air quality standards mandated by air pollution control laws, especially for ozone, has catapulted concern about future strategies for controlling sources of air pollution to the top of the priority list for federal, state, and local officials, health groups, and environmentalists. Areas that fail to meet the statutory deadline of December 31, 1987, set by Congress for meeting the federal ozone standard, face stiff economic sanctions, such as loss of federal highway funds, bans on new construction, and loss of sewage treatment grants.

Metropolitan areas across the country are considering new air pollution control measures targeted at smaller industrial sources, such as dry cleaners and automotive body shops, as well as automobiles and other mobile sources, such as marine vessels, in an effort to comply or to show progress toward compliance with the ozone standard by the statutory deadline. These additional sources emit volatile organic compounds, the primary precursors of ozone.

This paper discusses the statutory and regulatory framework affecting marine vessel emissions resulting from loading and unloading crude oil and petroleum products. The discussion is divided into two parts. The first section presents a general review of the structure of air pollution control laws, and marine pollution and safety laws and regulations. The second section describes how these laws and regulations interact, and how they may affect the ability of states and the federal government to regulate emissions from marine vessels.

SURVEY AND STRUCTURE OF LEGAL AUTHORITIES

The Clean Air Act

The Clean Air Act (CAA),[1] as the federal air pollution laws are commonly called, is the product of a series of major legislative initiatives from Congress, including the Clean Air Act of 1963,[2] the Air

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TABLE C-1 Federal Air Pollution Legislation

Legislation	Public Law	Date	Statutory Designation
Air Pollution Control Act	84-159	6/14/55	69 Stat. 3221
Air Pollution Control Act Extension	86-365	9/22/59	73 Stat. 646
Motor Vehicle Exhaust Study Act of 1960	86-493	6/8/60	74 Stat. 162
Air Pollution Control Act	87-761	10/9/62	76 Stat. 760
Clean Air Act of 1963	88-206	12/17/63	77 Stat. 392
Motor Vehicle Air Pollution Control Act	86-272	10/20/65	79 Stat. 954
Clean Air Act Amendments of 1966	89-675	10/15/66	80 Stat. 954
Air Quality Act of 1967	90-148	11/21/67	81 Stat. 485
Clean Air Act Amendments of 1970 (with technical amendments in the Comprehensive Health Man-power Training Act of 1971)	91-604	12/31/70	84 Stat. 1676
Clean Air Act Extension	93-15	4/9/73	87 Stat. 11
Energy Supply and Environmental Coordination Act of 1974	93-319	6/24/74	88 Stat. 246
Clean Air Act Amendments of 1977 (with technical amendments in the Safe Drinking Water Act of 1977)	95-95	8/7/77	91 Stat. 685
National Commission on Air Quality	96-300	7/2/80	94 Stat. 831
Steel Industry Compliance Extension Act	97-23	7/17/81	95 Stat. 139
Department of Housing and Urban Development Appropriation Act, 1984	98-45	7/12/83	97 Stat. 219

Quality Act of 1967,[3] the Clean Air Act Amendments of 1970,[4] and the Clear Air Act Amendments of 1977.[5] A chronology of the various federal clean air laws is shown in Table C-1.

The Clean Air Act Amendments of 1970 created a cooperative framework for federal and state enforcement of a rigorous and comprehensive program to control air pollution by dividing responsibility between federal agencies and the states to meet nationwide air quality goals. One objective was “to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and productive capacity of its population.”[6] To accomplish this purpose, Congress directed that National Ambient Air Quality Standards (NAAQS) be established (in the form of maximum concentration levels) for certain criteria pollutants. Congress wanted the air to be clean without providing a definition of what clean was; Congress left the definition of clean to be determined by the Environmental Protection Agency (EPA). Congress also stated that pollution emissions from new sources should be constrained, but again, the degree of constraint was left up to EPA.

The Clean Air Act Amendments of 1977 retained the basic structure of the 1970 law, but added new compliance dates and enforcement mechanisms. EPA was directed to set and enforce the regulations required by the CAA. EPA developed the criteria and set primary and secondary standards for certain pollutants deemed detrimental to public health, based on scientific and technical data, while the states were responsible for formulating and implementing a state plan to achieve, maintain, and enforce the federal standards.

The CAA established three regulatory schemes: one for pollution emissions from existing stationary sources, the second for emissions from future or “new” stationary sources, and the third for hazardous pollutants. The CAA applies to both major stationary sources, such as industrial plants or facilities, and mobile sources, such as automobiles and airplanes. In addition, indirect sources, such as parking lots and highways, which do not emit pollutants but which attract mobile sources are subject to regulation under the State Implementation Plan (SIP). The CAA does not expressly provide the authority to regulate marine vessel emissions.

Air Quality Control Regions

Section 107 requires each state to divide the area within its borders into smaller regions called Air Quality Control Regions (AQCRs) so that the regulations for air pollution control can be specified on a source-specific basis [42 USC § 7407]. These regions are listed in 40 C.F.R. Part 81 (1986). EPA regularly publishes data indicating which AQCRs are in compliance with primary and secondary standards, and which are not. Once the ambient concentrations of pollutants in an AQCR are determined, the region is placed into one of two classes:

1. Attainment areas, in which the ambient air concentration is below that specified in the NAAQS; and
2. Nonattainment areas, in which the ambient air concentration is above that specified in the NAAQS.

Air Quality Criteria

Section 108 directs EPA to publish, and to periodically revise, a list of air pollutants that “may reasonably be anticipated to endanger public health or welfare” [42 USC § 7408(a)(1)(A)]. Under this provision, EPA needs to show a reasonable basis for its determination that there is a risk of harm to the public, rather than evidence of actual harm, before regulating a pollutant. In 1971, standards were initially promulgated for six so-called criteria pollutants: sulfur dioxide

(SO_2), particulate matter or dust (PA), nitrogen oxides (NO_x), carbon monoxide (CO), photochemical oxidants or "ozone,"[7] and hydrocarbons.[8] In 1978, standards for another pollutant--lead--were added. After a pollutant is listed, EPA is required by section 108(a)(2) to publish air quality criteria for that pollutant, reflecting the latest scientific knowledge useful in indicating its identifiable effects on public health or welfare [42 USC § 7408(a)(2)].

National Ambient Air Quality Standards

Based on the criteria established for each pollutant listed under section 108, section 109(a) directs EPA to promulgate NAAQS for each pollutant [42 USC § 7409(a)]. The NAAQS are only minimum standards. Section 116 permits the states to set more rigorous standards under their SIPs [42 USC § 7416]. The NAAQS are not directly enforceable; all emission limitations are established to meet the NAAQS. It is the emission limits which are enforceable.

Two standards are to be set for each pollutant. Primary ambient air quality standards are standards the attainment and maintenance of which are necessary to protect the public health [42 USC § 7409(b)(1)]. Secondary ambient air quality standards are standards the attainment and maintenance of which are necessary to protect the public welfare from known or anticipated adverse effects associated with the presence of the corresponding pollutants in the ambient air [42 USC § 7409(b)(2)]. Achievement of these uniform standards throughout the country forms the primary goal of the CAA.

The NAAQS appear in 40 C.F.R. Part 50. The standard for ozone is found in 40 C.F.R. § 50.9. EPA is not required to consider factors such as technology or costs of compliance in setting ambient standards. Nor may such factors be used to justify a failure to attain the standards. It is the need to achieve the primary standards that is causing the states to consider regulating marine vessel emissions.

State Implementation Plans

The CAA places primary responsibility for attaining and maintaining the NAAQS with the states through development and adoption of a SIP that targets specific emission sources and sets limits on their emissions at levels that let the state meet the nationally set air quality standards. Section 110(a) specifies that each state must develop and submit to EPA a SIP that provides a control strategy for the attainment, maintenance, and enforcement of the NAAQS by that state in each air quality control region within its boundaries [42 USC § 7410 (a)(1)]. EPA must approve or disapprove the state plans within 4 months after submission of the proposed plan [42 USC § 7410(a)(2)]. The administrator may approve a state plan only if the plan meets the requirements of section 110(a)(2), which include, among other things, commitments to implement pollution-reduction programs pursuant to enforceable timetables [42 USC § 7410(a)(2)].

Each SIP describes the air quality in each AQCR in the state, sets forth emission inventories of all sources that emit the criteria pollutants, and establishes emission limitations and compliance schedules for each source. A state, through its SIP, may order particular factories and other sources of pollution to reduce emissions to a target level by a certain date. These emission limitations are applicable only to existing sources; EPA has preempted emission standards for new sources. In addition, each SIP contains procedures for granting permits for new sources under new source review systems, as well as procedures for reporting, monitoring, and enforcement. The 1977 CAA Amendments also require the states to classify the state's regions according to whether they are in compliance with air quality standards. The consequences of this designation are described below.

SIPs are the keystone of EPA's air pollution control effort. Once approved by EPA, a SIP becomes part of the federal/state cooperative framework and must be carried out by the state.[9] It can be enforced by either the state or EPA. Congress recognized that a state may need to revise its SIP to reflect changed local needs, new technology, or other developments. Accordingly, the CAA provides that a state may propose periodic revisions of its SIP to EPA. As with original proposals, EPA must approve revisions that satisfy the requirements listed in section 110 (a)(2) [42 USC § 7410(a)(2)].[10]

Section 110 of the CAA also requires EPA to notify a state and to set a time limit for revision of the state's SIP when available information indicate the SIP is inadequate to achieve a NAAQS by the statutory deadline [42 USC § 7410(a)(2); (c)(1)(C)].

Industry challenges to the technological and economic feasibility of the emission limitations in a SIP may be heard only at the state level when a SIP is under consideration.[11] The same is true of challenges to the allocation among various sources of the burden imposed by emission limitations in a SIP.[12] Therefore, early involvement by regulated industries in state proceedings for the adoption and revision of SIPs is essential to preserving rights to challenge the technological or economic features of a SIP regulation.

Standards of Performance for New Stationary Sources

The CAA directs EPA to establish new source performance standards (NSPS) under section 111 for new stationary sources and major modifications of existing stationary sources in particular industrial categories. These standards establish national limits for emissions from each category of sources, to keep new pollution at a minimum while emissions from existing sources are reduced to meet air quality goals.

The NSPS differ from ambient standards in that they are developed for particular sources of pollutants rather than to air quality generally. They target specific pollutants from specified industries. They are designed to allow limited industrial growth. Because they are established at a national level, they preclude any state from becoming a “pollution haven” and attracting industry by lenient air quality standards. The NSPS must reflect the “best system of continuous emissions reduction which (taking into account the cost of achieving such emission reduction . . .) the Administrator determines has been adequately demonstrated" [42 USC § 7411(a)(1)(C)]. This "best technology" requirement recognizes that it is usually more economical to build emission controls into new sources than to retrofit existing sources. The standards are minimums; states may impose more stringent standards.

As of July 1, 1986, NSPS had been promulgated for more than 51 source categories. These are published in 40 C.F.R. § 60.16 (1986). If it is not feasible to establish an emission standard, EPA may instead prescribe a design, equipment, work practice, or operation standard. The work practice regulation must be converted to a numerical emission limit as soon as it is practicable to establish such limits. Operators subject to NSPS must undergo preconstruction and prestart-up review and must demonstrate compliance.

EPA authority can be delegated to states pursuant to section 111(c) [42 USC § 7411(c)]. In addition, if EPA sets a NSPS for a source category, then states must regulate nonhazardous pollutant emissions not covered by air quality criteria from existing sources in that category [42 USC § 7411(d)]. Waivers are provided for new sources that use "innovative technology" [42 USC § 7411(j)].

Hazardous Air Pollutants

Under section 112 of the CAA, EPA is required to control hazardous pollutants discharged into the air [42 USC § 7412]. A "hazardous air pollutant" is defined as one that "causes, or contributes to, air pollution which may reasonably be anticipated to result in an increase in mortality" or "serious irreversible, or incapacitating reversible, illness," and for which no ambient air quality criteria or standards have been promulgated pursuant to section 108 or 109 [42 USC § 7412(a)(1)]. EPA is authorized to promulgate such national emission standards for hazardous air pollutants (NESHAPS) for both new and existing stationary sources. These pollutants are deleterious to health, but are not produced in large enough quantities to justify imposition of full NSPS programs.

Implementation and enforcement of NESHAPS may be delegated to the states pursuant to section 112(d) similar to the delegation of authority for NSPS pursuant to section 111(c) [42 USC § 7412(d)]. NESHAPS are published in 40 C.F.R. Part 61 (1986) for beryllium, asbestos, mercury, vinyl chloride, benzene, coke oven emissions, inorganic arsenic, radio-nuclides, and radon-222 emissions.

Prevention of Significant Deterioration

The 1977 amendments put in place a program for the "prevention of significant deterioration" (PSD), a concept developed by EPA to deal with new industrial growth in areas of the country that had attained NAAQS to ensure that economic growth will not degrade existing clean air resources. The PSD program is intended to preserve the attainment status of AQCRs that already meet the NAAQS [42 USC §§ 7470-7491]. All PSD areas in a state are designated as Class I, Class II, or Class III areas, reflecting the amount of industrial growth and resulting diminution of air quality that will be allowed in each area. Class I areas are the most pristine areas, such as large national parks and wilderness areas.

The amendments in section 163(b) presently set out the maximum increases allowed in the concentrations of sulfur dioxide and particulate matter [42 USC § 7473(b)]. EPA is directed to extend the applicability of PSD increment requirements to other pollutants as soon as possible. For pollutants other than sulfur dioxide and particulates, the maximum allowable concentration may not exceed the NAAQS [42 USC § 7473(b)].

Preconstruction Review The PSD program calls for rigorous preconstruction review of new sources and modifications to existing sources, including a permit system for imposing emission limitations and technology requirements on specific sources. Each state's SIP is to require the review of such sources. A new source must undergo preconstruction review if it is a “major emitting facility,” defined as a stationary source falling into one of 28 categories of sources that emit, or have the potential to emit, 100 or more tons per year of any air pollutant, or any other stationary source with the potential to emit 250 or more tons per year of any air pollutant [42 USC § 7479(1)]. The source categories are published at 40 C.F.R. § 52.21(b) (2)(iii). A modification of an existing major stationary source that creates a “significant” net increase in emissions of a pollutant regulated under the CAA is also subject to preconstruction review requirements [40 C.F.R. § 52.21(b)(2)].

The purpose of this “new source review,” as it is called by EPA, is to provide a broad overview of a proposed project before construction begins, to ensure compliance with all requirements. Generally, the review applies to permits and procedures that are required before a plant commences construction.

Technological Compliance A proposed major source or modification of an existing source in PSD areas must apply the best available control technology (BACT) for each pollutant regulated under the CAA that would emit in greater than de minimus amounts. BACT is defined as “an emission limitation based on the maximum degree of reduction of each pollutant . . . emitted from or which results from any major emitting facility, which the permitting authority . . . determines is achievable for such facility” [42 USC § 7473(3)]. BACT is determined on a case-by-case basis by EPA or by states with approved PSD revisions to their SIPs. Congress has stipulated that factors such as cost, available technology, energy consumption, and other non-air environmental impacts be taken into account in establishing BACT in PSD regulations. Thus, BACT will establish the effective NSPS in PSD areas.

Nonattainment of the NAAQS

Designation of Nonattainment The 1970 Act anticipated attainment of national primary ambient air quality standards by mid-1977. However, at the time the 1977 Amendments were passed, it was clear that despite deadlines, many areas of the country did not meet this target. Consequently, Congress adopted Part D of the 1977 CAA Amendments, which deals with nonattainment of the NAAQS.

Areas that did not achieve the NAAQS were designated as nonattainmerit areas for the various pollutants. Once an area was so designated, certain rules were triggered, including rules on new source review and offsets. Triggering of these rules has prompted states with nonattainment areas to seek reductions in new and existing sources of pollutants. Section 172 provided that reasonably available control technology (RACT) was required for existing sources [42 USC § 7502]. Attainment was to be achieved “as expeditiously as practicable,” with December 31, 1982 as the deadline for most criteria pollutants, but with December 31, 1987 as the deadline, under specified conditions, for CO and ozone [42 USC § 7502(a)(1) and (2)]. PSD and nonattainment requirements are not mutually exclusive: a region may be considered PSD for some pollutants and nonattainment for others.

New Source Review The 1977 Amendments set up a new source review program for nonattainment areas similar to the one set up under the PSD program for attainment areas. Prior to these amendments, attainment of the NAAQS was a precondition for construction and/or modification of sources in nonattainment areas. Consequently, a literal reading of EPA's regulations would have prohibited all new industrial growth. EPA developed a concept referred to as the “emissions offset” requirement to allow limited industrial growth in nonattainment areas. This concept was adopted by Congress in the 1977 amendments.

Any major source or major modification of an existing source in a state that would cause or contribute to a violation of a NAAQS within a designated nonattainment area is subject to preconstruction review [Section 173]. A major source is defined as a source that emits, or has the potential to emit, 100 tons per year or more of any pollutant subject to regulation under the CAA [40 C.F.R. § 51.18(j)(1)(iv)]. A major modification is defined as a physical change or change in the method of operation of a major source that would result in a significant emission increase of any pollutant subject to regulation under the CAA [40 C.F.R. § 51.18(j)(1)(v)].

Technological Compliance Section 173 provided that a proposed new source or modified major existing source must use emission control technology based on the lowest achievable emission rate (LAER) [42 USC § 7503(2)]. LAER is defined as “that rate of emissions which reflects the most stringent emission limitation which is contained in the implementation plan of any State for such class or category of source,” or “the most stringent emission limitation which is achieved in practice by such class or category of source, whichever is more stringent" [42 USC § 7501(3)]. This means that each time a newer, more stringent standard is achieved anywhere for a particular source, it becomes the new LAER standard for that source for the entire country, unless an owner or operator of a facility can demonstrate that such a limitation is not achievable by him.

Applicable NSPS are the effective maximum emission allowances for LAER in nonattainment areas. There is no stipulation that factors such as cost, available technology, energy consumption, and other environmental impacts must be taken into account in determining LAER in nonattainment regulations. Thus, the LAER standard is the effective NSPS in nonattainment areas for all new sources.

Emissions Trading Policy

As more experience was gained dealing with air quality regulations and emissions control technologies, it became apparent to EPA that the total quantity of pollutants emitted by a plant is more important than the amounts emitted by individual point sources within a plant, at least in terms of the public health effect. Emissions trading refers to several alternatives to traditional emission control regulations, including bubbling--a concept that allows existing facilities that emit air pollution to treat two or more emission points as if they were under a giant bubble. Plants can then control pollution less where the cost of emission reductions are high, in exchange for extra controls where costs are low, as long as the resulting emission levels are equal to or better than under the original standards.

An interim emissions trading policy was published in 1982[13] to encourage states to use emissions trades to achieve more flexible and rapid attainment of the NAAQS. This policy incorporated EPA's offset policy and bubble policy, originally issued in 1979,[14] and initiated a program for the use and banking of emission reduction credits (ERCs). This program allowed industry to make reductions and bank them for later use in a trade, or to meet a standard for a new source. These strategies, as well as "netting"--a scheme that may exempt plant expansions from new source review (NSR) (but not from applicable NSPS) if they can demonstrate there will be no "significant net increase" in plantwide emissions--were recently addressed in EPA's final emissions trading policy, published in December 1986.[15]

In general, emission trades must be for the same air pollutant and must be provided for in a state SIP. The final Emissions Trading Policy allows use of trades in areas not complying with CAA ambient standards, and in areas of a state which lacks a demonstration to show that its SIP in those areas will eventually attain the standard. The "baseline" for these trades is stipulated as actual emissions levels, or SIP-allowable emissions levels, whichever is lower. The baseline for a given source is that level of emissions below which any additional reductions may be credited for use in trades.

In addition, emission reduction "credits" from state efforts to control mobile sources may be used to meet SIP requirements applicable to existing stationary sources, provided such reductions are surplus, permanent, quantifiable, and enforceable. All such trades must be implemented as case-by-case SIP revisions.[16] Interstate trading is permitted, but also requires case-by-case SIP revisions. Firms applying for trades in these areas may not rely on banked reductions made before their applications for trading were submitted.

State assurances that efforts to meet an ambient standard will not be impaired by a proposed bubble are required for the first time for all trades taking place in primary nonattainment areas lacking demonstration plans to meet CAA standards. In such areas, a net air quality benefit that will produce extra interim environmental progress must be demonstrated.

One problem is that most large industrial pollution sources already are tightly regulated, and many future reductions (under the trading policy) will have to come from small emissions sources, such as dry cleaners and auto body shops. For a new marine terminal, or a major modification to an existing marine terminal, the availability of emissions trading may cause the terminal owner or operator to seek emissions reductions from marine vessels planning to utilize that terminal, as a means of ensuring compliance with NSPS, BACT, or LAER under a state's NSR program.

The Bubble Concept In 1979, EPA promulgated what has become known as the “Bubble Policy” as an alternative emission reduction option. This approach, which imposes controls on an entire plant rather than on each individual source, is designed to promote innovations in pollution control by allowing use of less costly techniques for achieving a given amount of pollution reduction. The bubble concept places an imaginary bubble over an entire plant, and all emissions are measured as coming out of a single hole in the bubble. The bubble concept is merely an extension of the offset policy in that it allows internal offsets within a plant. By permitting an owner or operator to place higher levels of emissions control on selected point sources, with lower marginal control cost, the bubble concept achieves more flexibility in air pollutant reduction and encourages emissions reduction in a more cost-efficient manner.

Use of the bubble has been held to be proper policy with respect to existing sources in PSD and nonattainment areas, but new sources are not permitted to bubble with existing sources to mitigate the requirements of NSPS in either PSD or nonattainment areas. Use of the bubble is only permitted if it does not result in any increase in applicable net baseline emissions[17] in any area, whether attainment or nonattainment, except under stringent conditions. Bubbles in primary ozone nonattainment areas are permitted, but must use the lowest of actual SIP-allowable or RACT-allowable emissions baseline for each source involved in the trade, and also must contribute to progress toward attainment by providing a 20 percent net reduction in emissions remaining after application of the baseline to all sources involved in the trade.[18]

Offset Policy Section 173(1)(A) of the 1977 Amendments put in place an offset system that allows construction of new sources or expansion of existing sources in nonattainment areas, only if emissions from such new or expanded sources are offset by emission reductions at existing facilities in the area [42 USC § 7503(1)(A)]. This system allows incremental growth while progress is still being made toward achievement of the NAAQS. The offset policy requires that any major new source construction or modification in nonattainment areas be accompanied by corresponding surplus decreases in emissions elsewhere to more than offset their emissions, so that the total emissions in the AQCRs do not increase, and the ambient pollutant concentration in the air does not increase.

Netting Netting may exempt modifications of existing major sources from certain preconstruction review requirements under NSR, provided there is no net emissions increase within the major source. By “netting out,” the modification is not considered major and is therefore not subject to all preconstruction review requirements under 40 C.F.R. Part 51. Netting's scope is determined by the definition of source, for review of major modifications.

In PSD areas, a single, plantwide definition may be used which allows actual emission reductions anywhere in a contiguous plant to compensate for potential emission increases at individual point sources within the plant. In nonattainment areas, the plantwide definition may be used, or a dual definition, in which emission increases at either the plant as a whole or individual emitting sources will trigger NSR.[19]

Banking of Emission Reduction Credits When an owner or operator of an existing industrial plant reduces the emissions of a particular pollutant beyond the baseline level required in the SIP through control technology or by closing down a portion of a plant, he gets a credit for the excess emission reduction. Banking of these credits has become a standard procedure, and a market in these credits has rapidly developed. In effect, an owner or operator can accumulate reduction credits for sale or later use for new construction.

An emission reduction credit is not synonymous with a simple emission reduction or offset. The credit extends only to that portion of the reduction which is in excess of what is required, and which is made enforceable by the state at the time it is banked.[20] The emission reduction credit (ERC) is an asset of the firm and can be bought by, or sold to, other sources. Under EPA's final emissions trading policy, reduction credits will only be granted for use in bubbles for those reductions occurring after an application to bank or trade credit (whichever is earlier) has been made.[21]

Deadlines for Attainment

The 1970 version of the CAA had mandated attainment of the primary NAAQS by mid-1975. No deadline was set for secondary standards, other than a requirement of achievement within a reasonable time. Section 110 imposed deadlines for submission of state plans and for compliance by sources [42 USC § 7410(a)(1)]. Only EPA had authority to grant extensions of the time for compliance with a NAAQS for certain pollutants [42 USC § 7410(a)(2)(A)].[22] While some modest efforts were made toward the 1975 goal, the deadline was not met in many parts of the country, including almost all major urban areas.

1987 Extension for Ozone and CO In the 1977 CAA Amendments, Congress extended the attainment deadline for the NAAQS to December 31, 1982, in section 172(a)(1) [42 USC § 7502(a)(1)]. Congress set December 31, 1987 as the final deadline for all areas of the country to reduce ozone and CO to no more than the national standard, if a state were able to demonstrate that attainment by the end of 1982 was not possible, despite the implementation of all RACT [42 USC § 7502(a)(2)]. The approach adopted by Congress was to require SIP revisions incorporating EPA's emission offset policy, as revised and expanded in Part D of the CAA.

SIP Revisions to Show Attainment by 1987 States that received the deadline extension were to submit revised SIPs by July 1, 1982. These SIPs were to provide for the attainment of the NAAQS for ozone in all nonattainment areas by December 31, 1987 [42 USC § 7502(c)]. Such revisions must include programs for (1) conducting stringent cost/benefit analyses as part of the preconstruction review for any proposed source, and (2) inspection and maintenance (I/M) for motor vehicles. If the ozone standard is not attained by the statutory deadline, imposition of sanctions, such as a cutoff of federal highway funds and a ban on construction, may be triggered.

VOC Emissions: Ozone Unlike other air pollutants, such as sulfur dioxide, ozone is not emitted from any point source that can be fitted with control equipment designed to remove it. Ozone is formed in the air as a result of photochemical reactions when hydrocarbons (such as gasoline vapors, paint fumes, or dry-cleaning fumes from solvents) combine with nitrogen oxides (that do come directly out of individual smokestacks and automobile tailpipes), oxygen, and sunlight. Ozone is a product of weather conditions, yet current knowledge of atmospheric chemistry is very limited. For example, there is a seasonal pattern to volatile organic compound (VOC) emissions, since a marked increase in VOCs occurs in summer months as heat causes gasoline and other hydrocarbon liquids to evaporate more quickly.[23] At high concentrations, ozone--or smog as it is colloquially called--can adversely affect human health, agricultural crops, forests and other materials.

EPA has established a primary standard to protect public health of 0.12 ppm (1-hour average)[24] or 235 micrograms/m^3 not to be exceeded more than 1 day per year. Currently, EPA is reviewing available scientific and technical information to determine whether this standard is adequate to protect human health and welfare. Some evidence suggests that even attainment of the existing standard for ozone will not protect public health with an adequate margin of safety.[25]

Other scientific analyses suggest that increases in ultraviolet-B radiation (caused in part by depletion of stratospheric ozone) may increase the rate of tropospheric (ground-level) ozone formation in urban areas. If these analyses are confirmed, it would appear likely that, in the future, more cities and regions may violate the ambient air standard for ozone, and that more restrictive measures to control hydrocarbons and nitrogen oxides may be required in order to comply with current standards.[26]

States now regulate ozone indirectly by trying to reduce hydrocarbons in the air. VOCs--the reactive or nonmethane hydrocarbons--are one of the primary precursors of ozone, along with nitrogen oxides. Therefore, to meet the 1987 deadline for attainment of the ozone standard, states must find ways to reduce the emissions of both VOCs and NO_x. EPA, on occasion, has published Control Techniques Guidelines (CTG) that set forth RACT requirements for most stationary sources of VOCs. No CTG on marine terminals or marine vessels have been issued.

EPA Proposed Ozone Strategy Between 70 and 75 areas in this country will likely fail to meet the 1987 deadline for attainment of the ozone standard. The administrator of EPA, Lee M. Thomas, has proposed a strategy for dealing with these noncompliance areas. The strategy includes a four-part proposed policy: (1) improving enforcement of existing laws; (2) possibly placing new controls on gasoline marketing and other sources of VOCs, whether at the refinery, on the fuel pump, or on motor vehicles; (3) establishing a 3-year plan for bringing noncompliance areas into attainment; and (4) establishing a sustained progress program for the estimated 25 areas with the worst ozone problems. Under the fourth part, states would consider additional controls based on advances in technology.

The fact that between 70 and 75 areas of this country will still likely fail to attain the ozone standard by the second congressionally extended deadline, seems to suggest that the problem overshadows the issue of emissions controls for ships and barges. In areas with the most intractable nonattainment problem, such as the New York City and Los Angeles metropolitan areas, drastic control measures, with enormous adverse social and economic impacts, would likely be necessary to bring about attainment.

Use of Economic Sanctions to Compel Compliance The major force behind the drive to meet the 1987 compliance deadline is the threat of sanctions; however, EPA is still debating its policy with regard to sanctions for areas which fail to meet the 1987 deadline. The mere threat of sanctions is forcing states to find new sources of VOCs whose emissions can be controlled.

There are strong arguments that economic sanctions are not available to EPA for areas for which EPA approved ozone SIPs, but which nonetheless remain in violation of the NAAQS after December 31, 1987. A key fact is that some states failed to meet the original 1982 deadline, and have not obtained EPA approval of a revised ozone SIP. EPA may be forced to disapprove these state SIPs in total, impose economic sanctions, and promulgate SIPs for those states.

Existing Enforcement Options The enforcement programs now being developed by EPA to gain cities' compliance with air quality standards could be subject to challenge, according to EPA's general counsel.[27] The agency's Sustained Progress Program (SPP) and Reasonable Extra Efforts Program (REEP) are designed to give cities more time to comply with national ambient air quality standards, rather than impose “Draconian” sanctions, such as construction bans or an embargo on federal highway funds.[28] The REEP is being implemented in California, and has been viewed by EPA for some time as the forerunner of a broader agency policy designed to deal with persistent violation of the ozone NAAQS by many large cities.[29]

Other EPA Regulatory Options EPA has a variety of options available to control hydrocarbon emissions--fuel volatility limits, on-board refueling controls, and service station controls (Stage II controls)--but so far has not imposed any of them. The automobile industry and the oil industry are often at odds over which option is likely to produce the greatest benefits in air quality by reducing vapors. The relative pros and cons of each option are beyond the scope of this paper.

Regulation of Gasoline Volatility EPA has been studying the need for a national volatility standard because of the disparity between the Reid Vapor Pressure (RVP)--a measure of volatility--of gasoline used to certify vehicle air pollution controls (9 pounds per square inch [psi]), and gasoline in the marketplace (as high as 11.5 psi).[30] This disparity is causing excess evaporative emissions that are a prime cause of ozone pollution.[31] This condition increases the level of hydrocarbons evaporating into the atmosphere during refueling. EPA recently sent the Office of Management and Budget (OMB) a draft proposal to control the volatility of gasoline through seasonal and regional limits of RVP beginning in 1988.[32]

Stage II Controls EPA is also considering establishing nationwide controls on gasoline vapor emissions from the refueling of motor vehicles through the use of Stage II controls. These controls are vapor recovery systems installed on gasoline station fuel Pumps and hoses to recover vapors emitted during refueling. Stage II[33] controls have been imposed for some years in California and the District of Columbia.[34] Allegedly because of pressure from the oil industry, EPA is reluctant to make Stage II gas station pump controls mandatory for nonattainment areas by designating Stage II as RACT, along with issuance of a CTG. At the same time, the auto industry contends that ozone nonattainment is a regional problem and that nationwide controls, such as on-board canisters, are unnecessary and not cost-effective. Moreover, many state air management officials believe a regional volatility standard will be more cost-effective in reducing ozone than Stage II controls or on-board vehicle canisters to control automotive evaporative emissions. EPA's current approach appears to be proposing all three options.

On-Board Vehicle Controls An EPA proposal, now under final review at OMB, would require all new motor vehicles to include equipment to trap gasoline fumes during refueling. The vapor recovery system involves enlarging small canisters now required to trap carburetor emissions, and would control evaporative emissions of VOCs that normally escape during refueling.[35] EPA would provide a 2-year lead time.

Litigation Involving Ozone Attainment

Several states are already facing suits by environmental interest groups for failure to implement controls, such as Stage II controls, designed to enable the state to attain the ozone standard by the deadline, which are included in their SIPs. These suits, in general, allege that a particular SIP is not adequate to enable the state to meet the ozone deadline, and that EPA has failed to order the state to correct inadequacies with its ozone control strategy.

In January 1987, the Natural Resources Defense Council (NRDC) and other environmental and health groups filed complaints against EPA and the states of New York and New Jersey, claiming that the SIPs of these states are inadequate to achieve attainment of the ambient ozone and carbon monoxide standards.[36]

In the suits, NRDC and the other health groups are claiming that neither New York nor New Jersey are living up to promises, made in their SIPs, that certain controls would be placed on VOC emissions, and that EPA must require new SIPs from these states to ensure compliance with the CAA.

A California trade group filed suit against EPA in an effort to keep the agency's REEP for attaining air quality standards from being put into practice in Los Angeles and several other areas in the state.[37] A California environmental group, the California Clean Air Condition, filed suit on December 22, 1986 claiming California has failed to submit a proper plan that will enable the state to attain the ozone standard.[38]

On October 9, 1986, the governor of Wisconsin authorized the state attorney general to prepare a lawsuit against Illinois, Indiana, and EPA to compel enforcement of the CAA over the issue of attaining the NAAQS for ozone.[39] Wisconsin believes air pollution from the other two states, particularly from the Chicago metropolitan area, is responsible for Wisconsin's failure to attain the ozone standard in an area surround ing Milwaukee. Wisconsin wants EPA to set timetables for compliance by Illinois and Indiana to meet the ozone attainment deadline.

The Conservation Law Foundation is threatening to sue the Commonwealth of Massachusetts and EPA, because Massachusetts allegedly is not properly controlling high levels of ozone in its air.[40]

Clean Air Act Treatment of Vessel Emissions

Sources of Air Pollutant Emissions Emissions from vessels result primarily from (1) fuel combustion in the vessel propulsion engines and boilers and in the cargo pumping engines, and (2) evaporation and subsequent displacement of liquid cargo during loading, unloading, ballasting, or purging. During loading or unloading at marine terminals, vessels operate engines to maintain power for basic services and to run pumps and other cargo equipment. Emissions from the operation of engines and boilers may include criteria pollutants such as NO_x, SO_2, CO, and particulates, as well as VOCs. In addition, emissions occur as organic vapors in empty cargo tanks are displaced to the atmosphere by cargo being loaded into the tanks. These vapors may be formed in the empty tank by evaporation of residual cargo from previous loads, or generated in the tank as new product is loaded.

Emissions may also occur during ballasting, as vapors in empty cargo tanks are displaced to the atmosphere by ballast water being pumped in. Coast Guard regulations currently require large tankers with crude oil washing systems, discussed below, to contain the organic vapors at marine terminals [33 C.F.R. § 157.166]. Ballasting of cargo tanks is also occurring with less frequency as a result of changes in international and domestic law, discussed below.

Emissions Control Authority There is no federal legislation explicitly authorizing the control of emissions from vessels. Although vessel emissions were covered in the original Senate version of the 1970 amendments concerning mobile sources, the power to control vessel emissions was omitted in the final bill that emerged from conference. The legislative history implies this provision was deleted because Congress did not consider vessel emissions significant enough to be included.[41] Therefore, while states may enforce air emission standards, it is debatable whether they may prescribe equipment or direct controls for tank vessels as mobile sources to achieve those standards, especially since the concepts of federal preemption and the prohibition on interference with interstate commerce would apply.

Aircraft and automobiles, on the other hand, are the only mobile sources which are expressly regulated, and emissions standards for both are set on a national basis.[42] Section 233 prohibits any state or political subdivision from adopting or enforcing any aircraft emission standard unless such standard is identical to the federal standard [42 USC § 7573]. Section 209(a) prohibits any state or political subdivision from adopting or attempting to enforce any standard relating to the control of emissions from new motor vehicles [42 USC § 7543].[43]

Regulation Under the NRDC Case

Indirect Source Controls In the 1970s, EPA attempted to force the states to regulate indirect sources of air pollution through a program called indirect source review.[44] Indirect sources are facilities, such as parking lots, which are not themselves significant sources of pollution but which attract, or may attract, substantial numbers of mobile pollution-emitting sources [42 USC § 7410(a)(5)(C)]. One difficulty presented to EPA was that nowhere in the statute was the term mobile source defined.

Congress reacted negatively and vigorously to EPA's attempt to mandate indirect source review. In the 1977 CAA Amendments, Congress made it clear that the states could not be required, although they were permitted, to regulate indirect sources of pollution.[45] The 1977 amendments stated that, in determining whether a new or modified source qualifies as major or significant and, therefore, subject to new source review, EPA may not require any indirect source review program as a condition of approval of a SIP. EPA can approve and enforce an indirect source review program that a state chooses to adopt and submit as part of its SIP. However, EPA cannot include, nor require the states to include, emissions from mobile sources located at a stationary source with the emissions from that stationary source [42 USC § 7410(a)(5)(A)]. The EPA regulation of indirect sources to which Congress acted so decisively concerned only facilities that attracted automobiles. No attention was focused on the problem of emissions from vessels docked at marine terminals.

In 1980, EPA revised its regulations.[46] The revision, which applied to all proposed major stationary sources, and to major modifications to existing sources, expressly stated that the term stationary source is intended “to encompass the activities of a marine terminal and only those dockside activities that would serve the purposes of the terminal directly, and would be under the control of its owner or operator.”[47] The process of loading and unloading vessels docked at marine terminals may contribute various quantities of air pollution in harbor areas. Also, pollutants emitted as a vessel approaches and leaves a marine terminal may contribute to the poor air quality of many harbors. Recognizing this potential source of air pollution, EPA promulgated regulations under which those activities engaged in by a vessel while docked at a terminal were considered activities of the terminal subject to air pollution controls.

EPA also ascribed to marine terminals the emissions of vessels coming to and from terminal [Id. at 52,737]. EPA took the position that vessels were not mobile sources “within the meaning of § 110(a)(5) of the Act, the provision restricting indirect source review” [Id. at 52,696]. Thus, pursuant to the revised regulations, both dockside and to-and-fro vessel emissions[48] were to be taken into account in regulating the construction and operation of new marine terminals, or the modification of existing terminals. The effective date of these regulations was August 7, 1980.

EPA revoked these requirements in 1982, after they were judicially challenged by GATX Terminals Corporation. The revocation deleted requirements for (1) the inclusion of vessel emissions in determinations of whether a proposed new source or modification would emit a pollutant in significant or major amounts; and (2) the inclusion of mobile source emissions as secondary emissions in assessments of the air quality impacts of proposed new sources and modifications.[49] EPA's rationale for the revocation, as set forth in its notice of proposed revocation, was that “the Clean Air Act bars it from requiring the inclusion of vessel emissions in any determination in the preconstruction review of new sources and modifications.”[50] EPA thus agreed with GATX and the industry that vessels are mobile sources, and that it had no authority to ascribe any vessel emissions to marine terminals because of the congressional ban on mandatory state indirect source review programs [Id. at 61,614-615].[51]

The EPA's final rule was then challenged by the Natural Resources Defense Council (NRDC) and the State of California.

Vessel Emissions Attributable to Stationary Sources In NRDC v. EPA, 725 F.2d 761 (D.C. Cir. 1984), the court was confronted with EPA's reversal of position, in which EPA first promulgated, then withdrew, regulations under which dockside vessel emissions, and to a limited extent, to-and-fro vessel emissions, were attributed to marine terminals.

The court agreed with EPA's conclusion that vessels are mobile sources for purposes of the ban on indirect source review, and also agreed that vessel to-and-fro emissions should not be attributed to marine terminals for purposes of new source review [725 F.2d at 771]. However, the court ruled that the ban on indirect source review did not automatically bar EPA from attributing any dockside vessel emissions to marine terminals for purposes of new source review, absent an attempt to identify the various vessel emissions, and the way they are discharged into the atmosphere.

The court suggested that EPA should have examined the nature of specific interactions between a vessel and a marine terminal to determine which categories of emissions can (as a matter of statutory authority) and should (as a matter of policy) be attributed to the terminal as a stationary source. Accordingly, the court vacated EPA's blanket repeal of the dockside component from the attribution rules [725 F.2d at 771].

The court ordered EPA, in reformulating its vessel emission regulations, to (1) apply its “control and proximity” regulations[52] to define which emissions from dockside activities of marine vessels are “stationary source” emissions of the marine terminal, and (2) develop attribution rules to determine which, if any, of the emissions defined above cannot be assigned to the terminal because to do so would be to violate the ban on indirect source review [Id.]. The court made it clear it was not suggesting that EPA must conclude that some dockside vessel emissions are necessarily attributable to marine terminals because these emissions are under the control of their terminal owner and directly serve his purposes. The court recognized that EPA's control and proximity regulations may already adequately divide responsibility for dockside vessel emissions between the vessel and the terminal. Thus, EPA is not under judicial mandate to ascribe some vessel emissions to marine terminals. Rather, EPA must decide if it is appropriate to do so.

Future Regulation of Vessels by EPA EPA's final rule is back before the agency on remand from the D.C. Circuit. The import of the court's decision in the NRDC case is that EPA cannot approve any SIP provision regarding marine terminal review until it undertakes the examination, either through new rulemaking or adjudication, of vessel emission mandated by the NRDC court. EPA is in the process of determining which, if any, vessel emissions should be attributed to marine terminals. Presumably, in making this determination, EPA is following the instructions of the NRDC court, which directed EPA to apply the same general approach it employed in developing the bulk gasoline terminal regulations. In addition, even though NRDC court's decision was directed to EPA's PSD regulations, it appears likely that the court's rationale for its decision would apply as well to EPA's nonattainment regulations.

Direct Regulation of Vessels by States

Vessels as Sources of VOC Emissions Because states must revise their SIPs to provide for the attainment of the NAAQS for ozone no later than December 31, 1987, the states are searching for VOC sources whose emissions can be reduced. Most of the obvious, larger sources of VOCs are already being regulated, yet the emission reductions resulting from their regulation are not sufficient to meet the air quality standard for ozone in the major urban air quality regions. Therefore, several states are targeting the more difficult to control or smaller sources, and thus are proposing that ships or barges that load VOCs be fitted with vapor control equipment.

The states have broad discretion as to which VOC sources they choose to regulate, and they are under no mandate to choose vessels. However, because section 116 permits the states to adopt emission standards or limitations that are more stringent than the federal standards, the states may go beyond attributing dockside vessel emissions to marine terminals and may decide to regulate to-and-fro emissions, absent restrictions on this authority under the supremacy and commerce clauses of the U.S. Constitution, discussed below.

Extraordinary Controls The states are required to adopt certain “minimum control measures,” specifically set out by EPA, in exchange for having received the 1987 extension for ozone. The states must adopt regulations to apply RACT to major stationary sources, and to implement vehicle inspection and maintenance programs, and transportation pro grams. If these minimum control measures are not adequate to demonstrate attainment by December 31, 1987, the state must adopt "additional measures."[53] EPA has not specified what additional measures the states must adopt, but instead has merely given examples of measures that could be introduced. These examples include requiring the control of all major stationary sources to levels more stringent than RACT, and extending controls to other stationary sources.

Control of marine vessel emissions is not a minimum control measure, and there is no RACT in place for vessel emissions control. Such control is not even thought of as an additional measure. Vessel emissions control is often referred to by the states as an extraordinary measure, and is seen as a further step the states can take to reduce VOC emissions.

State Activity Pursuant to the CAA

In general, two differing kinds of state air quality programs that affect marine vessels are being proposed or implemented. One is designed to regulate marine vessels directly by controlling emissions from such vessels: either engine emissions or displaced VOC vapors occurring as a result of the loading of cargo into vessels. The development of this kind of program is a result of the need of various states to attain the ozone standard by December 31, 1987. Thus, the primary impact of this program will fall on vessels carrying gasoline and crude oil, since vapors from these cargoes contribute to ozone formation. States such as California, Pennsylvania, and New Jersey fall into this category because they are searching for additional sources of VOC emissions that can be reduced to meet the statutory deadline for ozone.

The second kind of program indirectly regulates marine vessels by specifying that marine vessel emissions must be calculated and included in the calculation of a marine terminal's emissions for purposes of new source review. The calculation of marine vessel emissions would include not only VOC emissions, but also emissions of other criteria pollutants as well. This program is being considered as a result of the NRDC case. However, under the terms of the NRDC case, the actual regulation of vessel emissions is not a foregone conclusion since compliance could be achieved without resorting to direct vessel regulation.

Those state programs that propose to regulate marine vessels directly are perhaps most important, because they may affect vessel design, construction, and operation, in the near term. Programs that indirectly regulate marine vessels may be important only to the extent that a marine terminal may require vapor recovery onboard a vessel as a requirement of doing business at the terminal. There are indications that some states will refrain from implementing new vessel emission controls in the near future. Other states, such as New Jersey, feel that the time constraints imposed by the CAA in attaining the ozone standard do not permit them to await the results of the Marine Board study.

California

Current Regulations All coastal air quality management districts in California have regulations governing stack emissions that attribute dockside vessel emissions to marine terminals for purposes of new source review, although the extent of enforcement is uneven. California law permits local air pollution control authorities to take independent action to control emissions.

Proposed Regulations In June 1984, the California Air Resources Board presented its “Report to the California Legislature on Air Pollutant Emissions from Marine Vessels.” The report concluded that any future vessel emissions control measures should explicitly subordinate regulatory requirements to Coast Guard safety requirements, and excuse vessel operators from compliance when necessary to secure the safety of a vessel.[54]

Following the submission of that report, the Air Resources Board began developing, as part of its suggested control measures, a proposal that will cover emissions from ballasting and housekeeping operations. The Air Resources Board believes that reductions in ballasting and housekeeping emissions can be achieved without the installation of control equipment. The suggested control measures have no force in law, but have been sent to the South Coast, Bay Area, Santa Barbara County, and Ventura County air quality management districts for consideration and adoption.

County of Santa Barbara Santa Barbara regulates emissions from the loading of organic liquid cargo (oil) into marine vessels. The regulations[55] require the installation of vapor recovery systems or the employment of emission control practices and apply to both tankers and terminals. Regulations controlling vessel emissions during loading have been in place for several years. When the courts invalidated an earlier version of the regulations because they were unenforceable, Santa Barbara redrafted the regulations. Santa Barbara adopted the present version on December 16, 1985.

Under the new regulations, if a vessel or terminal was equipped with control equipment before January 1, 1986, it must use such control equipment after January 1, 1986. If a vessel or terminal did not have control equipment on January 1, 1986, it must be in final compliance with the new regulations by July 1, 1987, unless compliance would impair the safety of the vessel. Emissions attributable to stationary sources include displaced vapors into the atmosphere, fugitive emissions, combustion emissions in district waters; and emissions from the loading and unloading of cargo.

Santa Barbara faces sanctions from EPA because its ozone levels exceed federal standards.

South Coast Air Quality Management District The South Coast Air Quality Management District (SCAQMD) has no specific regulations directly addressing vessel hydrocarbon emissions, but it does require control of hydrocarbon emissions as part of its new source review program. This program requires that all new sources be equipped with BACT. A new source would include any new land-based bulk liquid transfer operation.

The district also proposed a rule requiring ships to “cold iron” their power plants; that is, use onshore electrical power sources while docked in port to reduce engine emissions. According to SCAQMD, the proposed rule would help reduce the level of NO_x in the Los Angeles area. The feasibility of such a rule was strongly contested by the marine industry.[56]

Bay Area Air Quality Management District The Bay Area Air Quality Management District (BAAQMD) regulated marine vessel emissions under its new source review regulations by treating marine vessels as a part of a stationary source when this source is a facility used to load cargo onto, or unload cargo from, marine vessels. Accordingly, the vessel emissions resulting from these cargo transfer operations, as well as the storage and processing of cargo, are attributed to the stationary source for new source review purposes. Only those vessel engine emissions occurring while the vessel is in the district's waters are included as attributable emissions.

In December 1986, the BAAQMD staff, in a report to the district's commissioners, recommended that a permit to load organics, including crude oil and gasoline, for a bulk liquid storage terminal should be denied because of the terminal's failure to impose BACT for organic emissions from the proposed terminal modification. (When cargo carriers are tied to the docks, they become a part of the stationary source for purposes of BACT review.)

The BAAQMD staff concluded that there is an effective emission control device or technique that is applicable to the Landsea marine terminal and, therefore, that BACT in the form of vapor recovery is required for the loading of organic liquids onto tankers at that facility. The staff also determined that imposition of a vapor recovery requirement on Landsea's proposed organic loading operations, a major modification to an existing stationary source, would not compromise vessel safety since some control systems, such as the *ARCO Jovelan* barge, have been approved by the Coast Guard.[57]

Florida

State regulations provide that VOCs may not be stored, processed, loaded, or unloaded, unless known and existing vapor control devices on systems are applied.[58] This regulation applies to bulk gasoline plants and bulk gasoline terminals. To date, this regulation has not been applied to ships or barges.

Illinois

The Illinois EPA has proposed an amendment to the state's new source review rules that would include dockside vessel emissions within the definition of stationary source. The Illinois proposal attributes dockside vessel emissions to marine terminals for purposes of determining whether a new source or modification is major and therefore subject to new source review. The Illinois EPA believes that failing to include vessel emissions will jeopardize federal EPA approval of Illinois' revised SIP.

The proposal would not directly impose equipment or vapor recovery requirements on vessels, but instead would be a means of indirectly controlling emissions by requiring terminal owners to account for dockside vessel emissions and presumably control these emissions. Enforcement actions would be brought against terminal operators, but would not directly affect vessel owners.

The proposal has two parts. The first attributes emissions directly caused by the handling of material to the marine terminal. The second attributes to the terminal emissions associated with the transfer of material, including, but not limited to, idling of propulsion engines; operation of engines to provide heat, refrigeration, or lighting; operation of auxiliary engines for pumps or cranes; and transfer of materials from hold to hold or tank to tank.

Maryland

In March 1986, the director of the Air Management Administration of the Maryland State Office of Environmental Programs proposed to the Air Quality Control Advisory Council that Maryland state regulations be amended to require emissions controls on gasoline barges loading gasoline. The proposed amendment was based on 1980 baseline data indicating that barge loading in the Baltimore area resulted in 4.5 tons of VOC emissions each day. Maryland is facing a 10-ton per day shortfall in 1987, due mainly to ambient air quality in the Baltimore area. Consequently, barge emissions became an attractive control source and the proposal to regulate and reduce these VOC emissions was introduced.

Soon afterward, the proposal was dropped because incorrect baseline data was utilized, and because of industry concerns about safety and competition from uncontrolled terminals. Maryland is in the process of identifying potential new sources of regulation; no marine sources are being considered.

New Jersey

In 1983, New Jersey submitted a revised SIP, which EPA proposed to approve, including a commitment to adopt sufficient “extraordinary measures” to provide the emission reductions required to demonstrate attainment of the NAAQS for ozone by 1987.[59] One of these extraordinary measures was control of emissions of gasoline vapors at barge loading facilities. The state anticipated requiring a 90 percent reduction in emissions.

EPA approved the revised SIP and conditionally approved the marine vessel emission control strategies.[60] EPA stated that before adopting any vessel emission requirements, however, New Jersey would have to ensure that it has adequate legal authority to regulate these sources, consult with the Coast Guard in developing its barge and tanker control regulation to ensure that the requirements do not conflict with Coast Guard regulations, and consider the cost, safety, and technological feasibility of the requirements.[61] The New Jersey Department of Environmental Protection is in the process of finalizing a report presenting the potential for regulation of marine emissions, which will provide the foundation for further evaluation within the department.

Ohio

Ohio is currently examining the feasibility of controlling emissions from the loading of barges. No final decision has been made about whether such emissions will be regulated, or about the format of any regulations that might be promulgated.

Pennsylvania

In 1985, the Pennsylvania Department of Environmental Resources, after studying the feasibility of regulating emissions from the off-loading of barges and from vessel ballasting, drafted proposed regulations to control vapor emissions during barge loading at marine terminals that have VOC emission potentials greater than 100 tons per year. These draft regulations were circulated for public comment. However, the department has suspended consideration of these regulations owing to the concerns about federal/state relations, and about the safety implications of such regulations.

Texas

Current Regulations Texas has in place requirements that apply to marine vessels in the same manner as to land-based sources. Excessive visible emissions from ships are prohibited except during reasonable periods of startup. Limits are imposed on ground level concentrations of particulate matter and sulfur dioxide. Emissions that cause or contribute to a condition of air pollution, as defined in the Texas Clean Air Act,[62] are prohibited.

As a result of a decision of the Texas Court of Appeals, Texas may not attribute vessel emissions to marine terminals for purposes of new source review. The court of appeals held that under the Texas Clean Air Act, vessels are not property of a crude oil unloading terminal so as to be considered part of the facility, and vessel emissions cannot be considered in the review of a permit application for such a facility.[63]

Proposed Regulations The Texas Legislature amended the Texas Clean Air Act to create a Clean Air Study Committee to study the regulation of emissions into the air from vessels directly, and indirectly under the new source review program,[64] and to make recommendations on whether or not to regulate vessel emissions under the Texas Clean Air Act.[65] The committee submitted a report to the legislature on December 1, 1986.[66] The committee found that vessel emissions accounted for 1.7 to 5.9 percent of the countywide VOC emissions in the five port counties. The committee also found that the control of these emissions presents technical, legal, and economic difficulties if not done on a national basis to provide consistency and enforceability. The committee therefore recommended that the legislature adopt a resolution supporting national review, and stated that action on the regulation of ship emissions would not result in any immediate changes in air quality.

Virginia

Virginia regulations provide that vessel emissions should not be attributed to marine terminals for purposes of new source review. EPA has told Virginia that these regulations are not acceptable as a result of the NRDC case. EPA has been unable to tell Virginia precisely what new regulations the state needs to adopt, since EPA has not yet finalized its policy on which vessel emissions should be attributed to marine terminals, if any.

Other States

Some states have considered imposing hydrocarbon controls on vessels, but for various reasons declined to require such controls. Louisiana, for example, found emission controls would be too expensive and potentially dangerous absent nationwide controls. Connecticut, at one time, considered controlling hydrocarbon emissions from ships and barges, but dropped a proposal from consideration because of perceived interference with interstate commerce. Connecticut favors regulating these emissions at the federal level. An emissions control proposal was considered in Kentucky, but was dropped because of insufficient data upon which to regulate. No current action is pending. Washington considered adopting vapor recovery requirements for barge loading of gasoline, but found that the Coast Guard has not approved generic vapor recovery systems for barges, and decided the institutional obstacles were too great. Washington will seriously consider requiring vapor recovery for barge loading if it is found to be technically feasible.

Domestic Marine Safety Laws

Coast Guard Statutory Authority

The U.S. Coast Guard has extensive statutory authority to regulate marine vessels in the interest of ensuring merchant marine safety and environmental protection. Section 2 of Title 14 of the United States Code provides that the Coast Guard “shall administer laws and promulgate and enforce regulations for the promotion of safety of life and property on and under the high seas and waters subject to the jurisdiction of the United States covering all matters not specifically delegated by law to some other executive department.” Section 2103 of Title 46 provides that the Coast Guard, by delegation from the secretary of Transportation, “has general superintendence over the merchant marine of the United States and of merchant marine personnel in so far as the enforcement of the subtitle [Subtitle II - Vessels and Seamen] is concerned.”

Many sections of Titles 33 and 46 of the United States Code also grant specific authority to the Coast Guard, including authority to regulate masters, ships' officers, and crew members; authority over the design, construction, and maintenance of vessels, their gear, and equipment; authority to regulate cargo carriage, vessel documentation, and certification; and authority to prevent pollution of the marine environment.

The Port and Waterways Safety Act of 1972 (PWSA),[67] as amended by the Port and Tanker Safety Act of 1978 (PTSA),[68] reaffirmed existing Coast Guard marine safety authority over tank vessels[69] and expanded that authority by authorizing the Coast Guard to specify mandatory design and construction requirements for tank vessels carrying crude oil and petroleum products to protect against hazards to life and property. The process of Coast Guard regulation of a vessel begins prior to actual construction and continues through the vessel's life.

The proposition that Congress intended the Coast Guard to be primarily responsible for maritime safety is supported by the legislative history of the recent recodification of Title 46 of the United States Code.[70] The Coast Guard has promulgated extensive regulations implementing this broad authority.[71]

The Coast Guard's comprehensive regulations provide an integrated approach, for both domestic and international requirements, to govern the safety of the whole maritime industry, and the protection of the marine environment, even to the exclusion of other federal agencies.[72] There have also been some recent cases confirming the Coast Guard's exclusive jurisdiction over working conditions on vessels, in spite of the broad powers given to a sister agency--the Occupational Safety and Health Administration.[73] Because the Coast Guard is predominantly responsible for promoting and implementing almost all aspects of marine safety, the agency has developed the expertise necessary to evaluate all marine safety requirements.

The Coast Guard has recognized the potential problems involving uniformity and safety presented by individual state initiatives to regulate vessel emissions. The Towing Safety Advisory Committee (TSAC)[74] has also brought to the Coast Guard's attention its concerns about marine safety and about the disadvantages of nonuniform regulation that might result from individual state action in this area. TSAC Resolution 44 recommended that the Coast Guard study the need for safety standards uniformity and requirements in applying air quality standards to marine vessel emissions.

The analysis and discussion of the Coast Guard's regulatory authority will concentrate on those provisions applicable to vessels that carry flammable or combustible liquid cargo in bulk as cargo, since state proposals for VOC vapor recovery involve cargo loading or unloading operations. The relevant statutory provisions are found in Chapter 37 of Title 46; they apply to self-propelled tank vessels (tankers) and to nonself-propelled tank vessels (tank barges). The provisions of Chapter 37 of Title 46 and its implementing regulations constitute most of the marine safety laws governing vessel design and equipment of the types of vessels that would be subject to the vapor recovery regulations proposed by several states.

In addition to the marine safety laws, several statutes deal with marine pollution and liability for damages and clean-up costs resulting from marine pollution;[75] these statutes will not be addressed as they do not directly affect the relation between federal marine safety laws and state vapor recovery activities. We note in passing, however, that vessel owners operate in a strict liability regime for pollution caused by a vessel, and, unlike land-based industries, vessel owners operate in a virtually absolute liability regime for personal injury to seamen and crew members occurring on board a vessel. With respect to the legal consequences of mandating vapor control equipment that may pose safety hazards, serious legal dilemmas can arise for vessel owners if such equipment causes a pollution incident or personal injury.[76]

Port and Tanker Safety Act of 1978

The PTSA (codified at 33 USC §§ 1221-31 and Chapter 37 of Title 46 USC) reaffirmed existing Coast Guard marine safety authority over tank vessels, dating back to 1936,[77] and in several instances broadened and expanded that authority by more explicitly specifying certain mandatory design and construction requirements for tank vessels carrying crude oil and petroleum products to reduce the hazards associated with handling these cargoes.[78]

Regulatory Authority for Tank Vessels With respect to the general regulatory authority, the Coast Guard is directed to “prescribe regulations for the design, construction, alteration, repair, maintenance, operation, equipping, personnel qualification, and manning of vessels . . . that may be necessary for increased protection against hazards to life and property, for navigation and vessel safety, and for enhanced protection of the marine environment” [46 USCA § 3703(a)]. This section further provides that the regulations shall include requirements for [46 USCA § 3703(a)]:

- superstructures, hulls, cargo holds or tanks, fittings, equipment, appliances, propulsion machinery, auxiliary machinery, and boilers;

- the handling or stowage of cargo, the manner of handling or stowage of cargo, and the machinery and appliances used in the handling or stowage;
- equipment and appliances for lifesaving, fire protection, and prevention and mitigation of damage to the marine environment;
- the manning of vessels and the duties, qualifications, and training of the officers and crew;
- improvements in vessel maneuvering and stopping ability and other features that reduce the possibility of marine casualties;
- the reduction of cargo loss if a marine casualty occurs; and
- the reduction or elimination of discharges during ballasting, deballasting, tank cleaning, cargo handling, or other such activity.

The implementing regulations for these statutory provisions, found at 33 C.F.R. Parts 151, 155, and 157, and 46 C.F.R. Subchapters D and O, comprehensively regulate all aspects of vessel design, construction, and operation, including detailed design specification and stability requirements, manning levels for officers and crew, and licensing procedures for officers and crew members.[79] The stated objective of these standards is promotion of merchant marine safety, but the resulting improvements in vessels' structural integrity also enhance environmental protection by preventing accidents that cause pollutant releases.

Tank Vessel Equipment Requirements The PTSA directed the Coast Guard to require, on new and existing tank vessels, of specified size categories, certain design and equipment features to minimize or eliminate operational pollution and to reduce the possibility of accidental releases of cargo due to collisions, groundings, rammings, or structural failure [46 USCA §§ 3704-3706]. These protections were achieved through three requirements: segregated ballast tanks (SBT);[80] crude oil washing (COW);[81] and inert gas systems (IGS).[82] The regulations governing SBT, COW, and IGS are found at 46 C.F.R. Part 32 and 33 C.F.R. Part 157. These regulations may have a direct impact on proposals to control hydrocarbon emissions from tank vessels, depending on the size and age of the vessel. The SBT, COW, and IGS requirements for new and existing vessels are set out in Table C-2, Table C-3 and Table C-4.

These technologies were incorporated in the PTSA in anticipation of the coming into force of the MARPOL 73/78 Convention,[83] discussed below, which, with a few exceptions, is mirrored by the 1978 Act. Together these technologies represent international agreement on how best to eliminate operational pollution caused by ballasting and tank cleaning at sea.

In addition to SBT, COW, and IGS, Coast Guard regulations currently contain other equipment requirements, including standards for navigation equipment, alarm systems, boilers and machinery, electrical installations, pumps, piping and hoses for cargo handling, bilge systems, ventilation and venting, and structural fire protection measures.

The significance of these Coast Guard requirements is manifold. The requirements evidence extensive, existing regulation of tank vessel design, equipment, and operations and a consistent pattern of

TABLE C-2 Requirements for U.S. Tank Vessels in Domestic Trade

Category	DWT Range	Crude Oil Carrier	Product Carrier	Date Required
A1	20,000 DWT or above but less than 30,000 DWT	PL/SBTa COW IGS	IGS	Upon delivery
	30,000 DWT or above	PL/SBTa COW IGS	PL/SBTa IGS	Upon delivery
B1	20,000 DWT or above but less than 40,000 DWT	IGS (1) SBT or (3) COW	IGS (2) SBT or (3) CBT	(1) 6/1/83 (2) 6/1/83, only if high tank washing machines are used (3) 1/1/86 or when the tanker is 15 yrs. old, whichever is later
	40,000 DWT or above but less than 70,000 DWT	IGS (1)(2) SBT CBT(3) or COW SBT or (4) COW	IGS (1)(2) SBT or (5) CBT	(1) 6/1/83 (2) On comb. carriers of 50,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) 6/1/81 until 6/1/85 (4) After 6/1/85 (5) 6/1/81
	70,000 DWT or above	IGS (1)(2) PL/SBTb (3)	IGS (1)(2) PL/SBTb (3)	(1) 6/1/81 (2) On tank vessel of 100,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) Upon delivery
C1	20,000 DWT or above but less than 40,000 DWT	Same as Category B1 for this deadweight range		

C1	40,000 DWT or above but less than 70,000 DWT	Same as Category B1 for this deadweight range		
	70,000 DWT or above	IGS (1)(2) SBT (3)	IGS (1)(2) SBT (3)	(1) 6/1/81 (2) On tank vessel of 100,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) Upon delivery
D1	20,000 DWT or above but less than 40,000 DWT	Same a Category B1 for this deadweight range		
	40,000 DWT or above but less than 70,000 DWT	Same as Category B1 for this deadweight range		
	70,000 DWT or above	IGS (1)(2) SBT CBT (3) or COW SBT (4) or COW	IGS (1)(2) SBT or (1) CBT	(1) 6/1/81 (2) On tank vessels 100,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) 6/1/81 until 6/1/83 (4) After 6/1/83

NOTES:

1. The numbers in parentheses under the “Crude Oil Carrier” and “Product Carrier” columns correspond to the numbers in parentheses under the “Date Required” column for each particular category. To determine when the equipment is required, read the corresponding number in parenthesis under the “Date Required” column.

2. Definition of categories:
A1 - A tank vessel that:

a. is contracted for after June 1, 1979; or
b. in the absence of a building contract, has the keel laid or is at a similar stage of construction after January 1, 1980; or
c. is delivered after June 1, 1982; or
d. has undergone a major conversion that is contracted for after June 1, 1979, or has begun the conversion after January 1, 1980, or has completed the conversion after June 1, 1982.

B1 - A tank vessel that is contracted for after January 7, 1976, BUT DOES NOT COME UNDER CATEGORY A1.
C1 - A tank vessel that:

a. is contracted for after December 31, 1974; or
b. in the absence of a building contract, has the keel laid or is at a similar stage of construction after June 30, 1975; or
c. is delivered after December 31, 1977; or
d. has undergone a major conversion that is contracted for after December 31, 1974, or has begun the conversion after June 30, 1975, or has completed the conversion after December 31, 1977; BUT
e. DOES NOT COME UNDER CATEGORIES A1 or B1.

D1 - A tank vessel that DOES NOT COME UNDER CATEGORIES A1, B1, or C1.

SOURCE: U.S. Coast Guard Navigation and Inspection Circular No. 1-81, Change 1 (July 14, 1986).

TABLE C-3 Requirements for U.S. Tank Vessels in Foreign Trade

Category	DWT Range	Crude Oil Carrier	Product Carrier	Date Required
A2	20,000 DWT or above but less than 30,000 DWT	PL/SBTa COW IGS	IGS	Upon delivery
	30,000 DWT or above	PL/SBTa CDW IGS	PL/SBTa IGS	Upon delivery
B2	20,000 DWT or above but less than 40,000	IGS (1) SBT or (3) COW	IGS (2) SBT or (3) CBT	(1) 6/1/83 (2) 6/1/83, only if high tank washing machines are used (3) 1/1/86 or when the tanker is 15 yrs. old, whichever is later
	40,000 DWT or above but less than 70,000 DWT	IGS (1)(2) SBT CBT (3) or COW SBT or (4) COW	IGS (1)(2) SBT or (5) CBT	(1) 6/1/83 (2) On comb. carriers of 50,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) 6/1/81 until 6/1/85 (4) After 6/1/85 (5) 6/1/81
	70,000 DWT or above	IGS (1)(2) PL/SBTb (3)	IGS (1)(2) PL/SBTb (3)	(1) 6/1/81 (2) On tank vessel of 100,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) Upon delivery
C2	20,000 DWT or above but less than 40,000 DWT	Same as Category B2 for this deadweight range		

C2	40,000 DWT or above but less than 70,000 DWT	Same as Category B2 for this deadweight range		
	70,000 DWT or above	IGS (1)(2) SBT (3)	IGS (1)(2) SBT (3)	(1) 6/1/81 (2) On tank vessel of 100,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) Upon delivery
D2	20,000 DWT or above but less than 40,000 DWT	Same as Category B2 for this deadweight range		
	40,000 DWT or above but less than 70,000 DWT	Same as Category B2 for this deadweight range		
	70,000 DWT or above	IGS (1)(2) SBT CBT (3) or COW SBT (4) or COW	IGS (1)(2) SBT or (1) CBT	(1) 6/1/81 (2) On tank vessels100,000 DWT or above with keel laid after 12/31/74, IGS required by 2/26/76 (3) 6/1/81 until 6/1/83 (4) After 6/1/83

NOTES:

1. The numbers in parentheses under the “Crude Oil Carrier” and “Product Carrier” columns correspond to the numbers in parentheses under the “Date Required” column for each particular category. To determine when the equipment is required read the corresponding number in parenthesis under the “Date Required” column.

2. Definition of categories:
A2 - A tank vessel that:

a. is contracted for after June 1, 1979; or
b. in the absence of a building contract, has the keel laid or is at a similar stage of construction after January 1, 1980; or
c. is delivered after June 1, 1982; or
d. has undergone a major conversion that is contracted for after June 1, 1979, or has begun the conversion after January 1, 1980, or has completed the conversion after June 1, 1982.

B2 - A tank vessel that is contracted for after March 31, 1977, BUT DOES NOT COME UNDER CATEGORY A2.
C2 - A tank vessel that:

a. is contracted for after December 31, 1975; or
b. in the absence of a building contract, has the keel laid or is at a similar stage of construction after June 30, 1976; or
c. is delivered after December 31, 1979; or
d. has undergone a major conversion that is contracted for after December 31, 1975, or has begun the conversion after June 30, 1976, or has completed the conversion after December 31, 1979; BUT
e. DOES NOT COME UNDER CATEGORIES A2 or B2

D2 - A tank vessel that DOES NOT COME UNDER CATEGORIES A2, B2, or C2.

SOURCE: U.S. Coast Guard Navigation and Inspection Circular No. 1-81, Change 1 (July 14, 1986).

TABLE C-4 Requirements for Foreign Tank Vessels Entering U.S. Waters for Commercial Service

Category	DWT Range	Crude Oil Carrier	Product Carrier	Date Required
A3	20,000 DWT or above but less than 30,000 DWT	PL/SBTa COW IGS	IGS	1/1/80
	30,000 DWT or above	PL/SBTa COW IGS	PL/SBTa IGS	1/1/80
B3	20,000 DWT or above but less than 40,000 DWT	IGS (1) SBT or (3) COW	IGS (2) SBT or (3) CBT	(1) 6/1/83 (2) 6/1/83, only if high tank washing machines are used (3) 1/1/86 or when the tanker is 15 yrs. old, whichever is later
	40,000 DWT or above but less than 70,000 DWT	IGS (1) SBT CBT (2) or COW SBT or (3) COW	IGS (1) SBT or (4) CBT	(1) 6/1/83 (2) 6/1/81 until 6/1/85 (3) After 6/1/85 (4) 6/1/81
	70,000 DWT or above	IGS (1) PL/SBTb (2)	IGS (1) PL/SBTb (2)	(1) 6/1/81 (2) 4/1/77
C3	20,000 DWT or above but less than 40,000 DWT	Same as Category B3 for this deadweight range		
	40,000 DWT or above but less than 70,000 DWT	Same as Category B3 for this deadweight range		
	70,000 DWT or above	IGS (1) SBT (2)	IGS (1) SBT (2)	(1) 6/1/81 (2) 4/1/77

D3	20,000 DWT or above but less than 40,000 DWT	Same as Category B3 for this deadweight range			
	40,000 DWT or above but less than 70,000 DWT	Same as Category B3 for this deadweight range			
	70,000 DWT or above	IGS (1) SBT CBT (2) or COW SBT (3) or COW	IGS (1) SBT or (1) CBT	(1) (2) (3)	6/1/81 6/1/81 until 6/1/83 After 6/1/83

NOTES:

1. The numbers in parentheses under the “Crude Oil Carrier” and “Product Carrier” columns correspond to the numbers in parentheses under the “Date Required” column for each particular category. To determine when the equipment is required, read the corresponding number in parenthesis under the “Date Required” column.

2. Definition of categories:

A3 - A tank vessel that:

a. is contracted for after June 1, 1979; or
b. in the absence of a building contract, has the keel laid or is at a similar stage of construction after January 1, 1980; or
c. is delivered after June 1, 1982; or
d. has undergone a major conversion that is contracted for after June 1, 1979, or has begun the conversion after January 1, 1980, or has completed the conversion after June 1, 1982.

B3 - A tank vessel that is contracted for after March 31, 1977, BUT DOES NOT COME UNDER CATEGORY A3.

C3 - A tank vessel that:

a. is contracted for after December 31, 1975; or
b. in the absence of a building contract, has the keel laid or is at a similar state of construction after June 30, 1976; or
c. is delivered after December 31, 1979; or
d. has undergone a major conversion that is contracted for after December 31, 1975, or has begun the conversion after June 30, 1976, or has completed the conversion after December 31, 1979; BUT
e. DOES NOT COME UNDER CATEGORIES A3 or B3.

D3 - A tank vessel that DOES NOT COME UNDER CATEGORIES A3, B3, or C3.
3. Foreign tank vessels must meet the applicable requirements when the vessel enters U.S. waters for commercial service after the date the equipment or construction standard is required.

SOURCE: U.S. Coast Guard Navigation and Inspection Circular No. 1-81, Change 1 (July 14, 1986).

congressional delegation of marine safety jurisdiction to the U.S. Coast Guard. Because these regulations apply to U.S. vessels in the domestic and foreign trades, as well as to foreign tank vessels entering U.S. waters for commercial service, the design and equipment requirements for all vessels need to be addressed at the federal and international levels through the authorities most knowledgable about marine safety issues. Otherwise, there could be significant impacts on maritime interstate and foreign commerce if nonuniform and piecemeal state-by-state regulations are implementated.

Regulation of Vapor Recovery Systems While the Coast Guard does not have authority to establish or enforce air emission standards for vessels, it does have authority to ensure that the marine equipment and requirements for meeting such standards are safe. Owing to limited state implementation of emission standards in the past, the Coast Guard has not promulgated a generic regulatory scheme. Therefore, although a few vapor recovery systems are in existence, the Coast Guard has no regulations that deal specifically with collection, recovery, or treatment of emissions generated during cargo loading.

Vapor recovery systems (VRS) for vessels, to the extent they have been used, are inspected under the general inspection authority set out at 46 C.F.R. Subpart 31.10. These regulations include mandatory review and approval by the Coast Guard of plans and specifications for the hull, cargo tanks, and machinery, and inspection during construction and upon completion [46 C.F.R. § 31.10-5]. In fact, the Coast Guard's current policy with regard to a landside facility's vapor recovery equipment is that such equipment will not be plan-reviewed, nor will design approval be given. However, the Coast Guard has the authority to stop an operation should an unsafe condition be identified during an inspection of the facility.

The Coast Guard will review vessel modifications to enable use of VRS on a case-by-case basis, taking into account general safety hazards and concerns. Coast Guard involvement in such reviews so far has been minimal. As interest in these systems increases, this case-by-case review will no longer be appropriate.

Vessel Operations The Coast Guard requires regularly scheduled drydocking of inspected vessels so that hull plating and frames can be thoroughly inspected. The cargo tanks must be gas-freed to enable physical inspection of the tank spaces [46 C.F.R. § 31.10-20]. There is concern about how gas-freeing will be accomplished while vapor emissions are restricted. Further, each tank vessel must meet stability requirements, 46 C.F.R. § 31.10-30, and be assigned a load line if it is engaged in coastal or ocean voyages to ensure sufficient freeboard to be seaworthy [46 C.F.R. Part 42]. The addition of vapor control equipment on board a vessel may require recalculation of both the stability and load line of a vessel.

Licensing and Certification of Tankermen The Coast Guard administers a rigorous licensing program to guarantee base levels of knowledge, demonstrated competence, and expertise for licensed deck officers and engineers. It issues licenses corresponding to licensees' skills and experience, and limits those licenses to vessels of specific size and type and to routes to be traversed. The licenses are graded to indicate varying levels of responsibility and skill. The safe operation of tank vessels requires a complement of skilled, trained individuals.

Tank barges that carry crude oil or petroleum products must have on board special crew members, called tankermen, to load and unload the cargo, ensuring that barges are not overloaded or ruptured. VRS requirements may impose new demands on these personnel, and may add a more complex operational function that may compound the possibility of human and mechanical error. Tankermen may require retraining to handle the VRS equipment, or in the alternative, a new class of personnel may be required solely to handle the VRS equipment.[84]

International Marine Safety and Pollution Conventions

The International Maritime Organization (IMO) has sponsored international conventions and codes, many of which have been adopted by the United States. EPA is frequently represented on U.S. delegations that advise IMO on international environmental measures affecting vessels.

The Role of IMO in U.S. Maritime Law

International harmony in marine transportation is essential. Accordingly, many U.S. marine safety and environmental protection laws have developed in conjunction with numerous international maritime agreements over the years. The IMO has sponsored international conventions and codes with applicable regulations to implement these conventions, and codes which have been signed and ratified by the United States. The IMO's standing committees, on a continuing basis, monitor the implementation of existing conventions, issue guidelines, and develop new initiatives. The IMO has no enforcement authority over either treaties, or regulations developed to implement these treaties; enforcement is left to the administering countries.

Many of these conventions and codes have been incorporated into domestic laws.[85] Domestic laws in several instances have been enacted or amended to implement these international treaties. Other conventions[86] have not been ratified by the United States, but nonetheless impact marine vessel operation. These conventions and codes represent an integrated, international response to maritime safety and environmental protection. A summary description of some of these IMO initiatives follows.

Safety of Life at Sea (SOLAS) The 1974 SOLAS Convention contains safety standards and procedures. SOLAS applies to ships engaged on interna tional voyages and governs inspection and maintenance of ships; subdivision and stability of vessels; machinery and electrical installations; fire protection, detection, and extinction; lifesaving equipment; radio communications equipment; navigation safety; and carriage of dangerous goods. SOLAS entered into force on May 25, 1980.

In June 1983, as part of its ongoing regulatory responsibilities, the IMO Maritime Safety Committee adopted the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, and the International Code for the Construction and Equipment of Ships Carrying Liquified Gases in Bulk. These codes have become mandatory under 1983 SOLAS amendments. The Coast Guard is in the process of drafting regulations to implement these codes. These codes address emissions control for toxic products not for air quality considerations, but rather for personnel protection and toxicity.

Standards for Training, Certification, and Watchkeeping (STCW) The STCW Convention establishes improved threshold requirements for training, certification, and watchkeeping for licensing masters, officers, and certain crew members of seagoing commercial vessels. These mandatory, minimum requirements are designed to provide highly qualified personnel on board vessels to reduce maritime casualties, protect the marine environment, and promote maritime safety. The standards vary according to size and type of vessel and class of seamen. Annex I, Chapter V of the convention contains special requirements for training and certification of seamen involved in loading, discharging, and care in transit of cargo on oil tankers, chemical tankers, and liquefied gas tankers. Although the United States has not yet ratified STCW, the Coast Guard is revising its licensing and training requirements to conform to these international standards.[87] Ratification seems likely to follow adoption of these regulations.

Marine Pollution (MARPOL) MARPOL 73/78 was established to prevent pollution of the marine environment by discharging harmful substances or effluents containing such substances into the sea from ships. To achieve its aim, MARPOL 73/78 contains five annexes in which detailed regulations are given with respect to the handling on board and the discharge into the sea of five main groups of harmful substances, that is, Annex I (oils), Annex II (noxious liquid substances carried in bulk), Annex III (harmful substances carried in packaged forms), Annex IV (sewage), and Annex V (garbage). For purposes of the Marine Board Study, only Annexes I and II are relevant. MARPOL 73/78 was ratified by the United States on August 12, 1980.

Annex II allows removal of cargo residues by tank ventilation. Appendix C of Annex II specifies that, with regard to safety aspects, the operational requirements for cargo tank openings in the International Bulk Chemical Code, the Bulk Chemical Code, and the ventilation procedures in the ICS Tanker Safety Guide (chemicals) should be consulted.

International Vapor Recovery Activity

United States Paper On November 26, 1980, the United States submitted an information paper to the IMO Subcommittee on Bulk Chemicals concerning Hydrocarbon Vapor Emission Control (BCH/59). The Coast Guard was considering the need for regulations concerning vessel emissions control, because emissions standards would be applied to both foreign and domestic vessels in United States ports. The U.S. solicited comments from all IMO nations and requested details concerning similar national plans.

Other Nations In 1983, the Netherlands Ministry of Housing, Physical Planning, and Environment commissioned a study on vapor-handling systems for the transfer of liquids between sources such as ships, inland barges, rail tank cars, and tank trucks, for use as technical background to permit issuing authorities.[88] Following the study on vapor control technology in 1984, the Netherlands government proposed legislation that would require the use of vapor recovery systems in Rotterdam when loading marine vessels with ethylene dichloride, epichlorohydrin, benzene, or acrylonitrile.

Because of the international character of marine bulk transportation, efforts by states to impose restrictions requiring equipment and operational modifications may conflict directly with the international regulation of marine vessels, and may interfere directly with international commerce.

ANALYSIS OF OVERLAPPING INTERESTS

The Relation Between Coast Guard and EPA Authority

The Coast Guard does not exercise authority over vessel emissions insofar as air quality considerations are concerned. However, the use of on-board control equipment may present significant safety hazards by, among other things, increasing the risk of harm to personnel or the possibility of tank rupture and explosions, or introducing a source of ignition in a vessel. Consequently, the Coast Guard does exercise jurisdiction over measures designed to control air emissions to the extent those measures affect the design, construction, or operation of marine vessels.

EPA has recognized on several occasions that safety, technological, and economic issues must be taken into account in the development of marine vessel emission control strategies and has deferred action on marine vessel regulations that would ascribe vessel emissions to marine terminals for purposes of new source review. Also, the Coast Guard and EPA have sponsored joint studies on the feasibility of controlling vessel emissions.

In 1974, control of vapor emissions from gasoline loading was being considered in the Houston-Galveston area. Potential safety problems associated with recovery of hydrocarbon vapors possibly in the flammable range were brought to the attention of the Coast Guard. The Coast Guard considered adding regulations to the PWSA regulations in 33 C.F.R. Subchapter P to establish a new Part 166 containing safety equipment requirements for VRS and operational requirements concerning the use of VRS equipment during vessel cargo loading and unloading at waterfront facilities. The Coast Guard solicited public comment through an Advance Notice of Proposed Rulemaking [41 Fed. Reg. 14,391 (April 5, 1976)]. All comments received expressed apprehension over the hazards inherent in collecting and transferring flammable vapors. The Coast Guard never took further formal action on the VRS proposal, but instead transmitted comments to EPA concerning the potential safety hazards associated with VRS.

The Coast Guard also sponsored a series of research studies including, for example, a study on devices to suppress detonations in pipelines transferring flammable vapors. These research studies are listed later in this appendix in the section, Coast Guard Sponsored Research Studies.[89]

Recognizing at an early stage that vessel emission controls would be stymied until the safety issues were resolved, EPA decided to delay promulgating marine vapor control regulations pending further research into safety and economic issues. With Coast Guard support and participation, EPA initiated a barge vapor control demonstration project in 1979 to consider the economics, performance, and general suitability of the control of emissions from barges during gasoline loading. Budget cuts in the early 1980s curtailed the program.

With respect to the legislative authority delegated to EPA and to the Coast Guard, the control of air emissions was not specifically addressed in the CAA or in the Coast Guard's regulatory authority. Consequently, the statutes themselves do not establish guidance other than a clear delegation to the Coast Guard of exclusive jurisdiction over matters pertaining to marine safety.

The Relation Between EPA and State Authority

The Clean Air Act: Silent on Vessels

As discussed previously, there is no federal legislation permitting the control of emissions from ships, barges, or other vessels. EPA's authority to require states to include in their SIPs transportation control plans for reducing pollution from motor vehicles generated tremendous controversy. In addition, EPA's authority to promulgate regulations requiring “indirect source review” was never clearly established. The CAA provisions on moving sources cover only automobiles and aircraft because Congress was primarily concerned with prohibiting EPA regulation of motor vehicles and parking facilities.

To the extent that states have proposed SIP modifications to regulate vessels, EPA has taken the position that the exercise of state environmental authority over marine vessels is open to question, especially in light of Coast Guard jurisdiction over marine safety. Since there is no specific mandate to regulate vessel emissions in the

CAA or other federal law, the states exercise discretion with respect to those sources which they select for regulation under their SIPs.

Conditional EPA Approval: Jurisdictional Doubts

Although it is unclear whether EPA may require states to regulate marine vessel emissions indirectly, the CAA does not preclude the states from voluntarily doing so. Any EPA approval of a SIP providing for the regulation of marine vessel emissions will have to be conditional, since the CAA does not confer authority on EPA to regulate marine vessel emissions directly. In fact, in its proposed approval of the revised New Jersey SIP, EPA stated that New Jersey would have to ensure that it has adequate legal authority to regulate marine sources, thus suggesting that New Jersey's authority to regulate marine vessels is independent and would not derive from EPA's authority pursuant to the CAA.[90]

Furthermore, since EPA has not formulated regulations concerning the attribution of marine vessel emissions to marine terminals, EPA cannot affirmatively approve SIP provisions governing marine terminals for new source review purposes. EPA only partially approved SIP amendments concerning PSD regulations proposed by Kansas, but expressly retained authority to issue permits for marine terminals.[91] EPA deferred action on Kansas's proposed exclusion of vessel activities in its definition of stationary source.

While EPA cannot require a state to include an indirect source review program in its SIP, a state, insofar as the CAA is concerned, may require such a program on its own pursuant to section 116, which provides that nothing in the CAA “shall preclude or deny the right of any State or political subdivision thereof to adopt or enforce (1) any standard or limitation respecting emissions of air pollutants or (2) any requirement respecting control or abatement of air pollution” [42 USC § 7416]. Uncertainties about state authority to regulate vessels and the safety of the equipment the vessels would be forced to install will remain until EPA takes affirmative regulatory action.

The Relation Between Coast Guard and State Authority

Compliance with state regulation of vapor emissions from marine vessels may require significant design modifications to vessels, whether the control equipment is placed on-board the vessel or onshore at a marine terminal. Such state regulation may be preempted by federal law granting the Coast Guard exclusive authority over vessel design and construction, or by constitutional provisions limiting the ability of states to impose burdens on interstate commerce.

The Supremacy Clause

The supremacy clause of the U.S. Constitution[92] elevates federal law above state law in the event of inconsistency or conflict. This is known as the preemption doctrine. Under the preemption doctrine, regulatory authority over maritime activities by state and local governments must not interfere with the comprehensive system of regulation enacted by the federal government.[93] The preemptive effect of a federal statute and implementing regulations may be established in several ways. First, acting pursuant to the supremacy clause, Congress may expressly provide in a statute that a state law that is inconsistent with the federal law is preempted or that the federal law preempts all state laws addressing the same subject, even if not inconsistent.[94]

Second, absent an explicit expression in the statute of congressional intent to preempt state authority, such intent will be inferred where Congress has created a federal regulatory scheme so pervasive that it leaves no room for state action, or where the federal interest is so predominant, and the need for uniformity so great, that the federal system will be assumed to preclude enforcement of state laws on the same subject.[95]

Third, even where Congress has not entirely displaced state regulation in a specific area, state law will be preempted when "compliance with both federal and state regulations is a physical impossibility,"[96] or where state law "stands as an obstacle to the accomplishment and execution of the full purposes and objectives of Congress."[97]

Preemption of Vessel Design Requirements Congress has enacted a comprehensive federal regulatory system governing marine vessels and maritime activities, discussed previously. Under authority granted by the PWSA and PTSA, the Coast Guard has promulgated extensive rules and regulations governing the design, construction, alteration, repair, crew training, maintenance, and operation of certain vessels. The Coast Guard was specifically authorized to set stricter standards for vessels engaged in domestic trade.

Although the PWSA and PTSA do not contain an explicit expression of congressional intent to preempt state law regulating vessel design and construction, the Supreme Court has held that Congress intended to preempt the field of vessel design and construction. Ray v. Atlantic Richfield Co., 435 U.S. 151 (1978). In Ray v. ARCO, the Court, in striking down a Washington State statute requiring certain design safety features for tankers, held that Congress had entirely preempted the field as to tanker design requirements. The Court stated:

> This statutory pattern shows that Congress, insofar as design characteristics are concerned, has entrusted to the Secretary the duty of determining which oil tankers are sufficiently safe to be allowed to proceed in the navigable waters of the United States. This indicates to us that Congress intended uniform national standards for design and construction of tankers that would foreclose the imposition of different or more stringent state requirements. [435 U.S. at 163 (emphasis added)]

The Court found that Washington's "design requirements, standing alone, are invalid in light of the PWSA and its regulatory implementation" [Id. at 160-61].

The basis for the Supreme Court's decision in Ray v. ARCO was recently applied in Chevron v. Hammond, 726 F.2d 483 (9th Cir. 1983), where the Court of Appeals for the Ninth Circuit upheld an Alaska statute prohibiting oil tankers from discharging ballast from oil cargo tanks into the territorial waters of Alaska against a challenge on preemption grounds. The Court distinguished the Alaska statute from the Washington statute at issue in Ray v. ARCO on the grounds that the Alaska statute did not address a vessel design requirement, but rather implemented the Clean Water Act of 1977[98] by regulating the discharge of a pollutant into navigable waters. However, the Court noted that the state regulation, despite its validity under the Clean Water Act, could still be challenged on the ground that it is preempted by the PWSA and PTSA [726 F.2d at 491]. With regard to the PWSA and PTSA, the Court stated:

> While design standards need to be uniform nationwide so that vessels do not confront conflicting requirements in different ports and so that the Coast Guard can promote international consensus on design standards, there is no corresponding dominant national interest in uniformity in the area of coastal environmental regulation. [Id. at 492]

The court also noted the following:

> Although national uniformity and international consensus are critical concerns in the establishment of tanker design standards, those concerns are not essential in the regulation of pollutant discharges into coastal waters. Once a ship is constructed, it cannot meet new or different design requirements in various ports. A ship's discharge of pollutants can, however, be varied according to environmental standards and conditions in different jurisdictions. [Id. at 492-93]

Thus, the Court's holding that the Alaska statute regulating the discharge of pollutants into state territorial waters is not preempted by the PWSA and PTSA was based on the fact that the law did not require any design or construction modifications on the marine vessel.

In sum, it is well established that the PWSA and PTSA preempt state laws and regulations relating to vessel design and construction requirements, and that state laws enacted for environmental purposes are likely to be preempted if such laws require vessel modifications.

Nondesign Requirements: Need for National Uniformity The preemptive effect of federal law on state laws that would impose nondesign require ments on marine vessels (e.g., standards for inspection, regulation, smoke abatement, or discharge of ballast in state territorial waters) is less clear. As a general rule, however, state laws that impose non-design requirements on marine vessels are preempted if they (a) directly conflict with any express provision of federal law or regulation; or (b) intrude into an area where the federal interest is so predominant, and the need for national uniformity so great, that such laws and regulations are precluded--even where Congress has not acted.[99]

In Huron Portland Cement Co. v. City of Detroit, 362 U.S. 440 (1960), the Court held that a Detroit smoke abatement code limiting vessel emissions during loading and unloading was not preempted by federal law because there was “no overlap between the scope of the federal ship inspection laws and that of the municipal ordinance” [362 U.S. at 446]. The Court found that the sole aim of the Detroit ordinance was the “elimination of air pollution, to protect the health and enhance the cleanliness of the local community,” while the federal regulatory scheme was designed to ensure “seagoing safety of vessels subject to inspection” [Id. at 445].

The continuing validity and precedential effect of this decision is subject to debate. Although the case has never been overruled, it must be emphasized that it was decided prior to the enactment of the CAA, PWSA, and PTSA. Moreover, the Court expressly noted that its consideration of the Detroit ordinance was limited to the enforcement of criminal provisions for violation of the smoke emission regulations, and did not encompass a review of the validity of the inspection sections of the ordinance [Id. at 442, n.1]. The Court also stated that a state “may not impose a burden which materially affects interstate commerce in an area where uniformity of regulation is necessary” [Id. at 446].

In sum, state laws affecting marine vessels or maritime affairs are preempted by federal law if they infringe on an area that is the subject of federal regulation because uniformity of regulation is essential, even where the state laws do not conflict directly with a federal requirement or where the congressional intent to preempt is not clear.

The Commerce Clause

The commerce clause,[100] by its terms, confers power on Congress to regulate interstate and foreign commerce. Even in the absence of an affirmative congressional exercise of the commerce power, however, the states may not enact laws that unduly restrict the free flow of interstate commerce.[101] The analysis of the validity of a state law under the commerce clause is distinct and independent from such an analysis under the supremacy clause. Thus, if a state or local law or regulation affecting maritime activities is not preempted by federal law or regulations, it may still be invalid if it creates an undue burden on interstate or foreign commerce.

If a state law discriminates against out-of-state vessels or foreign vessels, it is per se invalid under the commerce clause.[102] If a state or local law or regulation affecting marine vessels or maritime activities does not discriminate against out-of-state vessels, the courts employ a balancing test to determine its validity under the commerce clause.

Pursuant to the test set forth in Pike v. Bruce Church, Inc., 397 U.S. 137, 142 (1970), if a state law or regulation is nondiscriminatory, effectuates a legitimate local purpose, and has only an incidental effect on interstate commerce, the law or regulation will be upheld, unless the burden imposed on interstate commerce is clearly excessive in relation to the putative local benefits. In short, the court must balance the relative burden imposed on interstate or foreign commerce against the putative local benefit.

In conducting this balancing test, the court must determine whether the local safety benefits advanced by the state are real or illusory.[103] In addition, the court should not view the state or local law in isolation, but rather should consider the cumulative effect on commerce of numerous, and often conflicting, state laws addressing the same subject.[104]

Using the Pike v. Bruce Church analysis, a court could likely find that a state law restricting dockside vessel emissions is in violation of the commerce clause, in view of the Coast Guard's existing comprehensive regulation of vessels. Of course, the provisions of each state law will vary, and such laws must be considered individually in terms of both their effect on commerce and the local benefits likely to be achieved. As an initial matter, it should be noted that in Babcock & Wilcox Co. v. Township of Parks, Armstrong County, Pa., Cir. Action No. 85-3035 (W.D. Pa. May 14, 1986), the court considered the interaction of section 116 of the CAA and the commerce clause. Section 116 of the CAA, discussed previously, preserves the rights of states to adopt or enforce more stringent air emissions standards or limitations and abatement or control measures. Upon consideration of this provision, the court held that it did not support the inference that Congress intended to exempt any action taken by the states pursuant to the CAA from the reach of the commerce clause.[105]

The mandatory use of VOC control equipment on vessels may entail significant costs and risks. State requirements that result in design modifications and retrofitting of vessels may conflict with federal law. Moreover, if vessels do not have required equipment on board, they may be denied entry to certain ports or subjected to fines and criminal penalties for failing to adhere to state laws. This problem may be exacerbated if many states enact laws governing VOC emissions that require different modifications. Structural changes to a vessel to accommodate a terminal in one state may render the vessel incompatible with a terminal in another state.

Thus, state laws may impose a significant burden on interstate commerce. With respect to the local benefits to be achieved by state laws governing dockside vessel emissions, the factual record to date does not appear to support the conclusion that VOC equipment will enhance safety and reduce pollution in light of attendant risks. Moreover, if vessel emissions could be reduced, the efficacy of such reductions in improving overall state air quality may not be sufficient to justify the significant burden on commerce imposed thereby.

International Considerations

Regulation of Foreign Commerce: More Rigorous Scrutiny

There is a heightened federal interest in occupying a field through uniform federal regulation when the area of law involves international relations [Chevron v. Hammond, 726 F.2d at 483]. Very often, the vessels loading or unloading at marine terminals are foreign-flag vessels subject to the jurisdiction of foreign nations as well as to IMO treaties. In some cases, the foreign-flag vessels are the national property of foreign governments, such as Poland or the Soviet Union. Efforts to impose unilaterally the federal, state, and local laws and regulations governing vessel emissions may adversely affect diplomatic relations between the United States and such nations.

CONCLUSION

The specific delegation of marine safety responsibilities to the U.S. Coast Guard is clear and comprehensive. The extent of federal and state air quality jurisdiction over marine vessels is far from clear. A review of the authorities and cases suggests that air quality regulation of vessels is circumscribed by the presence of federal marine safety and environmental regulations. To the extent the air quality regulations intrude on the interests protected by marine safety and pollution laws, the marine laws will prevail. In addition, issues of national uniformity and deference to international regulation of vessels and the marine environment further limit the extent to which states may regulate marine vessels.

NOTES

[1] 42 USC §§ 7401-7642 (1982 & Supp. III 1985).

[2] Pub. L. No. 88-206, 77 Stat. 392.

[3] Pub. L. No. 90-148, 81 Stat. 485.

[4] Pub. L. No. 91-604, 84 Stat. 1676.

[5] Pub. L. No. 95-95, 91 Stat. 685.

[6] Clean Air Act Amendments of 1970, § 101(b)(1), 42 USC § 7401.

[7] In 1979, EPA changed the chemical designation in the standard for photochemical oxidants to ozone, thereby excluding about 10 percent of the compound oxidants, previously covered [44 Fed. Reg. 8202 (Feb. 8, 1979)].

[8] EPA revoked both the primary and secondary standards for hydrocarbons because the regulations were found to be technically inadequate. EPA also found that hydrocarbons, as a class, do not cause adverse health or welfare effects at or near ambient levels [48 Fed. Reg. 628 (Jan. 5, 1983)].

[9] Friends of the Earth v. Carey, 535 F.2d 165 (2d Cir. 1976).

[10] Section 110(a)(3) does not specify how long EPA has to accept or reject a proposed revision, but courts have generally held that EPA must

act on proposed revisions within 4 months, the same time given for rulings on original proposals. American Cyanamid v. EPA, 25 E.R.C. 1585 (5th Cir. 1987); Council of Commuter Organizations v. Thomas, 799 F.2d 879, 888 (2d Cir. 1986); Duquesne Light Co. v. EPA, 698 F.2d 456, 471 (D.C. Cir. 1983); but see United States v. National Steel Corp., 767 F.2d 1176, 1182 n.1 (6th Cir. 1985) (4-month rule applies only to general state plans and not to revisions).

[11] Union Electric Co. v. EPA, 427 U.S. 246 (1976).

[12] Train v. NRDC, Inc., 421 U.S. 60 (1975).

[13] EPA, “Interim Emissions Trading Policy Statement,” 47 Fed. Reg. 15,076 (Apr. 7, 1982).

[14] 44 Fed. Reg. 71,779 (Dec. 11, 1979).

[15] EPA, “Emissions Trading Policy Statement; General Principles for Creation, Banking and Use of Emission Reduction Credits,” 51 Fed. Reg. 43,814 (Dec. 4, 1986).

[16] EPA intends to issue a separate “mobile source bubble policy.” See Inside EPA Weekly Report, “Final EPA Bubble Policy Clarifies Toxics, Fugitive Dust Trades,” at 11 (Nov. 21, 1986).

[17] The baselines for sources participating in a bubble must take into account three factors relevant to total emissions: emission rate, capacity utilization, and hours of operation. 51 Fed. Reg. at 43,815.

[18] 51 Fed. Reg. at 43,816.

[19] See Chevron, U.S.A., Inc. v. NRDC, 467 U.S. 837 (1984).

[20] The credits are not federally enforceable until used.

[21] 51 Fed. Reg. at 43,825.

[22] See NRDC v. EPA, 475 F.2d 968 (D.C. Cir. 1973).

[23] EPA is planning to regulate ozone-forming hydrocarbon emissions from motor vehicles through a combination of gasoline volatility controls and more stringent on-board vehicle emission recovery system requirements (Stage II controls). Refueling emissions can be captured by installing either Stage II nozzles or other special equipment on gasoline pumps, or special emissions control canisters in cars.

[24] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1 [40 C.F.R. § 50.9].

[25] See, e.g., Env't Rep., Current Developments (BNA), “Tightening of Ambient Ozone Standards Recommended By EPA Air Office Staff Paper,” at 2155 (Apr. 4, 1986).

[26] See EPA, “Risk Assessment of Stratospheric Ozone Depletion,” Staff Report at Chapter 14, Nov. 1986.

[27] “Memorandum from EPA General Counsel to Administrator on Legality of Sustained Progress Program for Ozone Under Air Act,” Nov. 25, 1986.

[28] Id.

[29] EPA is planning to publish a Federal Register notice in late May 1987 describing the agency's course of action on municipal nonattainment of the ozone standard. See Env't Policy Alert, at 21 (Mar. 25, 1987). EPA will also initiate review of 20 SIPs that have yet to be approved which contain provisions on ozone attainment.

[30] EPA, “Study of Gasoline Volatility and Hydrocarbon Emissions from Motor Vehicles ” Office of Mobile Sources, Nov. 21, 1985.

[31] Vehicle evaporative control systems are designed to meet hydrocarbon standards when the vehicle is fueled with certification test gasoline, which has a typical RVP of 9 psi. Evaporative emissions are significantly greater with fuels of higher volatility; therefore, evaporative emissions from motor vehicles operating on commercial gasoline are well above certification standards.

[32] See Inside EPA Weekly Report, "EPA Sends OMB Proposal for On-Board Vehicle Gas Marketing Controls" at 1, 9 (Mar. 20, 1987). The current evaporative emissions of gasoline can be reduced either through commercial RVP controls or vehicle modifications; both approaches have the potential for significant VOC reductions. Because commercial fuel content has an immediate impact on the entire motor vehicle fleet (unlike strategies that affect only new vehicle design), greater short-term emission reductions are achievable via this strategy. One EPA official predicts that limiting summertime gasoline RVP to 9 psi could reduce motor vehicle hydrocarbon evaportive emissions by 53 percent in 1988. See Env't Rep. (BNA) Current Developments, "EPA Sends Vapor Recovery Proposal to OMB, Includes Onboard, Fuel Volatility Controls," at 1995 (Mar. 27, 1985).

[33] EPA already regulates bulk gasoline deliveries from tank trucks, which is known as Stage I control.

[34] A proposed New Jersey regulation would require installation of vapor recovery systems on gasoline pumps by December 31, 1987 at gasoline stations that pump more than 40,000 gallons a month, and by December 31, 1988 at stations that pump 10,000 to 40,000 gallons monthly. See Env't Rep. (BNA), Current Developments, "Petroleum, Auto Industries Differ Over N.J. Vapor Recovery Plan for Gas Pumps," at 1020 (Oct. 31, 1986). New Jersey officials contend that the regulation, when fully implemented, will reduce VOCs by 12,950 tons per year and save 4 million gallons of gasoline annually. In addition, all gasoline stations on the Missouri side of the St. Louis metropolitan area must be equipped with a vapor recovery system by the end of 1987 under a regulation adopted in 1986.

[35] See Env't Rep. (BNA), Current Developments, "Safety Issue Clouds Vapor Recovery Plan as Dingell, Insurers Question EPA Proposal," at 3 (May 1, 1987).

[36] See Env't Rep. (BNA), Current Developments, "NRDC notifies New York, EPA of Intent to Sue to Force Air Act Standard Attainment," at 979 (Oct. 24, 1986); Inside EPA Weekly Letter, "Environmentalists Sue EPA, New Jersey, New York Over No Ozone Controls," at 1-3 (Jan. 30, 1987).

[37] The suit was filed on November 18, 1986 by the Los Angeles-based Western Oil and Gas Association. See Western Oil and Gas Association v. EPA, CV 86-7530TJH TX (C.D. Cal.). See also Env't Rep. (BNA), Current Developments, "Oil Industry Group Challenges EPA Program for Meeting Air Quality Standards in California," at 1303 (Dec. 5, 1986).

[38] Abramowitz v. EPA, Civ. No. 84-7642 (9th Cir.). Abramowitz filed suit in 1984, followed by negotiations with California and EPA over modifications to the SIP to attain standards in the South Coast Air Basin. After California and EPA tried to carry out an agreement on the reasonable extra efforts program, Abramowitz asked the court to allow him to continue to prosecute his challenge of the program. See Env't

Rep. (BNA), Current Developments, “California Plan Inadequate to Meet Ambient Air Quality Standards, Suit Charges,” at 1620 (Jan. 23, 1987).

[39] See Env't Rep. (BNA), Current Developments, “Wisconsin Begins Preparing Suit Against EPA, Illinois, Indiana over Ozone Attainment Issue.” at 979 (Oct. 24, 1986).

[40] See Env't Rep. (BNA), Current Developments, “New England Legal Group Threatens Suit Over Ozone Compliance By Massachusetts,” at 1497 (Jan 2, 1987).

[41] Conf. Rep. No. 1783, reprinted in 1970 U.S. Code Cong. & Admin. News 5381.

[42] See Title II, Emission Standards for Moving Sources, 42 USC § 7535 - 7574.

[43] However, California has obtained a waiver permitting it to set automobile emissions standards that are different from the national standards.

[44] An indirect source review program is a facility-by-facility review program to take necessary measures to ensure that a new or modified indirect source will not attract mobile sources of air pollution, the emissions from which would cause or contribute to air pollution concentrations [42 USC § 7410(a)(5)(D)].

[45] See Pub. L. No. 95-95, 91 Stat. 685, 695-96 (1977).

[46] 45 Fed. Reg. 52,676 (Aug. 7, 1980).

[47] Id. at 52,695-696.

[48] These are emissions of vessels occurring when the vessels are moving to or leaving from marine terminals.

[49] 47 Fed. Reg. 27,554 (June 25, 1982).

[50] 46 Fed. Reg. 61,613 (Dec. 17, 1981) (emphasis in original).

[51] At the same time, the Coast Guard and the Maritime Administration were cooperatively developing a proposal for a preemptive statutory treatment for vessel emissions similar to that in the CAA for aircraft emissions.

[52] The factors of “proximity” and “control” are applied in deciding whether to combine a particular pollutant-emitting activity with other activities in defining what is a stationary source. See 45 Fed. Reg. 6803 (1980).

[53] 46 Fed. Reg. 7182 (1981).

[54] See letter from Jananne Sharpless, secretary of environmental affairs, State of California, to Secretary Elizabeth Dole, U.S. Department of Transportation, Washington, D.C., May 8, 1986.

[55] District Rule 327, “Organic Liquid Cargo Tank Vessel Loading”; Rule 205.C, “New Source Review (NSR)/ Prevention of Significant Deterioration (PSD).”

[56] Recently, the California state senate voted to prevent air quality management officials from ordering marine vessels to shut off their engines while docking under the proposed rule. See “Smog Rule Barred in Calif.,” Journal of Commerce, at 1B (May 18, 1987).

[57] See Summary of Engineering Analysis, Landsea Oil Company, BAAQMD Staff Report, Nov. 3, 1986.

[58] Rule 17-2.650(1)(f)9 and 10.

[59] 48 Fed. Reg. 36,139 (Aug. 9, 1983).

[60] 48 Fed. Reg. 51,472 (Nov. 9, 1983).

[61] 48 Fed. Reg. at 51,478.

[62] Tex. Rev. Civ. Stat. Ann. art. 4477-5 (Vernon 1976 & Supp. 1986)

[63] Scurry v. Texas Air Control Board, 622 S.W.2d 155 (Tex. Civ. App. Austin 1981, writ ref'd n.r.e.).

[64] Section 7.05(a)(3).

[65] Section 7.05(b).

[66] Report of the Clean Air Study Committee to the 70th Legislature, Nov. 1986.

[67] Pub. L. No. 92-340, 86 Stat. 424.

[68] Pub. L. No. 95-474, 92 Stat. 1471.

[69] Most VOC emissions from marine vessels involve bulk carriage of organic liquids by tank vessels, including self-propelled tankers and nonself-propelled tank barges. Organic liquids such as crude oil, gasoline, petroleum products, and petrochemicals all contribute VOC emissions in varying degrees depending on volatility, loading rates, and temperature.

[70] See H.R. Rep. No. 338, 98th Cong., 1st Sess., reprinted in 1983 U.S. Code Cong. & Admin. News 924.

[71] See, for example, 46 USCA §§ 3301-18 (governing inspection of vessels).

[72] See, generally, 33 C.F.R. Subchapter O (Pollution): Part 155 (Oil Pollution Prevention Regulations for Vessels) and Part 157 (Rules for the Protection of the Marine Environment Relating to Tank Vessels Carrying Oil in Bulk); 46 C.F.R. Subchapter D (Tank Vessels): Part 30 (General Provisions), Part 31 (Inspection and Certification), Part 32 (Special Equipment, Machinery, and Rule Requirements); Subchapter F Marine Engineering): Part 56 (Piping Systems and Appurtenances), Part 57 (Welding and Brazing), Part 61 (Periodic Tests and Inspections), and Part 64 (Marine Portable Tanks [MPT]); 46 C.F.R. Subchapter I (Cargo and Miscellaneous Vessels): Part 91 (Inspection and Certification), Part 92 (Construction and Arrangement), Part 93 (Stability), Part 96 (Vessel Control and Miscellaneous Systems and Equipment), Part 97 (Operations), and Part 98 (Special Construction, Arrangement, and Other Provisions for Certain Dangerous Cargoes in Bulk); 46 C.F.R. Subchapter O (Certain Bulk Dangerous Cargoes): Part 150 (Compatibility of Cargoes and Operational Requirements for Bulk Liquid Hazardous Waste Cargoes) and Part 153 (Safety Rules for Self-propelled Vessels Carrying Hazardous Liquids); 46 C.F.R. Subchapter Q (Equipment, Construction, and Materials: Specifications and Approval): Part 159 (Approval of Equipment and Materials), Part 161 (Electrical Equipment), Part 163 (Construction), and Part 164 (Materials); and 46 C.F.R. Subchapter S (Subdivision and Stability): Part 170 (Stability Requirements for All Inspected Vessels), Part 172 (Special Rules Pertaining to Bulk Cargoes), Part 173 (Special Rules Pertaining to Vessel Use), and Part 174 (Special Rules Pertaining to Specific Vessel Types).

[73] Donovan v. Texaco, Inc., 720 F.2d 825 (5th Cir. 1983) ("OSHA regulations do not apply to working conditions of seamen on vessels in navigation . . ."); Dillingham Tug & Barge Corp., 10 O.S.H. Cas. (BNA) 1859 (1982). But cf. In re Inspection of Norfolk Dredging Co., 785 F.2d 1526 (11th Cir. 1986) (OSHA's jurisdiction over working conditions on

uninspected vessels is not preempted); Donovan v. Red Star Marine Services, Inc., 739 F.2d 774 (2d Cir. 1984).

[74] TSAC is an advisory committee to the secretary of Transportation, authorized by the Towing Safety Advisory Committee Act, Pub. L. No. 96-380, 94 Stat. 1521 (1980) (codified at 33 USCA § 1231a).

[75] The Comprehensive Environmental Response, Compensation, and Liability Act, Pub. L. No. 95-510, 94 Stat. 2767 (1980), as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. No. 99-499, 100 Stst. 1613 (1986); the Federal Water Pollution Control Act, Pub. L. No. 92-500, 86 Stat. 816 (1972), as amended by the Clean Water Act of 1977, Pub. L. No. 95-217, 91 Stat. 1566 (1977); the Outer Continental Shelf Lands Act Amendments of 1978, Pub. L. No. 95-372, 92 Stat. 629 (1978); the Deepwater Port Act of 1974, Pub. L. No. 93-627, 88 Stat. 2126 (1975).

[76] See Merchant Marine Act of 1920, 41 Stat. 1007 (1920) (codified at 46 USCA § 688 and commonly referred to as "the Jones Act").

[77] See Tank Vessel Act of 1936, Pub. L. No. 74-765, 49 Stat. 1889 (1936) (extending manning, inspection and safety laws to encompass all vessels, including tank barges, whether self-propelled or not, which transport inflammable, explosive, or dangerous cargo). See also Moran Maritime Associates, Inc. v. Coast Guard, 526 F. Supp. 335 (D.D.C. 1981) aff'd, 679 F.2d 61 (D.C. Cir. 1982).

[78] See H.R. Rep. No. 1384, 95th Cong., 2d Sess. 4, reprinted in 1978 U.S. Code Cong. & Admin. News 3270, 3271.

[79] These latter topics are important because changes in vessel design and equipment imposed to accomplish states' vessel emissions reduction goals may necessitate increased personnel to operate the equipment and/or further training in the operation or use of such equipment. If additional training is required, licenses would have to be appropriately endorsed to reflect that training.

[80] Certain tank vessels take in seawater to ballast the vessel (to deepen draft and achieve proper trim), after cargoes have been discharged. Prior to the advent of international marine regulation, this ballast was normally drawn into cargo tanks, where seawater mixed with cargo residues. Ballasting often took place in port, so that the vapors in off-loaded cargo tanks were displaced into the atmosphere by the incoming seawater. Mandatory segregated ballast tanks, where required, are now dedicated to ballasting; consequently, the intake of seawater displaces no vapors, and the discharged ballast is uncontaminated.

[81] Crude oil washing (COW) systems are related to segregated ballast tanks, and obviate the need for using seawater to clean cargo tanks. COW uses the solvent properties of oil from cargo tanks in a closed system, spraying crude oil at very high pressure to strip clinging cargo from tank walls and structural supports.

[82] An inert gas system is a system that supplies to the cargo tanks a gas or mixture of gases so deficient in oxygen content that combustion cannot take place in the tanks. The inert gas may be supplied by a tank vessel's boiler or by an inert gas generator. This gas is pumped into the cargo tanks via deck piping to displace the air in the tank that has an oxygen content sufficient to allow combustion. As the cargo is

pumped out during off-loading, inert gas is introduced at an equal or greater volume rate, with excess inert gas vented to the atmosphere.

[83] MARPOL 73/78 in turn was implemented by the Act to Prevent Pollution from Ships of 1980, Pub. L. No. 96-478, 94 Stat. 2297 (1980) (codified at 33 USC §§ 1901-1911).

[84] The Coast Guard is in the process of establishing new, stiffer requirements for certifying individuals engaged in the carriage and transfer of petroleum and other dangerous cargoes in bulk. “Qualifications of the Person in Charge of Oil Transfer Operations, Tankerman Requirements,” Docket Nos. CGD 79-116 & 116a, Notice of Proposed Rule-making, 45 Fed. Reg. 83,290 (December 18, 1980).

[85] These include the following: (1) the International Convention on Safety of Life at Sea, 1974 (SOLAS); (2) the Officers' Competency Certificates Convention, 1936; (3) the International Convention for the Prevention of Pollution from Ships, 1973, and the Protocol of 1978 (“MARPOL 73/78”); (4) the International Convention on Load Lines, 1966; (5) the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969; (6) the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Materials, 1972 (known as the London Dumping Convention); (7) the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (BCH Code) (adopted as amendments to MARPOL 73/78); (8) the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, 1983 (IBC Code) (adopted as an amendment to SOLAS); the International Code for the Construction and Equipment of Ships Carrying Liquified Gases in Bulk, 1983 (adopted as amendment to

[86] For example, the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW).

[87] “Licensing of Maritime Personnel,” Docket No. CGD 81-059, Supplemental Notice of Proposed Rulemaking, 50 Fed. Reg. 43,316 (Oct 24, 1985).

[88] Rapport Studieproject Dampretoursystemen, Proj. No. VROM LB 671001, Proj. No. Badger B.V.: BN-3580, 1984. Ministry of Housing, Physical Planning, and Environment, Dokter v.d. Stamstraat 2, 2260 MB Leidschendam, The Netherlands.

[89] At the same time, the Coast Guard and the Maritime Administration were developing a proposal for a preemptive statutory treatment for vessel emissions similar to that in the CAA for aircraft emissions.

[90] 48 Fed. Reg. at 51,478.

[91] 49 Fed. Reg. 48,185 (Dec. 11, 1984).

[92] U.S. Const., art. VI, cl. 2.

[93] Kelly v. Washington, 302 U.S. 1 (1937).

[94] Jones v. Rath Packing Co., 430 U.S. 519, 525, reh. denied, 431 U.S. 925 (1977).

[95] Pacific Gas and Electric Co. v. State Energy Resources Conservation & Dev. Comm'n, 461 U.S. 190, 203-04 (1983); Ray v. Atlantic Richfield Co., 435 U.S. 151, 163 (1978); Rice v. Santa Fe Elevator Corp., 331 U.S. 218, 230 (1947).

[96] Florida Lime & Avocado Growers, Inc. v. Paul, 373 U.S.132, 142-43 (1963).

[97] Hines v. Davidowitz, 312 U.S. 52, 67 (1941).

[98] Pub. L. No. 95-217, 91 Stat. 1566 (1977), amending the Federal Water Pollution Control Act, Pub. L. No. 92-500, 86 Stat. 816 (1972) (codified at 33 USC § 1321 et seq.).

[99] Romero v. Int'l Terminal Co., 358 U.S. 354, 357 (1959); Just v. Chambers, 312 U.S. 383, 389-90 (1941); Kelly v. Washington, 302 U.S. 1, 8-14 (1937).

[100] U.S. Const., art. I, § 8, cl. 3.

[101] Great Atlantic & Pacific Tea Co. v. Cottrell, 424 U.S. 366, 370-72 (1976).

[102] Philadelphia v. New Jersey, 437 U.S. 617 (1978).

[103] Kassel v. Consolidated Freightways Corp., 450 U.S. 662 (1981).

[104] See, for example, Browning-Ferris, Inc. v. Anne Arundel County, Maryland, 292 Md. 136, 438 A.2d 269 (1981).

[105] See also Norfolk Southern Corp. v. Oberly, 632 F. Supp. 1225 (D. Del. 1986), in which the court held that the congressional power to consent to otherwise impermissible state regulation of interstate commerce must be exercised expressly. Although specific language need not be expressly included in the statute or legislative history, intent must be clear.

GLOSSARY OF TERMS

AQCR	Air Quality Control Region
ARCO	Atlantic Richfield Company
BAAQMD	Bay Area Air Quality Management District
BACT	best available control technology
BNA	Bureau of National Affairs
CAA	Clean Air Act
CFR	Code of Federal Regulations
CO	carbon monoxide
COW	crude oil washing
CTG	Control Techniques Guidelines
EPA	Environmental Protection Agency
ERC	emission reduction credit
IGS	inert gas system
I/M	inspection and maintenance
IMO	International Maritime Organization
LAER	lowest achievable emission rate
MARPOL	International Convention for the Prevention of Pollution from Ships
MPT	marine portable tank
NAAQS	National Ambient Air Quality Standards
NESHAPS	national emission standards for hazardous air pollutants
NO_x	nitrogen oxides
NRDC	Natural Resources Defense Council
NSPS	new source performance standards
NSR	new source review
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration

	Ozone photochemical oxidants
PA	particulate matter
ppm	parts per million
PSD	prevention of significant deterioration
PTSA	Port and Tanker Safety Act of 1978
PWSA	Port and Waterways Safety Act of 1972
RACT	reasonably available control technology
REEP	Reasonable Extra Efforts Program
RVP	Reid Vapor Pressure
SBT	segregated ballast tanks
SCAQMD	South Coast Air Quality Management District
SIP	State Implementation Plan
SO_2	sulfur dioxide
SOLAS	International Convention on Safety of Life at Sea
SPP	Sustained Progress Program
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers
TSAC	Towing Safety Advisory Committee
USC	United States Code
USCA	United States Code Annotated
VOC	volatile organic compounds
VRS	vapor recovery systems

COAST GUARD SPONSORED RESEARCH STUDIES

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APPENDIX D

CALCULATIONS OF VESSEL EMISSIONS

CRUDE OIL EMISSIONS

1. The average specific gravity of crude oil is about 0.87 g/cc. Density is calculated to be 3.62 tons/1,000 gal.
2. From the U.S. Environmental Protection Agency (EPA): ship loading, f = 0.61; barge loading, f = 1.0; and ballasting, f = 1.2.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (20,000 tons/yr/3.62 tons/1,000 gal) x 0.61 1b/1,000 gal = 3,370 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (135,000,000 tons/yr/3.62 tons/1,000 gal) x 0.61 = 22,748,619 1b/yr.
Barge emissions	= (45,800,000 tons/yr/3.62 tons/1,000 gal) x 1.0 = 12,652,934 1b/yr.

5. Ballasting emissions: Oil will be carried in oil or oil/product tankers. For foreign vessels, the combined total of these two groups has only 5.8 percent of the deadweight tons (dwt) of these vessels without equipment that would prevent ballasting emissions. For U.S. vessels, that figure is 4.6 percent.
6. Foreign Ballasting Emissions

Import emissions	= (171,640,000 tons/yr/3.62 tons/1,000 gal) x 0.058 x 0.30 cargo tank ballast x 1.1 1b/1,000 gal = 907,510 1b/yr.
Export emissions	= 0.

7. Domestic Ballasting Emissions

Tankship emissions	= (135,000,000 tons/yr/3.62 tons/1,000 gal) x 0.046 x 0.30 cargo tank ballast x 1.1 1b/1,000 gal = 566,105 1b/yr.
Barge emissions	= 0.

8. Lightering Emissions

Emissions	= (20,000,000 tons/yr/3.62 tons/1,000 gal) x 1.0 1b/1,000 gal = 5,524,862 1b/yr.

This assumes that cargo is lightered into barges. Emissions would be somewhat lower for cargo lightered into ships.

GASOLINE EMISSIONS

1. Density = 0.75 g/cc − 3.125 tons/1,000 gal.
2. From EPA: ship loading, f = 1.8; barge loading, f = 3.4; ballasting, f = 0.8.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (440,000 tons/yr/3.125 tons/1,000 gal) x 1.8 1b/1,000 gal = 253,440 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (17,400,000 tons/yr/3.125 tons/1,000 gal) x 1.8 = 10,022,400 1b/yr.
Barge emissions	= (59,610,000 tons/yr/3.125 tons/1,000 gal) x 3.4 = 64,855,680 1b/yr.

5. Ballasting emissions for gasoline and other chemicals: These products may be carried in product only or oil/product carriers. About 25 percent of the foreign fleet does not have equipment to prevent emissions, and 21 percent of the U.S. fleet does not have such equipment. These figures are used for all other products as well as gasoline.
6. Foreign Ballasting Emissions

Import emissions	= (12,550,000 tons/yr/3.125 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.8 1b/1,000 gal = 243,852 1b/yr.
Export emissions	= 0.

7. Domestic Ballasting Emissions

Tankship emissions	= (17,400,000 tons/yr/3.125 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.8 1b/1,000 gal = 280,627 1b/yr.

CRUDE TAR, OIL AND GAS PRODUCT EMISSIONS

1. Density (approx.) = 0.73 g/cc = 3.04 tons/1,000 gal.
2. Estimated from EPA and Scott (see Table 1-1 and Table 1-2), f = 0.5 for all cases.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (436,000 tons/yr/3.04 tons/1,000 gal) x 0.5 1b/1,000 gal = 71,711 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (119,000 tons/yr/3.04 tons/1,000 gal) x 0.5 1b/1,000 gal = 19,572 1b/yr.
Barge emissions	= (1,168,000 tons/yr/3.04 tons/1,000 gal) x 0.5 1b/1,000 gal = 192,105 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (405,000 tons/yr/3.04 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.5 1b/1,000 gal = 5,068 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (119,000 tons/yr/3.04 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.5 1b/1,000 gal = 1,233 1b/yr.
Barge emissions	= 0.

EMISSIONS FROM ALCOHOLS

1. Density (approx.) = 0.83 g/cc = 3.46 tons/1,000 gal.
2. From Scott (see Table 1-2), f = 0.005 for all cases.

3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (913,000 tons/yr/3.46 tons/1,000 gal) x 0.005 1b/1,000 gal = 1,319 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (478,000 tons/yr/3.46 tons/1,000 gal) x 0.005 = 690 1b/yr.
Barge emissions	= (3,810,000 tons/yr/3.46 tons/1,000 gal) x 0.005 = 5,506 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (1,036,000 tons/yr/3.46 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 114 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (478,000 tons/yr/3.46 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 44 1b/yr.

BASIC CHEMICALS EMISSIONS

1. Density (approx.) = 0.9 g/cc = 3.75 tons/1,000 gal.
2. From Scott, f = 0.005 for all cases.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (10,689,000 tons/yr/3.75 tons/1,000 gal) x 0.005 1b/1,000 gal = 14,252 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (2,510,000 tons/yr/3.75 tons/1,000 gal) x 0.005 = 3,347 1b/yr.
Barge emissions	= (20,440,000 tons/yr/3.75 tons/1,000 gal) x 0.005 = 27,253 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (16,197,000 tons/yr/3.75 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 1,639 1b/yr.
Export Emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (2,510,000 tons/yr/3.75 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 211 1b/yr.
Barge emissions	= 0.

EMISSIONS FROM MISCELLANEOUS CHEMICALS

1. Density (approx.) = 0.9 = 3.75 tons/1,000 gal.
2. From Scott, f = 0.005 for all cases.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (942,000 tons/yr/3.75 tons/1,000 gal) x 0.005 1b/1,000 gal = 1,256 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (229,000 tons/yr/3,75 tons/1,000 gal) x 0.005 1b/1,000 gal = 305 1b/yr.
Barge emissions	= (527,000 tons/yr/3.75 tons/1,000 gal) x 0.005 1b/1,000 gal = 703 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (1,212,000 tons/yr/3.75 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 123 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (229 tons/yr/3,175 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 19 1b/yr.
Barge emissions	= 0.

JET FUEL EMISSIONS

1. Density = 0.738 g/cc = 3.075 tons/1,000 gal (JP-4).
2. From EPA, ship loading, f = 0.5; barge loading, f = 1.2; assume ballasting, f = 0.5.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (390,000 tons/yr/3.075 tons/1,000 gal) x 0.5 1b/1,000 gal = 63,415 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (4,630,000 tons/yr/3.075 tons/1,000 gal) x 0.5 1b/1,000 gal = 752,846 1b/yr.
Barge emissions	= (911,000 tons/yr/3.075 tons/1,000 gal) x 1.2 1b/1,000 gal = 3,555,122 1b/yr.

5. Foreign Ballasting Emission

Import emissions	= (2,120,000 tons/yr/3.075 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.5 1b/1,000 gal = 26,164 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (4,630,000 tons/yr/3.075 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.5 1b/1,000 gal = 47,429 1b/yr.

KEROSENE EMISSIONS

1. Density = 0.81 g/cc = 3.375 tons/1,000 gal.
2. From EPA, ship loading, f = 0.005; barge loading, f = 0.013; assume ballasting, f = 0.005.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= 0.

4. Domestic Loading Emissions

Tankship emissions	= (600,000 tons/yr/3.375 tons/1,000 gal) x 0.005 1b/1,000 gal = 889 1b/yr.
Barge emissions	= (1,690,000 tons/yr/3.375 tons/1,000 gal) x 0.013 1b/1,000 gal = 6,510 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (280,000 tons/yr/3.375 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 32 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (600,000 tons/yr/3.375 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 56 1b/yr.

DISTILLATE (LIGHT) FUEL OIL EMISSIONS

1. Density = 0.67 g/cc = 2.792 tons/1,000 gal.
2. From EPA, ship loading, f = 0.005; barge loading, f = 0.012; assume ballasting, f = 0.005.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (3,140,000 tons/yr/2.792 tons/1,000 gal) x 0.005 1b/1,000 gal = 5,623 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (14,710,000 tons/yr/2.792 tons/1,000 gal) x 0.005 = 26,343 1b/yr.
Barge emissions	= (45,810,000 tons/yr/2.792 tons/1,000 gal) x 0.012 = 196,891 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (14,680,000 tons/yr/2.792 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 1,995 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (14,710,000 tons/yr/2.792 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 1,660 1b/yr.
Barge emissions	= 0.

RESIDUAL (HEAVY) FUEL OIL EMISSIONS

1. Density = 0.773 g/cc = 3.22 tons/1,000 gal.
2. From EPA, ship loading, f = 0.0004; barge loading, f = 0.00009; assume ballasting, f = 0.0004.

3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (12,220,000 tons/yr/3.22 tons/1,000 gal) x 0.00004 = 152 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (20,340,000 tons/yr/3.22 tons/1,000 gal) x 0.00004 = 253 1b/yr.
Barge emissions	= (74,890,000 tons/yr/3.22 tons/1,000 gal) x 0.00009 = 2,093 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (40,860,000 tons/yr/3.22 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.0004 = 39 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (20,340,000 tons/yr/3.22 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.00004 = 16 1b/yr.
Barge emissions	= 0.

LUBE OIL EMISSIONS

1. Density (approx.) = 0.88 g/cc = 3.7 tons/1,000 gal.
2. From Scott (see Table 1-2), assume f = 0.005 for all cases.

3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (1,650,000 tons/yr/3.7 tons/1,000 gal) x 0.005 1b/1,000 = 2,230 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (2,180,000 tons/yr/3.7 tons/1,000 gal) x 0.005 1b/1,000 gal = 2,946 1b/yr.
Barge emissions	= (3,020,000 tons/yr/3.7 tons/1,000 gal) x 0.005 1b/1,000 gal = 4,081 1b/yr.

5. Foreign Ballasting Emissions

Import emissions	= (1,200,000 tons/yr/3.7 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 123 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (2,180,000 tons/yr/3.7 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.005 1b/1,000 gal = 186 1b/yr.
Barge emissions	= 0.

EMISSIONS FROM NAPHTHAS AND SOLVENTS

1. Density (approx.) = 0.74 g/cc = 3.1 tons/1,000 gal.
2. From Scott, assume f = 0.3 for all cases.
3. Foreign Loading Emissions

Import emissions	= 0.
Export emissions	= (130,000 tons/yr/3.1 tons/1,000 gal) x 0.3 1b/1,000 gal = 12,581 1b/yr.

4. Domestic Loading Emissions

Tankship emissions	= (1,110,000 tons/yr/3.1 tons/1,000 gal) x 0.3 1b/1,000 gal = 107,419 1b/yr.
Barge emissions	= (4,590,000 tons/yr/3.1 tons/1,000 gal) x 0.3 1b/1,000 gal = 444,194 1b/100 gal.

5. Foreign Ballasting Emissions

Import emissions	= (9,230,000 tons/yr/3.1 tons/1,000 gal) x 0.253 x 0.30 cargo tank ballast x 0.3 1b/1,000 gal = 67,796 1b/yr.
Export emissions	= 0.

6. Domestic Ballasting Emissions

Tankship emissions	= (1,110,000 tons/yr/3.1 tons/1,000 gal) x 0.21 x 0.30 cargo tank ballast x 0.3 1b/1,000 gal = 6,767 1b/yr.
Barge emissions	= 0.

APPENDIX E

TANK BARGE SURVEILLANCE--AN OVERVIEW

The following tables summarize regulations related to the surveillance of unmanned tank barges (while not gas free) during three modes of operation.

TABLE E-1 Mode I: In Tow/Underway

Applicable Regulations	Limiting Conditions	Requirements
Subchapter D		
46 CFR 35.01-50(e)	Applies only to tank barges carrying flammable liquids with a Reid vapor pressure in excess of 25 psi in independent tanks and liquefied flammable gases.	Checked periodically to insure free of water.
46 CFR 35.01-50(f)(1)	Same as above.	Strict watch of each tank barge shall be maintained from towing vessel.
46 CFR 35.05-15(b)(1)	None given.	Same as above.

NOTES: 46 CFR 31.15-5 requires that towing vessels with tank barges in tow shall carry and have on board at all times either a licensed officer or certificated tankerman.

46 CFR 35.01-50(f)(2) prohibits towing vessels from leaving barges with independent cargo tanks, carrying any amount of flammable liquid or liquefied flammable gas, “unattended.” No exception or alternative is provided in the regulations.

Subchapter O		
46 CFR 151.45-2(f)(1)	Cargo tanks contain any amount of liquid or gaseous subchapter O cargo which requires a type I or II hull.	Strict watch of each tank barge shall be maintained from towing vessel while underway.

NOTE: 46 CFR 151.45-2(f)(2) prohibits towing vessels from leaving tank barges, carrying subchapter O cargoes that require a type I or II hull, "unattended." No exception or alternative provided in the regulations.

TABLE E-2 Mode II: While Moored (includes fleeted barges)

Applicable Regulations	Limiting Conditions	Requirements
Subchapter D		
46CFR 35.01-50(f)(2)	Applies only to tank barges carrying flammable liquids with a Reid vapor pressure in excess of 25 psi in independent tanks or any barge carrying a liquefied flammable gas.	Barge shall be under the observation of a watchman.* Such barges shall be under "constant surveillance." No alternative provided.
46 CFR 35.01-50(e)	Same as above.	Checked periodically to insure free of water.
46 CFR 35.05-15(b)(2) and (b)(3)	None given.	Barge shall be under the observation of a watchman.* (Also, see alternative below.)
*Description of Watchman		
46 CRF 35-01-50(f)(2) 46 CFR 35.05-15(b)(2)(i)	Watchman may be member of towboat crew, a terminal employee or other competent person.	

*Responsibility of Watchman		
46 CFR 35.01-50(f)(2) 46 CFR 35.05-15(b)(2)	Watchman is responsible for security of tankbarge and for keeping unauthorized persons off the barge.	
ALTERNATIVE: 46 CFR 35.05-15(b)(3)(ii) provides for an alternative. A watchman is not required for moored subchapter D barges that contain no oil but are not gas free if all cargo tank hatches are clearly marked in 3-in. letters, “Danger--Keep Out,” and all hatch covers are closed and dogged down (or otherwise secured) by a tooloperated device. Hatches are to be secured in such a way that they cannot be opened with bare hands.		
Subchapter O		
46 CFR 151.45-2(f)(2)	Cargo tanks contain any amount of liquid or gaseous subchapter O cargo which requires a type I or II hull. (See list attached at end of this chart.)	Barge shall be under the care of a watchman.*
NOTES: 46 CFR 151.45-2(f)(2) requires watchman to have in his possession and to have read applicable cargo information card(s) that are required by 46 CFR 151.45-2(e).		
46 CFR 151.45-2(g) requires all cargo hatches to be closed, dogged down, or otherwise secured.		
46 CFR 151.45-2(c) prohibits the opening of any cargo hatch, ullage hole, or tank cleaning opening (or the leaving open of these) except when under the supervision of the person in charge.		
*Description of Watchman		
46 CFR 151.45-2(f)(2)	Watchman may be member of towboat crew, a terminal employee, or other person.	
*Responsibility of Watchman		
46 CFR 151.45-2(f)(2)	Watchman is responsible for the security of tankbarge and for keeping unauthorized persons off the barge.	
These regulations apply to tankbarges carrying any subchapter O product, regardless of the required hull type.		

TABLE E-3 Mode III: During Cargo Transfer Operations

Applicable Regulations	Limiting Conditions	Requirements
<u>Subchapter D</u>		
46 CFR 35.35-1(b)	Not given.	A person holding a valid license as a master, mate pilot, or engineer or a certificated tankerman shall be on duty to perform transfer operations. This person shall be considered the person in charge of the transfer operation for the vessel involved.
<u>Subchapter O</u> (chemical cargoes)		
46 CFR 151.45-4(a)(1)	When cargo being transferred meets classification of flammable or combustible.	(Same requirement as listed immediately above.)
46 CFR 151.45-4(a)(2)	When cargo being transferred <u>does not</u> meet classification of flammable or combustible.	Person especially qualified in handling specific product shall be on duty to perform or supervise the transfer operations. This person shall be considered the person in charge of the transfer operation for the vessel involved.
<u>Subchapter O</u> (oil products)		
33 CFR 155.810	Vessel cargo tanks contain more than normal clingage and unpumpable bilge or sump residues.	Vessel operator maintains surveillance of tank barge.*

33 CFR 156.120(s)	Transfer of oil to, from, or within a vessel.	Oil shall not be transferred unless there is a person in charge on the transferring vessel or facility <u>and on</u> the receiving vessel or facility, except when authorized by the cognizant Captain of the port.
33 CFR 156.160(a)	In addition to those conditions listed immediately above, when connecting, disconnecting transfer line/hose, and when "topping off" any cargo tank.	The critical operations listed to the left shall be conducted under the supervision of the person in charge of the transfer operation abroad the vessel.
33 CFR 156.160(b)	When starting the flow of <u>oil</u> to or from a tankbarge.	The activity listed at the left is prohibited unless and until such activity is directed or instructed to start by the person in charge.
33 CFR 156.160(c)	Occurrence (start or continue) of an <u>oil</u> transfer to or from a tank barge.	The activity listed at the left is prohibited unless the person in charge is in the immediate vicinity and immediately available to the transfer operation.

*This requirement applies to tank vessels carrying oil whether or not a transfer operation is in progress.

RELATED REGULATIONS:

33 CFR 155.750	(Contents of oil transfer procedure)
33 CFR 155.750(a)(3)	(Number of persons required to be on duty during transfer operations)
33 CFR 155.750(a)(4)	(Duties of each person required to be on duty during transfer operations)
33 CFR 155.750(a)(5)	(Duty assignments for tending vessels moorings during transfer operations)

TABLE E-4 Subchapter O Products Requiring Type I or II Hulls

Acetaldehyde
Acetone cyanohydrin
Acrylonitrile
Adiponitrile
Allyl alcohol
Allyl chloride
Anhydrous ammonia
Aniline
Butadiene (inhibited)
Camphor oil (light)
Carbolic oil
Carbon bisulfide
Chlorine
Chlorohydrins (crude)
Crotonaldehyde
Dichloropropene
Dimethylamine
Epichlorohydrin
Ethyl chloride
Ethyl ether
Ethylene oxide
Hydrofluoric acid (3)
Hydrofluoric chloride (3)
Hydrogen fluoride (3)
Methyl bromide
Methyl chloride
Motorfuel antiknock compounds
Nitrobenzene
Phenol
Phosphorus (elemental)
Polymethylene-polyphenyl isocyanate
Polyvinylbenzltrimethyl ammonium chloride solution
Isopropylamine
Propylene oxide
Sodium sulfide, hydrosulfide solutions (H_2S greater than 200 ppm)
Sulfur dioxide
Toluene diisocyanate
1,2,3-Trichloropropane
Triethylamine
Vinyl chloride
Vinylidene chloride (inhibited)

SOURCE: 46 CFR Table 151.05

TABLE E-5 Subchapter O Dangerous Cargoes that Are Not Combustible or Flammable*

Ammonia, anhydrous
Ammonium hydroxide (NH3, 28% or less)
Butadiene (inhibited)
Carbon dioxide (liquid)
Carbon tetrachloride
Caustic potash solution
Caustic soda solution
Chemical wastes (mixture of chlorinated hydrocarbons and caustic materials)
Chlorine
Chlorosulfonic acid
Cresylate spent caustic
Dichloromethane
Dimethylamine
Ethylene dibromide
Ferric chloride solutions
Hydrochloric acid
Hydrochloric acid, spent (15% or less)
Hydrofluorosilicic acid (25% or less)
Hydrogen chloride
Hydrogen fluoride
Methylbromide
Methylchloride
Monochlorodifluoromethane
Nitric acid (70% or less)
Perchloroethylene
Polyvinylbenzyltrimethyl ammonium chloride solution
Sodium chlorate solution (50% or less)
Sodium sulfide, hydrosulfide solutions (H_2S 15 ppm or less)
Sodium sulfide, hydrosulfide solutions (H_2S greater than 15 ppm but less than 200 ppm)
Sodium sulfide, hydrosulfide solutions (H_2S greater than 200 ppm)
Sulfur dioxide
Sulfuric acid
Sulfuric acid spent
Trichloroethylene

*All other subchapter O dangerous cargoes listed in 46 CFR Table 151.01-10(b) are combustible or flammable.

APPENDIX F

LOADING OPERATION OF STRAIGHT CARGO GASOLINE INTO BARGES WITH DEEPWELL PUMPS

Steps	Key Points
Preliminary	
1. Inspect and read loading orders and sign Declaration of Inspection. Be sure tankerman license is current and covers grade of product to be loaded. Coast Guard (USCG) requires a valid tankerman's license covering grade B and lower to transfer gasoline.	A. Amount of draft. B. Type of cargo. C. Make sure tankerman orders are the same as dock. D. Tankerman certified to transfer cargo to be loded.
2. Put on life jacket before going on barge.	A. Personal vessel safety.
3. Inspect barge. Insure warning signs are in place, cargo transfer manual, valid USCG Certificate of Inspection, Certificate of Financial Responsibility, and current cargo header test papers are aboard. Confirm that cargo transfer hoses are in date and properly marked.	A. Confirm vessel is certified to carry cargo to be loaded. B. Compliance with applicable laws.
4. Make sure dock bonding switch (ground) is open.	
5. Attach bonding cable or check connection if dock has it attached.	A. To prevent static electricity by grounding the barge. B. Attach to loading header.
6. Check with dock to be sure switch is closed.	A. This assures the ground and keeps sparking off the vessel.

7. Check the barge.	A. Have good bow, stern, and midship lines.
	B. Visually walk barge checking for holes or cracks. Inspect each compartment by opening main hatch. Check cargo bottom--confirm previous cargo bottoms if available.
8. Close main hatches.	A. Close and dog them down.
9. Inspect fire screen.	A. Open and inspect fire screen in the small ullage opening of the cover.
	B. Leave open to vent barge.
	C. Ensure a good screen or replace if defective.
	D. Never load overhead through this opening.
10. Place drip pans under loading header.	A. No pollution.
Startup	
1. Hook hose to loading header.	A. Ensure good gaskets.
	B. Use at least six good nuts and bolts.
	C. Use spark proof wrench.
	D. Use stagger method to tighten the bolts on the flange to ensure even tension on all parts of the flange--top to bottom, side to side; go back over two or three times before tightening completely.
2. Close valve on opposite end of header and position drip pan correctly.	A. Tighten clockwise--hand tight.
	B. Install blind on end with good gasket and six bolts.
	C. No pollution.
3. Close pump valve.	A. Discharge valve from pump. Clockwise.
4. Open loading valve.	A. Located under main load line.
5. Open all compartment valves that will be loaded.	A. Located on top of dome on each compartment.

6. Open header valve where hose is connected.	
7. Give dock man the OK to start loading.	A. Watch for leaks at header. B. If no leaks, continue. C. If leak develops: 1. Minor leak--i.e., small drips--attempt to tighten bolts again with pumps running. 2. Major leak--notify dock to STOP their pumps. NOTE!! DO NOT attempt to close value against the pump at any time. In case of major leak, tighten bolts; if this doesn't stop leak, put in new gasket and start over. 3. If spill, notify USCG and dock.
Intermediate	
1. Check each compartment to see if product is loading.	A. Life screen--look in compartment.
2. Insure the barge is loading level (side to side).	A. End to end unevenness is acceptable. This assists in topping off or trim operation. B. Check draft marks on each side of the stern.
3. Make continual visual inspection for oil slick--to prevent oil pollution. If slick appears, shut dock down and notify USGC.	A. These indicate oil leaks from small fractures or holes.
4. Make continual visual check of each compartment during entire loading operation.	A. Make sure one compartment isn't loading faster or slower than another. B. Make whatever adjustments are necessary. C. Prevent spill out of dome.
5. Continual check on mooring lines.	A. So barge does not hang up and either break lines or cause unequal draft.

6. When barge is nearing completion (20 to 25 minutes) notify the dock to stand by to shut down.	A. Give yourself plenty of time.
Shutdown	
1. When loaded to draft, start shutting off valves on each compartment from the heavy end forward.	A. Use outside draft marks. B. Bring barge to level position.
2. Notify dock man to shut off pump and close dock valve.	A. Leave one compartment valve open to drain hose.
3. Leave header valve open until the hose and header line are blown clear of product either by air or gravity.	
4. Close header valve.	A. Only after line has been cleared.
Final Stage	
1. Disconnect hose from header.	A. Dock hose is pulled back.
2. Place a blank on header.	A. Eliminate sparking on vessel.
3. Pick up tools.	
4. Notify dock to open bonding switch and remove bonding cable.	A. Use good gasket, bolts and nuts.
5. Wait for dock man or gauger to gauge the barge.	
6. Close last compartment valve.	
7. Close all ullage holes.	
8. Secure all dogs with spark proof wrench.	
9. Sign papers and put bill of lading and chemical data card in proper place.	
10. Make final visual check of vessel and emergency shutdown system.	A. No pollution or unsafe conditions exist.

APPENDIX G

CALCULATIONS OF COST-EFFECTIVENESS AS A FUNCTION OF TERMINAL THROUGHPUT

The cost-effectiveness of an emission control system may be measured by the dollars spent per metric ton of emissions abated. The cost per metric ton of emissions abated for marine terminals will generally decrease as terminal throughput increases. This appendix presents assumptions, calculations, and plotted results showing the relationships for three model terminals.

The resultant cost-effectiveness calculations of the vapor recovery systems for the three model terminal cases with varying throughput are shown in Figure G-1, Figure G-2, and Figure G-3. The system assumptions, calculation approach, and the results and their presentation in Figure G-1, Figure G-2, and Figure G-3 are discussed herein.

SYSTEM ASSUMPTIONS

The United Technical Design, Inc. study (UTD, 1987) is the cost basis for the analyses in this appendix. These and other assumptions are noted below:

- Normal annual terminal use--2,000 hr/yr
- Interest rate for amortization--10%
- Equipment life (including retrofit)--20 years
- Vapor recovery efficiency--99.8%
- Incinerator costs (capital, amortization of capital, maintenance, pilot gas, fans)
  a. Products terminal loading barges--UTD Case 5
  b. Crude oil terminal loading ships--UTD Case 6
  c. Products terminal loading barges and ships--UTD Case 7
- Vessel retrofit costs (capital, amortization of capital, maintenance)
  a. 70-kdwt oil carrier--UTD Case 1
  b. 35-kdwt products carrier--UTD Case 2
  c. 19-kdwt ocean barge--UTD Case 3
  d. Inland river barge--UTD Case 4

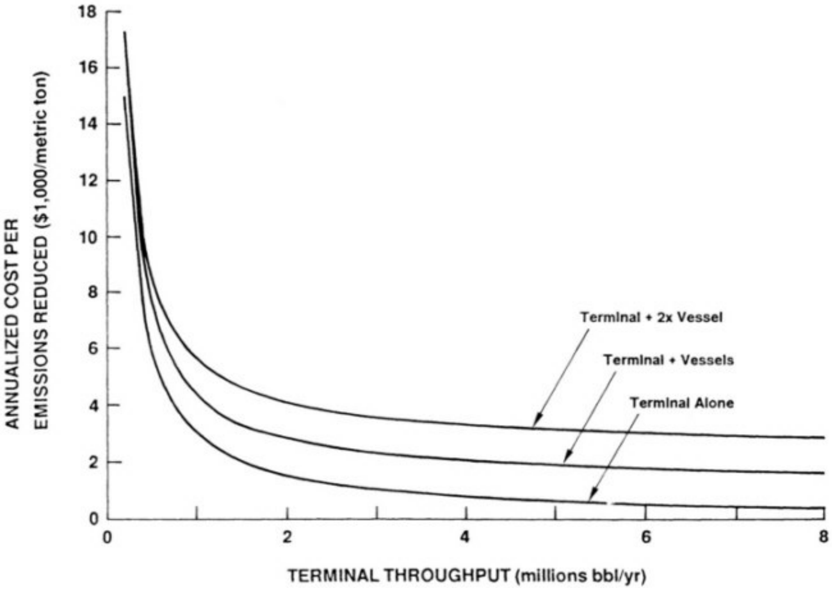

FIGURE G-1 Cost-effectiveness as a function of throughput--inland terminal serving barges. Source: UTD (1987).

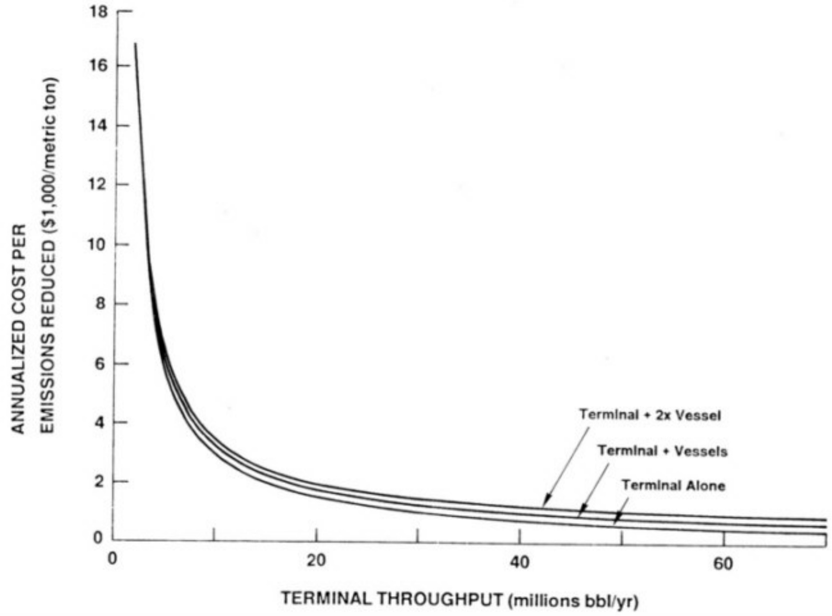

FIGURE G-2 Cost-effectiveness as a function of throughput--crude oil terminal for ships. Source: UTD (1987).

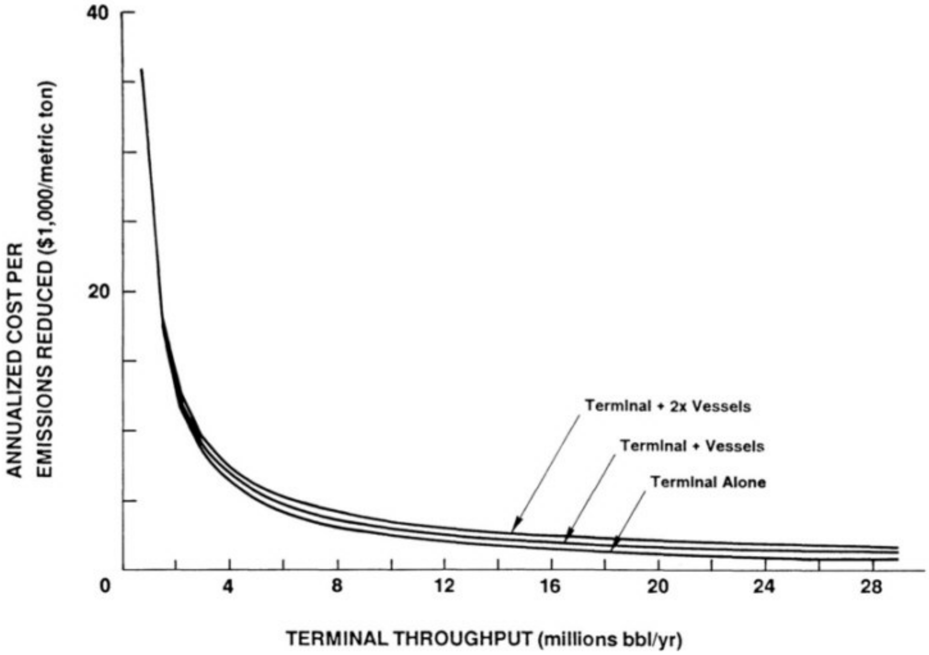

FIGURE G-3 Cost-effectiveness as a function of throughput--product terminal serving ships or barges. Source: UTD (1987).

- Vapor emission factors (1b/1,000 gal)

  a. 70-kdwt oil carrier--0.61
  b. 35-kdwt products carrier--1.8
  c. 19-kdwt ocean barge--1.8
  d. Inland river barge--3.4

- Vessel voyage assumptions (fleet factors) as discussed later in this appendix.

CALCULATION APPROACH

The annual throughput of a terminal is a function not only of its design capability, but also of the number and type of vessels serviced. To review cost variations with throughput, assumptions must be made about the size and composition of the fleet of vessels frequenting the terminal. These assumptions relate strongly to the typical voyage length of the vessels. Approximate rule-of-thumb fleet factors were used for this purpose, as shown in Table G-1. The “fleet factor” is the average vessel lay down or throughput of cargo per unit time. The values in the table are very rough assumptions and can vary greatly for a specific terminal.

TABLE G-1 Fleet Factors

Vessel Capacity (1,000 bbl)	Fleet Factors (bbl/ day/vessel)	Average Trips/Year	Average Days/Trip	Type of Vessel
25	1,000	14.6	25.0	Inland river barge
120-150	10,000	27.0	13.5 1	9-kdwt ocean barge
262.5	20,000	27.8	13.1	35-kdwt products carrier
400-600	25,000	18.3	20.0	70-kdwt oil carrier

The calculations of cost per emissions abated versus terminal throughput were performed using a computer spreadsheet, as shown in the example Table G-2 and Table G-3. Annualized terminal costs for vapor recovery are developed in columns (7) through (14). Annualized vessel retrofit and operational costs are also developed on the sheets by first determining the number of vessels needed to service the terminal (column 29). The mix of vessels and their terminal loading rates are assumed in columns (19) and (27) and determine terminal throughput in column (28). The number of vessels to produce the throughput is then calculated in column (29) based on the fleet factor assumption. Vessel related costs are then developed in column (33) and emissions in columns (34) and (35). Costs per emission abated are presented in columns (15), terminal related costs only, and (16).

CALCULATED RESULTS

Results of the calculation for the specific cases of interest can then be repeatedly calculated by varying the value of annual use (hours/year) in column (1) to result in varying terminal throughputs. The calculation results for the cases analyzed are shown in Table G-4, Table G-5, Table G-6, Table G-7 through Table G-8 and in concluding Figure G-1, Figure G-2 through Figure G-3. Table G-4, for example, shows the variation with throughput of the costs per emissions abated for three cases:

- terminal only,
- terminal and vessels, and
- terminal and twice as many vessels.

The third case was derived by arbitrarily doubling the determined fleet size. This was done to look at sensitivity and put an upper-bound on vessel costs because of the roughness of the fleet factors. It is possible, however, that the fleet factors as provided already yield the high-cost case.

TABLE G-2 Ship and Barge Transfer Operations[a]

(1) Annual Use (hr/yr)	(2) Interest	(3) Life Time (years)	(4) Control Eff. (%)	(5) Capital Recovery Factor[b]	(6) Control Unit
2,000	10.00%	20	99.8	0.1175	Incinerator

(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
			Operating Costs					Cost per Vapors Abated[c]	
Case	Capital Cost ($1,000)	Ammort. Capital Cost ($1,000) (5x8)	Maint. Cost ($1,000) +	Pilot Gas ($1,000) +	Fans Elect. ($1,000) =	Sum ($1,000) (10+11+12)	Annual Cost ($1,000) (9+13)	Incin. Only ($/Mg) (14/34)	Incin. & Retro. ($/Mg) ([14+32]/34)
5	1,225	144	41	7.65	5.96	54.61	198.50	180	1,162
6	2,571	302	28	7.65	5.96	41.61	343.60	311	1,294
7	7,502	881	79	7.65	23.84	110.49	991.67	898	1,881

[a] Numbers in columns in parenthesis indicate calculations. For instance (5x8) in column (9) indicates that the value in column (9) is developed by multiplying the value in column (5) by the value in column (8).

[b] Based on 10 percent interest and 20-year life.

[c] Mg = megagram or metric ton.

TABLE G-3 Retrofiting Costs of Vessels

(17) Case	(18) Vessel Type	(19) Percentage of Facility Use	(20) Vessel Capacity (1,000 bbl)	(21) Emission Factor (lb per 1,000 gal)	(22) Retrofit Capital Cost ($1,000)	(23) Ammort. Capital Cost ($1,000) (22x5)	(24) Operating Cost ($1,000) (1,19)	(25) Maint. Cost ($1,000)	(26) Fleet Factor (1 vessel/ bbl/day)
1	70-kdwt oil carrier	0%	490	0.61	168	20	0	5	25,000
2	35-kdwt products carrier	50%	262.5	1.8	426	50	0	14	20,000
3	19-kdwt ocean barge	0%	142.5	1.8	266	31	0	13	10,000
4	Inland river barge	50%	25	3.4	168	20	0	10	1,000

(17)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)
				Cumulative Vessel Retrofit			Emissions[a]	
Case	Loading Rate (bbl/hr)	Through-Put (bbl/yr) (1x19x27)	Number Vessels (28/26/365)	Ammort. Capital Cost ($1,000) (23x29) +	Total Maint. Cost ($1,000) (25x29) =	Total Annual Cost ($1,000) (30+31)	Uncontrolled (Mg/yr) (21x28)	Reduction (Mg/yr) (4x33)
1	35,000	0	0.00	0	0	0	0	0
2	25,000	25,000,000	6.85	343	99	441	856	848
3	15,000	0	0.00	0	0	0	0	0
4	4,000	4,000,000	21.92	433	210	643	259	256
Total		29,000,000		755	309	1,084	1,115	1,104

[a] Mg = megagram or metric ton.

TABLE G-4 Inland Terminal Serving River Barges, UTD Case 5

		Cost-Effectiveness (fleet factors)		
Hours	Throughput	1,000	500	Incin. Only
50	200,000	16,299	17,554	15,044
100	400,000	8,783	10,038	7,528
150	600,000	6,277	7,532	5,022
200	800,000	5,025	6,279	3,770
250	1,000,000	4,273	5,528	3,018
300	1,200,000	3,772	5,027	2,517
350	1,400,000	3,414	4,669	2,159
400	1,600,000	3,146	4,400	1,891
450	1,800,000	2,937	4,192	1,682
500	2,000,000	2,770	4,025	1,515
550	2,200,000	2,633	3,888	1,378
600	2,400,000	2,519	3,774	1,264
650	2,600,000	2,423	3,678	1,168
700	2,800,000	2,340	3,595	1,085
750	3,000,000	2,269	3,524	1,014
800	3,200,000	2,206	3,461	951
850	3,400,000	2,151	3,406	896
900	3,600,000	2,102	3,357	847
950	3,800,000	2,058	3,313	803
1,000	4,000,000	2,018	3,273	763
1,050	4,200,000	1,982	3,237	727
1,100	4,400,000	1,950	3,205	695
1,150	4,600,000	1,920	3,175	665
1,200	4,800,000	1,893	3,148	638
1,250	5,000,000	1,868	3,123	613
1,300	5,200,000	1,845	3,100	590
1,350	5,400,000	1,823	3,078	568
1,400	5,600,000	1,803	3,058	549
1,450	5,800,000	1,785	3,040	530
1,500	6,000,000	1,768	3,022	513
1,550	6,200,000	1,751	3,006	497
1,600	6,400,000	1,736	2,991	481
1,650	6,600,000	1,722	2,977	467
1,700	6,800,000	1,709	2,964	454
1,750	7,000,000	1,696	2,951	441
1,800	7,200,000	1,684	2,939	429
1,850	7,400,000	1,673	2,928	418
1,900	7,600,000	1,662	2,917	407
1,950	7,800,000	1,652	2,907	397
2,000	8,000,000	1,642	2,897	387

TABLE G-5 Crude Oil Terminal for 70-kdwt Ships, UTD Case 6

		Cost-Effectiveness (fleet factors)		
Hours	Throughput	25,000	12,500	Incin. Only
50	1,750,000	17,033	17,267	16,799
100	3,500,000	8,637	8,871	8,403
150	5,250,000	5,839	6,073	5,605
200	7,000,000	4,439	4,673	4,205
250	8,750,000	3,600	3,834	3,366
300	10,500,000	3,040	3,274	2,806
350	12,250,000	2,640	2,874	2,406
400	14,000,000	2,340	2,574	2,106
450	15,750,000	2,107	2,341	1,873
500	17,500,000	1,921	2,155	1,687
550	19,250,000	1,768	2,002	1,534
600	21,000,000	1,641	1,875	1,407
650	22,750,000	1,533	1,767	1,299
700	24,500,000	1,441	1,675	1,207
750	26,250,000	1,361	1,595	1,127
800	28,000,000	1,291	1,525	1,057
850	29,750,000	1,229	1,463	995
900	31,500,000	1,174	1,408	940
950	33,250,000	1,125	1,359	891
1,000	35,000,000	1,081	1,315	847
1,050	36,750,000	1,041	1,275	807
1,100	38,500,000	1,005	1,239	771
1,150	40,250,000	971	1,205	737
1,200	42,000,000	941	1,175	707
1,250	43,750,000	913	1,147	679
1,300	45,500,000	887	1,121	653
1,350	47,250,000	863	1,097	629
1,400	49,000,000	841	1,075	607
1,450	50,750,000	820	1,054	586
1,500	52,500,000	801	1,035	567
1,550	54,250,000	783	1,017	549
1,600	56,000,000	766	1,000	532
1,650	57,750,000	750	984	516
1,700	59,500,000	735	969	501
1,750	61,250,000	721	955	487
1,800	63,000,000	708	942	474
1,850	64,750,000	695	929	461
1,900	66,500,000	683	917	449
1,950	68,250,000	672	906	438
2,000	70,000,000	661	895	427

TABLE G-6 Products Terminal Serving 35-kdwt Ships, UTD Case 7

		Cost-Effectiveness (fleet factors)		
Hours	Throughput	20,000	10,000	Incin. Only
50	1,250,000	23,111	23,372	22,851
100	2,500,000	11,693	11,953	11,432
150	3,750,000	7,887	8,147	7,626
200	5,000,000	5,984	6,244	5,723
250	6,250,000	4,842	5,102	4,581
300	7,500,000	4,081	4,341	3,820
350	8,750,000	3,537	3,797	3,276
400	10,000,000	3,129	3,389	2,869
450	11,250,000	2,812	3,072	2,551
500	12,500,000	2,558	2,818	2,298
550	13,750,000	2,350	2,611	2,090
600	15,000,000	2,177	2,438	1,917
650	16,250,000	2,031	2,291	1,771
700	17,500,000	1,906	2,166	1,645
750	18,750,000	1,797	2,057	1,537
800	20,000,000	1,702	1,962	1,441
850	21,250,000	1,618	1,878	1,357
900	22,500,000	1,543	1,803	1,283
950	23,750,000	1,476	1,737	1,216
1,000	25,000,000	1,416	1,677	1,156
1,050	26,250,000	1,362	1,622	1,102
1,100	27,500,000	1,312	1,573	1,052
1,150	28,750,000	1,267	1,528	1,007
1,200	30,000,000	1,226	1,486	966
1,250	31,250,000	1,188	1,448	928
1,300	32,500,000	1,153	1,413	892
1,350	33,750,000	1,120	1,381	860
1,400	35,000,000	1,090	1,350	830
1,450	36,250,000	1,062	1,322	802
1,500	37,500,000	1,036	1,296	775
1,550	38,750,000	1,011	1,271	751
1,600	40,000,000	988	1,248	728
1,650	41,250,000	966	1,227	706
1,700	42,500,000	946	1,206	686
1,750	43,750,000	927	1,187	667
1,800	45,000,000	909	1,169	648
1,850	46,250,000	892	1,152	631
1,900	47,500,000	875	1,136	615
1,950	48,750,000	860	1,120	600
2,000	50,000,000	845	1,106	585

TABLE G-7 Products Terminal Serving Inland River Barges, UTD Case 7

		Cost-Effectiveness (fleet factors)		
Hours	Throughput	1,000	500	Incin. Only
50	200,000	76,864	78,119	75,609
100	400,000	39,083	40,338	37,828
150	600,000	26,489	27,744	25,234
200	800,000	20,192	21,447	18,937
250	1,000,000	16,414	17,669	15,159
300	1,200,000	13,895	15,150	12,640
350	1,400,000	12,096	13,351	10,841
400	1,600,000	10,747	12,002	9,492
450	1,800,000	9,697	10,952	8,442
500	2,000,000	8,858	10,113	7,603
550	2,200,000	8,171	9,426	6,916
600	2,400,000	7,598	8,853	6,343
650	2,600,000	7,114	8,369	5,859
700	2,800,000	6,699	7,954	5,444
750	3,000,000	6,339	7,594	5,084
800	3,200,000	6,024	7,279	4,769
850	3,400,000	5,746	7,001	4,491
900	3,600,000	5,499	6,754	4,244
950	3,800,000	5,278	6,533	4,024
1,000	4,000,000	5,080	6,334	3,825
1,050	4,200,000	4,900	6,155	3,645
1,100	4,400,000	4,736	5,991	3,481
1,150	4,600,000	4,587	5,842	3,332
1,200	4,800,000	4,450	5,705	3,195
1,250	5,000,000	4,324	5,579	3,069
1,300	5,200,000	4,208	5,463	2,953
1,350	5,400,000	4,100	5,355	2,845
1,400	5,600,000	4,000	5,255	2,745
1,450	5,800,000	3,907	5,162	2,652
1,500	6,000,000	3,820	5,075	2,565
1,550	6,200,000	3,739	4,994	2,484
1,600	6,400,000	3,663	4,918	2,408
1,650	6,600,000	3,591	4,846	2,336
1,700	6,800,000	3,524	4,779	2,269
1,750	7,000,000	3,460	4,715	2,205
1,800	7,200,000	3,400	4,655	2,146
1,850	7,400,000	3,344	4,599	2,089
1,900	7,600,000	3,290	4,545	2,035
1,950	7,800,000	3,239	4,494	1,984
2,000	8,000,000	3,190	4,445	1,936

TABLE G-8 Products Terminal Serving Both Inland River Barges and 35-kdwt Ships, UTD Case 7

		Cost-Effectiveness (fleet factors)		
Hours	Throughput	High	Low	Incin. Only
50	725,000	35,786	36,477	35,095
100	1,450,000	18,249	18,941	17,558
150	2,175,000	12,404	13,095	11,713
200	2,900,000	9,481	10,172	8,790
250	3,625,000	7,727	8,419	7,036
300	4,350,000	6,558	7,249	5,867
350	5,075,000	5,723	6,414	5,032
400	5,800,000	5,097	5,788	4,406
450	6,525,000	4,610	5,301	3,919
500	7,250,000	4,220	4,911	3,529
550	7,975,000	3,901	4,592	3,210
600	8,700,000	3,635	4,327	2,944
650	9,425,000	3,411	4,102	2,720
700	10,150,000	3,218	3,909	2,527
750	10,875,000	3,051	3,742	2,360
800	11,600,000	2,905	3,596	2,214
850	12,325,000	2,776	3,467	2,085
900	13,050,000	2,661	3,352	1,970
950	13,775,000	2,559	3,250	1,868
1,000	14,500,000	2,466	3,157	1,775
1,050	15,225,000	2,383	3,074	1,692
1,100	15,950,000	2,307	2,998	1,616
1,150	16,675,000	2,238	2,929	1,547
1,200	17,400,000	2,174	2,865	1,483
1,250	18,125,000	2,116	2,807	1,425
1,300	18,850,000	2,062	2,753	1,371
1,350	19,575,000	2,012	2,703	1,321
1,400	20,300,000	1,965	2,656	1,274
1,450	21,025,000	1,922	2,613	1,231
1,500	21,750,000	1,882	2,573	1,191
1,550	22,475,000	1,844	2,535	1,153
1,600	23,200,000	1,809	2,500	1,118
1,650	23,925,000	1,776	2,467	1,084
1,700	24,650,000	1,744	2,435	1,053
1,750	25,375,000	1,715	2,406	1,024
1,800	26,100,000	1,687	2,378	996
1,850	26,825,000	1,661	2,352	970
1,900	27,550,000	1,636	2,327	945
1,950	28,275,000	1,612	2,303	921
2,000	29,000,000	1,590	2,281	898

Figure G-1, Figure G-2 through Figure G-3 present these results as three curves. For the products terminal in Figure G-3, both inland and 35-dwt tankships could dock at the terminal. A sensitivity analysis was performed to determine the effect of change of vessel type. Table G-6, Table G-7 and Table G-8 show cost-effectiveness as a function of throughput assuming cases of only 35-kdwt tankships, only inland barges, and half barge and half tankships. The case of half barges and half tankships (Table G-8) provides the widest cost-effectiveness range for a given throughput and is thus the one presented in Figure G-3.

It must be understood that the costs for a specific terminal can be very different than the results presented here since costs are very sensitive to length of piping run and other terminal specifics.

REFERENCE

United Technical Design, Inc. (UTD). 1987. Scoping Quality Cost Estimate for Marine Vapor Control Systems. Unpublished study. Available from the Marine Board, National Research Council, Washington, D.C.