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IMPLICATIONS OF THE U.S. COAST GUARD SEGREGATED BALLAST RETROFIT RULING ON IMPORT ALTERNATIVES AND POLLUTION OF THE MARINE ENVIRONMENT

OPERATIONS RESEARCH, INCORPORATED
SILVER SPRING, MARYLAND

OCTOBER 1976

Report No. CG-M-06-77

IMPLICATIONS OF THE U.S. COAST GUARD SEGREGATED BALLAST RETROFIT RULING ON IMPORT ALTERNATIVES AND POLLUTION OF THE MARINE ENVIRONMENT

FINAL REPORT

OCTOBER 1976

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Merchant Marine Safety
Washington, D.C. 20590

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16. Abstract

In May of 1976, the U.S. Coast Guard published an advance notice of proposed rulemaking which would require the backfitting of segregated ballast tanks (SBT) on all tankers engaged in importing oil to the United States which displace 70,000 DWT or more. This study was commissioned to: (1) Estimate the economic costs and environmental benefits to be derived from implementation of the regulation, and (2) Examine the economic feasibility of alternative oil importing schemes (i.e., transshipment and lightering) which could circumvent the proposed regulation.

The approach taken by ORI was to define in detail the U.S. oil import transportation system for a base year, 1975, in terms of the volume of crude and products delivered, the number and size of tankers involved, and the tankers' last port of call. Similar scenarios were developed for the following: (1) 1980 Status Quo, (2) 1980 SBT Retrofit Required (non-compliance), (3) 1980 Status Quo Plus Deepwater Ports, (4) 1980 SBT Retrofit Required Plus Deepwater Ports (non-compliance), (5) 1980 SBT Retrofit Required (compliance), (6) 1980 SBT Retrofit Required Plus Deepwater Ports (compliance).

Within each scenario, required freight rates for tankers of various sizes were developed, and operational and accidental oil spills were calculated.

It was determined that the 16 percent of the tankers in the present fleet which are subject to the SBT ruling, would very likely circumvent the retrofit requirement by lightering which is the most cost-effective transportation mode. There is no evidence that the proposed SBT ruling will be effective in reducing oil pollution of the marine environment.

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EXECUTIVE SUMMARY

INTRODUCTION

Segregated ballast tanks (SBT) have been a major issue in international petroleum transportation discussions for several years. A recent study done by Greece, Italy, and Norway supports the backfitting of such facilities on all existing tankers greater than 70,000 DWT. In May of this year, the U.S. Coast Guard published an advance notice of proposed rulemaking which would effectively implement this proposal for tankers engaged in the U.S. import trade.

The publication of the advance notice by the U.S. Coast Guard resulted in a large number of responses. Among these responses were several which suggested that transshipment and offshore lightering were operational strategies that might successfully circumvent the intent of the proposed regulation.

This study was commissioned in early August to provide additional information which would assist the U.S. Coast Guard in the process of formulating a national position on the SBT retrofit issue prior to the next meeting of the IMCO Marine Environmental Protection Committee.

STUDY OBJECTIVES

The objectives of this Segregated Ballast Retrofit Study are to:

- Estimate the economic costs and environmental benefits to be derived from implementation of regulations based on the concept published in the Federal Register of May 13, 1976.
- Examine the economic feasibility of alternative oil importing schemes (i.e., transshipment and lightering) which could circumvent the proposed regulation.

STUDY TEAM

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P. Daniels
J. Kirkland
L. Stoehr

Consultant
A. McKenzie, Tanker Advisory Center

The assistance and guidance of many professionals in the marine and petroleum industries, and in the government departments and agencies related to them, is gratefully acknowledged. Many of the contacts were made by telephone to expedite the work and obtain up-to-date information on both technical and operational subjects. The response to questions and requests for information was uniformly excellent.

APPROACH

The approach taken by the ORI study team has its foundation in the definition of the U.S. petroleum importing system for a baseline year—1975. This definition focused on marine imports and included both economic and environmental data.

Economic and operational data encompassed the volume of both crude petroleum and refined products delivered to each of three U.S. regions: East Coast, Gulf Coast, and West Coast. Each of these regions was further analyzed to determine the numbers and size of tankers delivering oil to each, and the volume delivered as a function of tanker size and last port of call. These data formed the 1975 status quo definition.

Similar estimates were developed for the following predictions:

- 1980 Status Quo
- 1980 SBT Retrofit Required (full compliance)
- 1980 SBT Retrofit Required (circumvention)
- 1980 Status Quo with Deepwater Ports
- 1980 SBT Retrofit Required with Deepwater Ports (full compliance)
- 1980 SBT Retrofit Required with Deepwater Ports (circumvention).

When each of these system definitions was prepared, individual cost estimates were developed to reflect tanker operating costs, terminal charges, pipeline charges, and other miscellaneous costs. Costs were finally summarized in terms of the required freight rate for tankers of various sizes operating in direct shipment, transshipment, and lightering modes from the major petroleum exporting areas to the U.S. East and Gulf Coasts.

Environmental effects were also developed for each of the above scenarios. These environmental effects were measured in terms of the total volume of oil discharged into the sea for each of the scenarios. Discharges were estimated on the basis of total oil imports, systems used for the handling of dirty ballast and tank cleaning, the number of ships in the system, and characteristics of the type of cargo transported. Operational discharge volumes were also estimated assuming complete compliance with the 1969 Amendments to the 1954 International Convention for Prevention of Pollution from Ships. Accidental discharge estimates were derived from casualty and pollution incident data. The total volume of accidental discharges was estimated as a function of tanker size, number of incidents, volume spilled per incident, and number of port calls.

The final output of the study is the definition of required freight rates and shipping port calls associated with the operational transport systems that would operate within each of the six defined scenarios. Operational and accidental discharge predictions are also presented for each scenario.

FINDINGS

- Total petroleum imports to the United States will increase by 71 percent between 1975 and 1980. The annual increase will be greater than the mean of 14.2 percent during the initial part of this five-year period. The increase begins to slow during the later years as Trans Alaskan Pipeline (TAPS) petroleum enters the picture. Figure S.1 illustrates this effect.

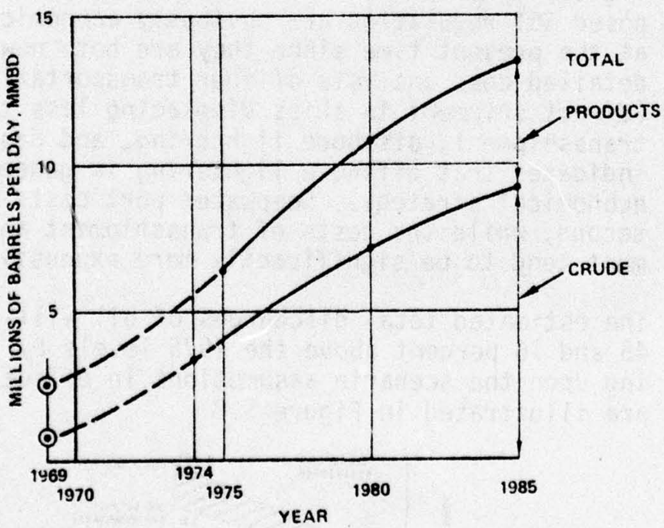

FIGURE S.1. TOTAL U.S. OIL IMPORTS

- Increasing oil imports will cause an overall increase of 89 percent in the number of port calls at U.S. ports. The impact of increased port calls, as with the increase in oil import volume, will be most strongly felt in Gulf Coast ports. The number of port calls at Gulf Coast port facilities will increase by 150 percent if no deepwater ports are available. Even with LOOP and SEADOCK in operation, the number of port calls in 1980 will approximately equal those in 1975, with port congestion a continuing problem.

- The impact of the increase in total oil imports will be most strongly felt along the Gulf Coast. The increase in this area will be approximately 100 percent while the volume imported to the East and West Coasts will remain relatively constant.

- Only 16 percent of the ships in the U.S. oil import fleet currently displace greater than 70,000 DWT and would therefore be affected by the proposed SBT retrofit regulation. If the industry elects to replace these ships with others displacing less than 70,000 DWT, as industry representatives have indicated, the effect would be only a slight increase in the total import fleet and an increase of about 4 percent in the number of port calls. Thus the proposed ruling would have only a negligible effect on the current import system characterized most noticeably by an increased volume flowing through transshipment terminals and lightering operations.

- The operational strategies of transshipment and offshore lightering proposed as methods for circumventing the proposed SBT regulation are obviously economically feasible at the present time since they are both now in use. A detailed cost analysis of four transportation alternatives (direct shipment in ships displacing less than 70,000 DWT, transshipment, offshore lightering, and deepwater ports) indicates that offshore lightering is generally the most economical strategy. Deepwater port costs run a close second, while the costs of transshipment and direct shipment tend to be significantly more expensive.

- The estimated total discharges of oil will rise between 45 and 76 percent above the 1975 levels by 1980, depending upon the scenario assumptions in effect. These changes are illustrated in Figure S.2

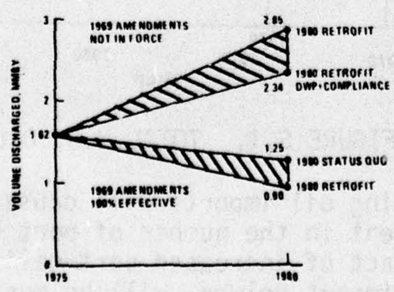

FIGURE S.2. OIL DISCHARGED TO THE OCEANS

CONCLUSIONS

- The primary conclusion of this analysis is that the proposed regulation on retrofit of segregated ballast facilities will not be effective in significantly reducing oil pollution of the marine environment.

- The dangers of increasing environmental pollution from marine petroleum transport is more closely related to the increasing volume of oil imports than to any regulatory control that may or may not be instituted. Environmental interests will be better served through the development of alternative, non-polluting energy sources than through regulations of the type examined in this study.

- Offshore lightering between VLCCs and smaller tankers in the 50-70,000 DWT range is an economic and practical operational strategy. The cost advantage of lightering is one of the main reasons for its rapid rise in popularity during recent years. Less than full utilization of the lightering tankers due to scheduling problems may raise costs somewhat, but it is unlikely that this rise would be sufficient to change the economic advantage indicated for lightering operations.

- Scheduling problems involved in lightering operations will be greatest where port congestion is a significant factor. Lightering will therefore, in future years, tend to be more attractive off the East Coast than in the Gulf of Mexico. Off the East Coast, lightering would appear to be competitive with, and might be economically preferable to, deepwater ports.

- While industry sources report an outstanding pollution-free record associated with offshore lightering operations, it must be pointed out that this is a new technology field where increases in operational and accidental spills may be expected once operations increase to the point where they may be considered routine.

- The construction of deepwater ports in the Gulf of Mexico will be necessary in order to alleviate substantial delays and increasing costs due to excessive congestion at Gulf shore terminal facilities.

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I. INTRODUCTION

BACKGROUND

On May 13, 1976, the U.S. Coast Guard published an advance notice of proposed rulemaking in the Federal Register.[1] This notice proposed a regulation which would extend a requirement for segregated ballast capacity to existing U.S. tank vessels of 70,000 DWT and over, and to existing foreign tank vessels of 70,000 DWT and over that enter navigable waters of the United States. In effect, this regulation would implement for the United States some of the recommendations contained in the three-nation (Greece, Italy, Norway) study submitted to the International Maritime Consultative Organization (IMCO) in March 1976.[2]

The publication of this notice elicited a very large number of responses. As of mid-August, 95 letters had been received, and a wide range of opinion and viewpoint was expressed. Several of the responses suggested that the proposed regulation could be effectively circumvented by alternative shipping schemes and others recommended a thorough study of the probable costs and benefits resulting from implementation of the regulations.

In early August, RADM William M. Benkert, Chief of the Coast Guard Headquarters Office of Merchant Marine Safety ordered a study of the various shipping alternatives available to tanker operators, including associated costs and estimates of operational and accidental pollution as a function of changes in the delivery system due to the proposed regulation. This study was to be completed in approximately two months, in order to provide the Coast Guard with information to help establish a national position prior to the next meeting of the IMCO Marine Environmental Protection Committee in December 1976.

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[1] Advanced Notice for Proposed Rulemaking, CGD76-075.

[2] Introduction of Segregated Ballast in Existing Tankers, presentation of a joint study by the delegations of Greece, Italy and Norway to the Fifth Session of the IMCO Marine Environmental Protection Committee, March 8, 1976.

Operations Research, Inc. (ORI) was selected to conduct the study under the technical direction of CDR R.A. Sutherland, USCG.

PURPOSE OF THE STUDY

The purpose of the study undertaken by ORI was to:

- Thoroughly examine the literature relating to the segregated ballast concept
- Collect statistics on petroleum imports by source, trade routes, ship sizes, ports of arrival, and shipping mode
- Determine freight rates for the various shipping modes
- Collect statistics on operational and accidental oil spillage by volume, ship size and area
- Present an accurate assessment of the current situation relative to foreign seaborne oil imports and environmental pollution resulting therefrom
- Project import and environmental pollution statistics to 1980
- Estimate the relavant changes in the 1980 picture resulting from implementation of the proposed regulation
- Analyze the effect of these changes on the oil importing industry and the environment
- Assess the potential effects of alternative regulatory initiatives and possible economic side effects
- Prepare a briefing on the results of the analysis.

REPORT OUTLINE

This report is divided into four major sections. Following this Introduction, Section II presents economic and operational considerations. Environmental considerations are presented in Section III, and the findings, conclusions and recommendations are given in Section IV. References and Appendices follow Section IV.

II. ECONOMIC AND OPERATIONAL CONSIDERATIONS

U.S. OCEANBORNE OIL IMPORTS

Oil imports in millions of barrels per day (MMBD) are shown in Figure 2.1. Both crude and product imports are shown on a cumulative basis for a 16-year period 1969 through 1985. Total imported volumes increased by about 71 percent between 1975 and 1980. Products represented 40 percent of imports in 1975, and tapered off to 34 percent in 1980.

Several sources were researched to obtain import information. Historical, current and future forecast data were obtained from References 1, 2, 3, 4, 5, 11, and 12. This information was used to establish the total U.S. import base represented by Figure 2.1 for use in this study. Future forecasts vary over a wide range of values depending on the assumptions of the forecasters. The validity of Figure 2.1 beyond 1975 must be considered an estimate at best, and subject to the volatile political situations at the sources of supply.

REGIONAL OCEANBORNE OIL IMPORTS

For purposes of this study, the United States has been divided into regions (East Coast, Gulf Coast, and West Coast) to reduce the number of reception areas from all pertinent coastal ports to three general regions. Each region receives oil, both crude and products, from a variety of foreign sources which are also designated by region. These regions are listed in Table 2.1, along with a breakdown of exporting nations.

Oil imports, both crude and products, delivered to the East Coast are shown in Figure 2.2. The quantity of imported crude will remain relatively constant during the next 15 years due to the slow expected growth in refinery capacity in the major refinery areas of New York, New Jersey and Delaware. Increasing demand for refined products will be met by rising imports which are expected to increase approximately 40 percent between 1975 and 1980.

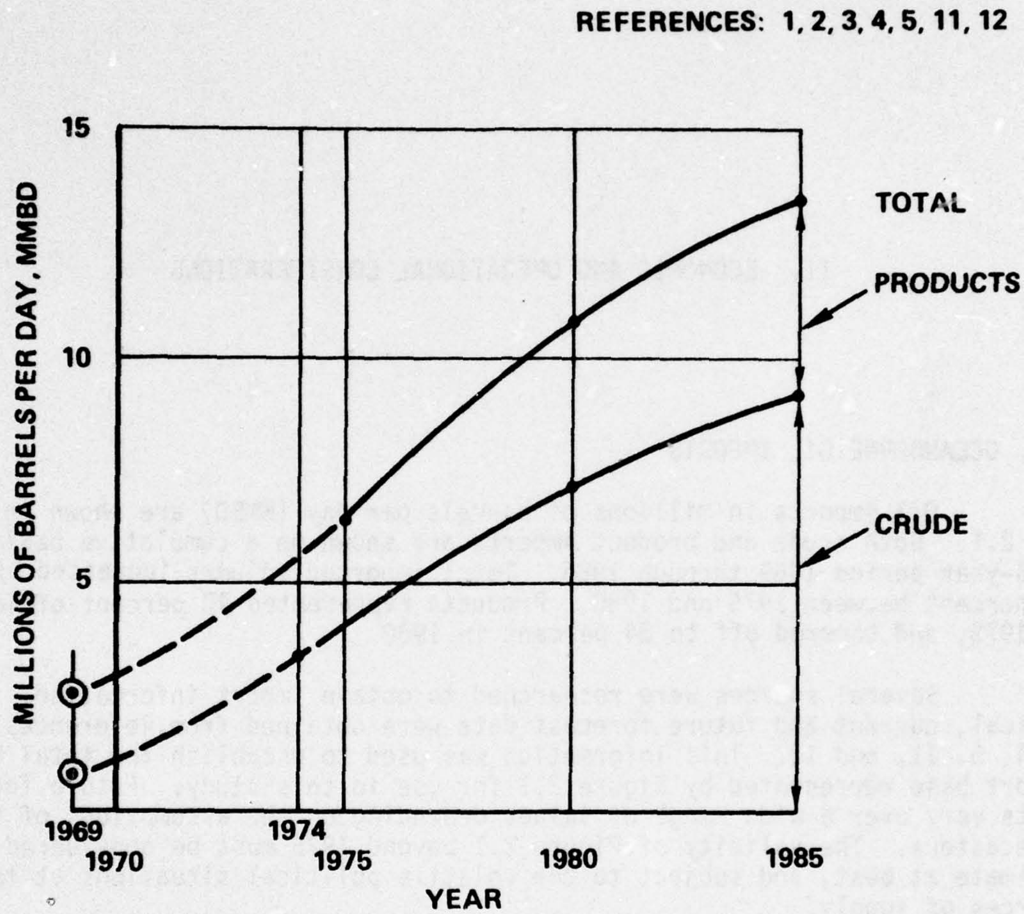

FIGURE 2.1. TOTAL U.S. OIL IMPORTS

TABLE 2.1

FOREIGN SOURCES OF CRUDE AND PRODUCTS

Export Regions	Export Nations	Remarks
Caribbean Aruba Curacao Bonaire	Caribbean Nations Trinidad Venezuela Columbia Virgin Islands Equador Mexico	Crude & Products
Bahamas Freeport	Bahamas	Crude & Fuel Oil
Nova Scotia Canso	Canada	Crude
North Africa Brega	African Nations Algiers Libya Egypt	Crude
West Africa Bonny	Nigeria	Crude
Arabian Gulf Ras Tanura	Gulf Nations Iran Kuwait Saudi Arabia Quatar Arab Emirates	Crude & Products

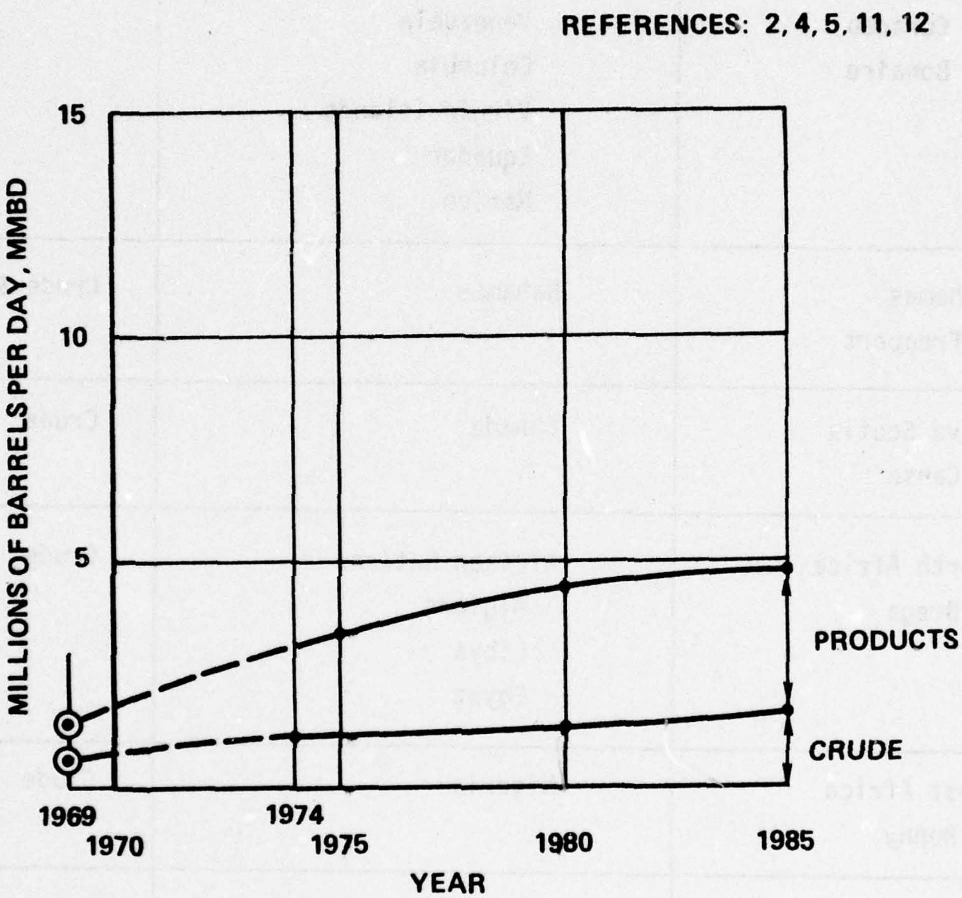

FIGURE 2.2. FOREIGN IMPORTS TO U.S. EAST COAST

The U.S. Gulf region shows the most dramatic increase in import volume. Figure 2.3 indicates that the rise is due almost wholly to crude imports which increase approximately 140 percent between 1975 and 1980. This increase is due mainly to a reduction in domestic crude production and large anticipated increases in the refining capacity within the Gulf-Mississippi area.

The U.S. West Coast region is shown in Figure 2.4. This region includes the entire West Coast between Canadian and Mexican borders. There are no products of any appreciable amount imported into this area. Crude imports remain relatively constant between 1975 and 1980, and taper off to almost zero by 1985. Imports of Alaskan crude are anticipated by 1980, which will gradually replace foreign imports. Alaskan crude is a domestic import and is not shown in Figure 2.4.

TRADE ROUTES AND SHIP MIXES

Introduction

Detailed information on the tanker transportation system has been obtained from a study of customs manifest data for two major East Coast ports and one major Gulf Coast port. Data for an entire year, 1975, has been obtained. Pertinent information includes designation of the oil receiving port, the port of origin, the tanker size, and the volume of product delivered. This information will be used to extrapolate the major port data to a regional basis.

Certain detailed developments relevant to this section are contained in Appendix A.

Two sources of data on petroleum imports were available, i.e., the Bureau of the Census (Reference 11) and the Corps of Engineers (Reference 12). The former was the prime source supplemented by the Corps of Engineers material. The types, amount, and form of this data will be discussed in the next section.

Bureau of the Census Data

Description. The Bureau of the Census (Census) processes and publishes data on vessels entering U.S. ports from raw data supplied by the U.S. Customs Service (Customs) for use by the Corps of Engineers (Engineers). The raw data is taken from ship's manifest information as set forth on Customs forms. Census organized this material in a manner useful to the Engineers. It is published annually in a report known as the "Engineer's Annuals" (Report AE 495).

Summary. The basic data from the Census Bureau was organized by ship size and origin. The results are shown in Tables 2.2, 2.3, and 2.4. Summaries of the data in Tables 2.2, 2.3, and 2.4 are given in Tables 2.5 and 2.6.

Corps of Engineers Data

Description. Initially, it had been thought that crude imports into New York, Delaware Bay, and New Orleans would constitute the bulk of the total

REFERENCES: 2, 4, 5, 11, 12

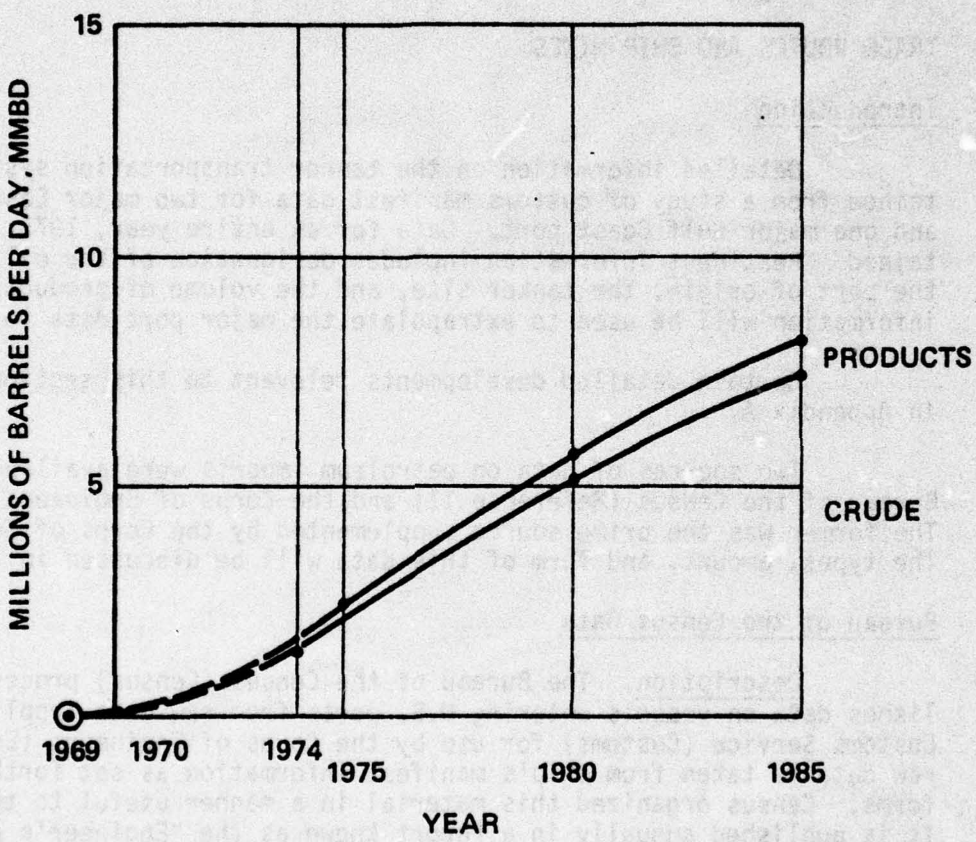

FIGURE 2.3. FOREIGN IMPORTS TO U.S. GULF COAST

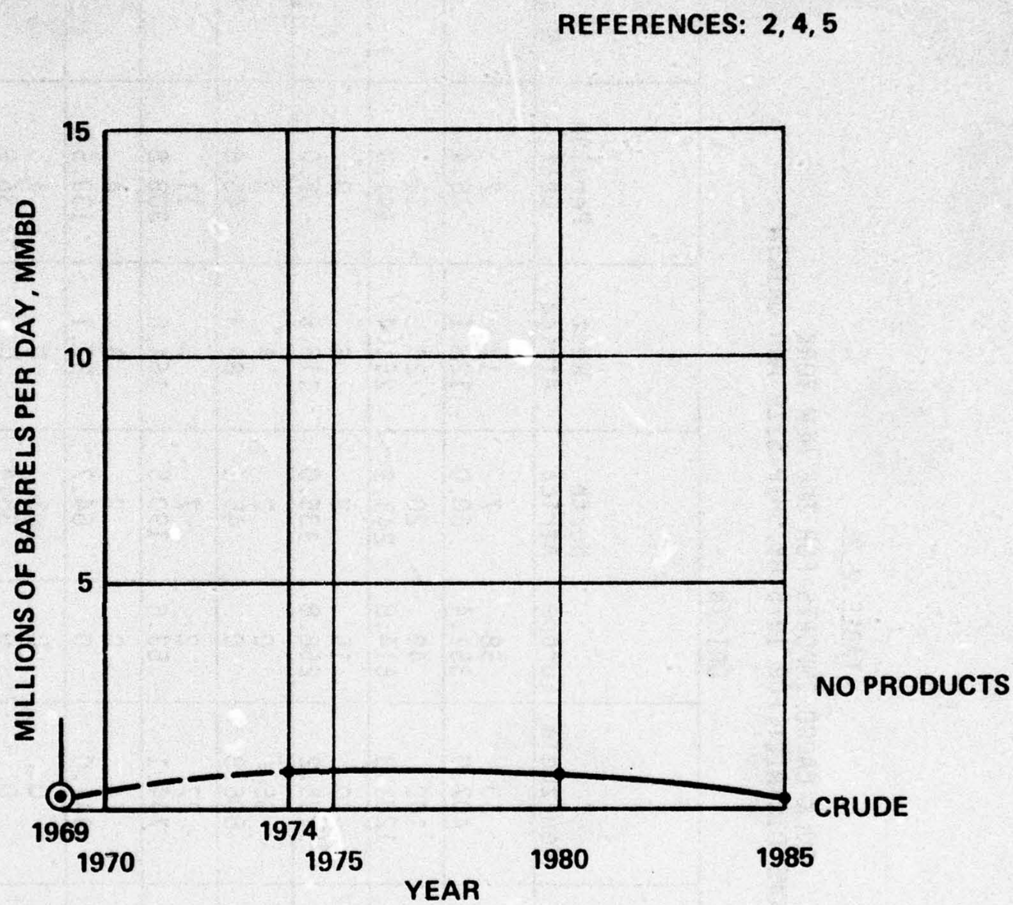

FIGURE 2.4. FOREIGN IMPORTS TO U.S. WEST COAST

TABLE 2.2

BULK CARGO IMPORTS FOR THE NEW YORK
CUSTOMS DISTRICT FOR 1975 BY SHIP SIZE AND ORIGIN

ORIGIN

Tanker Size Net Registered Tons x 10^3	Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Miscellaneous
0-10	41 302.1	7 61.4	50 407.9	58 351.4	7 60.0	17 128.1	2 16.4	21 153.7
10-15	112 1355.9	41 504.0	102 1281.3	49 614.8	20 243.3	20 251.4	11 141.9	14 150.9
15-20	53 909.5	28 511.7	70 1235.2	15 256.8	8 135.0	6 115.6	3 55.0	5 89.6
20-25	9 199.2	14 334.9	35 806.8	0 0	2 45.4	4 89.3	2 45.6	0 0
25-30	4 110.7	5 139.2	27 744.1	2 53.6	7 190.5	6 164.0	11 308.8	0 0
30-35	7 [illegible]	1 32.6	14 444.0	0 0	2 64.7	3 97.1	4 133.5	1 30.4
35-40	0 0	0 0	0 0	0 0	1 35.4	0 0	1 36.9	0 0

Note 1 - Upper Number in Square is Number of Ship Calls
Note 2 - Lower Number is the Sum of the Net Registered Tons of these Ships (Thousands)
Note 3 - Bureau of Census Data

TABLE 2.3

BULK CARGO IMPORTS FOR THE PHILADELPHIA
CUSTOMS DISTRICT FOR 1975 BY SHIP SIZE AND ORIGIN

ORIGIN

Tanker Size Net Registered Tons x 10^3	Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Miscellaneous
0-10	12 94.5	1 7.3	26 204.4	27 162.1	2 14.9	1 7.6	2 19.1	4 18.9
10-15	53 661.7	6 70.8	58 738.3	12 147.5	9 113.7	5 59.4	2 24.6	1 14.0
15-20	85 1542.1	24 421.9	51 906.3	8 137.2	29 524.7	28 498.6	7 127.4	2 34.0
20-25	14 306.9	4 90.2	10 214.5	2 43.2	18 403.2	26 590.2	19 448.6	2 43.0
25-30	6 156.6	0 0	8 222.0	6 156.4	17 463.1	15 416.6	16 423.7	7 186.8
30-35	14 457.6	3 99.1	0 0	1 32.9	26 805.9	18 590.5	19 604.7	3 97.7
35-40	1 37.2	1 37.9	0 0	0 0	14 519.2	45 1619.5	6 230.0	1 38.3
40-45	2 83.7	0 0	0 0	0 0	6 251.1	4 165.2	1 40.9	0 0
45-50	0 0	0 0	0 0	0 0	1 45.1	1 49.8	8 370.3	1 48.7
50-55	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
55-60	0 0	0 0	0 0	0 0	0 0	2 113.2	0 0	0 0

Note 1 - Upper Number in Square is Number of Ship Calls
Note 2 - Lower Number is the Sum of the Net Registered Tons of These Ships (Thousands)
Note 3 - Bureau of Census Data

TABLE 2.4

BULK CARGO IMPORTS FOR THE NEW ORLEANS
CUSTOMS DISTRICT FOR 1975 BY SHIP SIZE AND ORIGIN

Tanker Size Net Registered Tons x 10^3	Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Miscellaneous
0-10	44 288.5	3 19.8	23 137.0	17 105.3	1 1.2	1 1.2	1 1.6	8 47.2
10-15	56 708.9	16 230.4	9 113.5	6 67.3	9 116.4	2 26.6	2 26.0	3 38.0
15-20	114 1971.2	27 466.1	7 126.0	1 19.0	24 424.4	41 710.0	4 66.0	1 19.5
20-25	50 1091.5	11 250.2	3 65.9	1 23.1	16 353.7	14 306.2	2 42.0	1 22.4
25-30	19 513.7	0 0	0 0	0 0	26 715.8	8 227.2	1 25.0	0 0
30-35	10 312.2	2 65.2	1 30.4	0 0	3 95.0	1 30.9	1 31.1	0 0
35-40	3 110.4	0 0	0 0	0 0	0 109.0	0 0	0 0	0 0
40-45	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
45-50	0 0	0 0	0 0	0 0	2 94.2	0 0	0 0	0 0

Note 1 - Upper Number in Square is Number of Ship Calls
Note 2 - Lower Number is the Sum of the Net Registered Tons of these Ships (Thousands)
Note 3 - Bureau of Census Data

TABLE 2.5

SUM OF NET REGISTERED TONNAGE OF TANKERS DOCKING AT PORTS IN THREE CUSTOMS DISTRICTS FROM VARIOUS ORIGINS (1975 - Thousands of Tons)

Destination \ Origin	Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Misc.	Totals
New York	3070	1584	4919	1277	774	846	738	425	13,633
Philadelphia	3340	727	2286	679	3141	4111	2289	481	17,054
New Orleans	4995	1032	473	215	1910	1302	192	127	10,246
TOTALS	11405	3343	7678	2171	5825	6259	3219	1033	40,933

TABLE 2.6

NUMBER OF TANKERS DOCKING AT PORTS IN THREE CUSTOMS DISTRICTS FROM VARIOUS ORIGINS (1975)

Destination \ Origin	Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Misc.	Totals
New York	226	96	298	124	47	56	34	41	922
Philadelphia	187	39	153	56	122	145	80	21	803
New Orleans	296	59	43	25	84	67	11	13	598
TOTALS	709	194	494	205	253	268	125	75	2323

U.S. crude imports into Atlantic and Gulf ports. Comparison of the Census data discussed in the previous section and with independent estimates from other sources (References 1, 2, 3, 4, and 5) disclosed this not to be the case. Returning to the Census data would have required many days or weeks of searching. Rather than this, it was decided to use more readily available import data from the Engineers, even though it was not as detailed as desired.

The Engineer's data is contained in an annual publication, Waterborne Commerce of the United States (Reference 12). The latest available edition was for 1974. This contains summaries of imports of various commodities for ports within Engineer Districts. This was collected for a series of 16 Atlantic Coast ports in addition to New York and Delaware Bay, and for 13 Gulf Coast ports in addition to New Orleans. The amounts of imports at these smaller ports when added to the values for New York, Philadelphia, and New Orleans, give totals that agree quite well with totals from the other data sources listed previously.

Summary. The data collected is summarized in Tables 2.7 and 2.8. The 29 ports were selected because they are the most important of the smaller petroleum importing ports. A number of less important ports were ignored.

TABLE 2.7

IMPORTS OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS INTO ATLANTIC PORTS

(1974 - Short Tons-10^3)

PORT	Crude	Distil-late & Residual	Other Products	Total Products	Crude Plus Products
Portland, Maine	21,291	1,017	359	1,376	22,667
Portsmouth, N. H.	79	582	205	787	866
Boston, Mass.	15	5,903	1,403	7,306	7,321
Fall River, Mass.	0	1,229	142	1,371	1,371
Providence, R.I.	21	1,398	422	1,820	1,841
New Haven, Conn.	42	2,673	151	2,824	2,866
Bridgeport, Conn.	12	1,298	57	1,355	1,367
Port Jefferson, N.Y.	36	0	134	134	170
Baltimore, Md.	956	3,446	252	3,698	4,654
Hampton Roads, Va.	745	5,796	284	6,080	6,825
Wilmington, N.C.	259	2,031	0	2,031	2,290
Charleston, S.C.	0	2,001	75	2,076	2,076
Savannah, Ga.	913	1,165	0	1,165	2,078
Jacksonville, Fla.	20	3,247	48	3,295	3,315
Port Everglades, Fla.	4	1,485	506	1,991	1,995
Palm Beach, Fla.	0	626	0	626	626
Σ(all)	24,393	33,897	4,038	37,935	62,328
New York & Albany	16,096	26,791	4,390	31,181	47,277
Delaware River	41,088	6,025	843	6,868	47,956

TABLE 2.8

IMPORTS OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS INTO GULF COAST PORTS

(1974 - Short Tons - 10^3)

PORT	Crude	Distil-late & Residual	Other Products	Total Products	Crude Plus Products
Tampa, Fla.	0	2,753	35	2,788	2,788
Mobile, Ala.	21	16	8	24	45
Panama City, Fla.	0	261	0	261	261
Pensacola, Fla.	176	0	0	0	176
Pascagoula, Miss.	1,393	147	0	147	1,540
Lake Charles, La.	1,772	136	111	247	2,019
Port Arthur & Beaumont, Tx.	26,476	4,968	5,683	10,651	37,127
Houston, Tx.	10,809	835	1,217	2,052	12,861
Texas City, Tx.	2,470	35	0	35	2,505
Galveston, Tx.	203	0	0	0	203
Freeport, Tx.	1,519	0	0	0	1,519
Corpus Christi, Tx.	8,104	41	244	285	8,389
Brownsville, Tx.	247	121	0	121	368
Σ(Gulf)*	53,190	9,313	7,298	16,611	69,801

*Excludes New Orleans & Mississippi River Ports

The Engineer data does not contain origin or ship size information. Assumptions concerning these factors are given in a following section.

Of the 29 smaller ports, the main contributors to imports are:

- Crude petroleum for the Canadian pipeline unloaded at Portland, Maine.
- Distillate and residual fuel oil unloaded at many Atlantic Ports.
- Crude petroleum bound for the Sabine Pass ports of Beaumont, Port Arthur, and Orange.
- Crude petroleum unloaded at Houston.

Data Analysis Problems

As noted previously, values of total petroleum imports into Atlantic and Gulf Coast ports were available from several sources other than the Census and Engineer sources just discussed. However, these other sources did not give the distribution of these values over origin, tanker size, and unloading port that was partially available from the Census/Engineer data. Thus, two problems had to be faced. First, the total import values from different sources had to be reconciled; and second, the distribution of these totals over origin, tanker size, and unloading port had to be completed. The method and assumptions used to solve these two problems are given in the following section.

Total Petroleum Imports

The two base sources of data, i.e., Census and Engineers, were used to produce values for the total imports into Atlantic Coast ports and Gulf Coast ports. The summary of data on total imports is given in Table 2.9, as obtained from Tables 2.5 and 2.8.[1]

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[1] Units translated, see Appendix A for formulae.

$$\text{MMBD} = \left[\frac{\text{NRT}(10^3)}{\text{year}}\right]\left(\frac{1}{10^3}\right)\left(\frac{1}{0.4}\right)\left(7.4\ \frac{\text{bbl}}{\text{ton}}\right)\left(\frac{1}{365\ \frac{\text{days}}{\text{year}}}\right)$$

$$= \left(\frac{1}{20{,}000}\right)\left[\frac{\text{NRT}(10^3)}{\text{year}}\right]$$

and when using Tables 2.8 and 2.9,

$$\text{MMBD} = \left[\frac{\text{Short Tons }(10^3)}{\text{year}}\right]\left(\frac{1}{10^3}\right)\left(\frac{2{,}400}{2{,}000}\right)\left(7.4\ \frac{\text{bbl}}{\text{ton}}\right)\left(\frac{1}{365\ \frac{\text{days}}{\text{year}}}\right)$$

$$= \left(2.24 \times 10^{-5}\right)\left[\frac{\text{Short tons }(10^3)}{\text{year}}\right]$$

TABLE 2.9

TOTAL PETROLEUM IMPORTS INTO VARIOUS REGIONS (MMBD)

Region	Engineers 1974	Census 1975
New York	1.06	0.68
Philadelphia	1.07	0.85
New Orleans	-	0.51
Atlantic (excluding New York and Philadelphia)	1.40	-
Gulf (excluding New Orleans)	1.56	-

Three things are evident in Table 2.9, i.e.,

- The two data sources disagree for New York and Philadelphia
- One set of data is for 1974, and the other for 1975
- Cross-checking is not possible in three cases.

In spite of these deficiencies, it was decided to use the values in Table 2.9 to generate estimates for total Atlantic and Gulf Coasts. This was done by taking the average of the maximum and minimum possible combination of appreciable values. The result is shown in Table 2.10.

TABLE 2.10

GENERATION OF AVERAGE TOTAL (1974-1975) IMPORT VALUES

Region	Maximum Possible Value	Minimum Possible Value	MMBD Average
Atlantic Coast	1.06 + 1.07 + 1.40 = 3.53	0.68 + 0.85 + 1.40 = 2.93	3.23
Gulf Coast	0.51 + 1.56 = 2.07	0.51 + 1.56 = 2.07	2.07

In spite of this somewhat simple approach, the values are in good agreement with values obtained from references 2, 4, 5, 11, 12. Also, the maximum error in using the mean rather thah the maximum or minimum is only 10 percent. The average values are plotted in Figures 2.2 and 2.3. Base import values for 1975 will be 3.2 MMBD for Atlantic Coast and 2.3 MMBD for Gulf Coast. The base 1975 value for the West Coast is 0.8 MMBD (see Figure 2.4).

TRANSPORTATION ALTERNATIVES

One of the objectives of this study is to investigate the various marine transport modes used to import oil into the three United States coastal regions. Three modes are currently being used: (1) direct shipment, (2) transshipment, and (3) offshore lightering.

Direct Shipment

In the direct shipment mode, oil is loaded at the source (foreign port) and unloaded at the dock in a U.S. port. Only two transfer operations are involved, the first at the loading terminal, and the second at the unloading dock.

The ships engaged in direct shipment generally range in size from 20,000 DWT to a maximum of 70,000 DWT. The limit on size is based on a maximum 40-foot draft in the harbors of most U.S. oil receiving ports. A few U.S. ports like Portland and Long Beach have deeper water and do accommodate larger tankers, but the majority of the direct shipment fleet is restricted to 40 feet or less.

In general, the direct shipment mode is used on the shorter trade routes for economic reasons. Cargoes are mostly products with some crude. Table 2.11 shows a 12-month sample of port calls for New York, Philadelphia and New Orleans during 1975. The large majority of vessels calling at New York were smaller than 70 MDWT and most of these ships originated from nearby sources in the Caribbean, Bahamas and Venezuela, and both direct shipment and transshipment from terminals in the Caribbean and Bahamas. The remaining source regions, 28 percent, are located at much greater distances from New York. These sources are Europe, Africa, and the Persian Gulf. The majority of calls from these areas are by direct shipment with limited partial lightering.

It is assumed that the New York sample of ship mix and port calls is typical of most other ports on the East Coast, except Philadelphia. Philadelphia receives a larger proportion of crude (43 percent) which originates in Africa and the Persian Gulf. This crude is delivered to Delaware Bay in larger than 70 MDWT tankers where the vessels are partially lightered to a 40-foot draft before proceeding to the dock for offloading the remaining cargo. Some crude will come into Philadelphia from Venezuela but almost all of it is direct shipped in smaller vessels. The transshipment terminals in the Caribbean and Bahamas account for 28 percent of the calls to Philadelphia. Crude is transshipped and products are direct shipped from refineries in these two regions.

New Orleans was selected as one of the major Gulf Coast ports. Referring to Table 2.11, New Orleans receives 61 percent of its calls from the Caribbean and Bahamas mainly in vessels smaller than 70 MDWT representing a mix of direct shipment of products and transshipment of crude. Crude also originates from Africa and the Persian Gulf (28 percent), and is delivered both by direct shipment and offshore lightering from VLCCs where all of the cargo is offloaded into lighters.

Figure 2.5 shows the volumes of oil delivered to the three sample ports as a function of the percent of ships less than 70 MDWT and the percent greater than 70 MDWT. Note the similarity between New York and New Orleans and the disparity between these two ports and Philadelphia. The main reason

TABLE 2.11

SAMPLE SHIP MIX AND PORT CALLS, 1975

	New York			Philadelphia			New Orleans		
Source Region	Percent Calls From Source	Percent Calls Less Than 70 MDWT	Percent Calls Greater Than 70 MDWT	Percent Calls From Source	Percent Calls Less Than 70 MDWT	Percent Calls Greater Than 70 MDWT	Percent Calls From Source	Percent Calls Less Than 70 MDWT	Percent Calls Greater Than 70 MDWT
Caribbean	24	96	4	23	89	11	51	93	7
Bahamas	10	96	4	5	90	10	10	97	3
Venezuela	34	91	9	19	97	3	6	98	2
Europe	13	99	1	7	93	7	3	100	0
N. Africa	5	85	15	15	54	46	14	75	25
W. Africa	6	89	11	18	46	54	12	93	7
Persian Gulf	4	72	28	10	48	52	2	82	18
Misc.	4	98	2	3	57	43	2	100	0

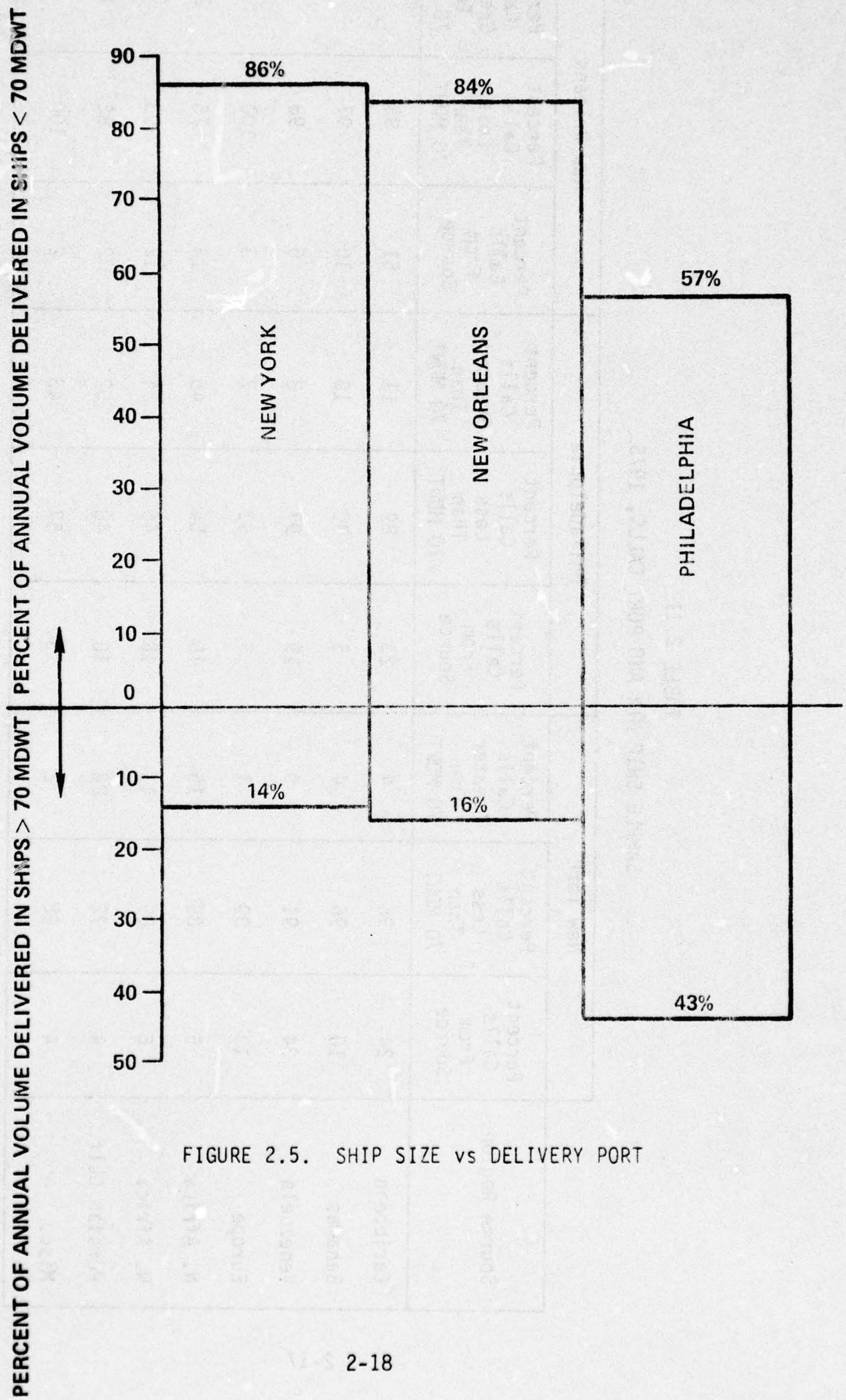


FIGURE 2.5. SHIP SIZE vs DELIVERY PORT

for this difference is the large amount of crude delivered to Delaware Bay in large vessels which are partially lightered before proceeding up to Philadelphia.

Transshipment

The transshipment mode consists of a journey with two legs. The primary leg is traversed by a VLCC from the loading port, which is usually a distant one in the Persian Gulf or Africa, to a deepwater transshipment terminal in the Bahamas or the Caribbean. The crude is offloaded and stored at the terminal. The secondary leg of this route originates at the transshipment terminal where the crude is loaded into smaller vessels for delivery to U.S. ports. Thus a ton of crude is transferred four times, the first time at the foreign loading port, the second time at the terminal, the third time at the terminal, and the fourth time at the U.S. offloading port.

Table 2.12 gives the present status of various transshipment terminals in this hemisphere. The largest and most active ones are in the Caribbean and Bahamas. The thruput capacity of each terminal has been obtained from industry sources. The Caribbean and Bahamas combined have an estimated potential of 2.8 MMBD. Some of the remaining terminals are either out of service or just coming on line. Referring back to Table 2.11, a significant amount of oil, probably crude, is transshipped into Philadelphia in vessels larger than 70 MDWT from the Caribbean and the Bahamas. Very little is shipped into New York or New Orleans in these larger vessels. Large amounts of oil, products and crude, are shipped into all these sample cities from the terminals in the Caribbean, in ships smaller than 70 MDWT.

Lightering

Lightering is a relatively new operation that has gained considerable momentum during the past year or two. It is a form of transshipment which eliminates the terminal and its associated costs. VLCCs are used on the primary or long distance leg and the major portion of the oil comes from Africa and the Middle East. Smaller vessels, "lighters," meet the VLCC at some inshore or offshore location and the VLCC cargo is transferred directly to the lightering vessels for transport to the offloading docks. This transfer operation can take place inshore at a sheltered anchorage or offshore depending on the location of the receiving port, the size of the VLCC, water depth, traffic congestion, lighter size, etc.

The lightering operation in Delaware Bay is typical of inshore lightering. Ships of 90 MDWT to 150 MDWT offload a portion of their cargo into barges. Only sufficient cargo is removed to lighten the vessel to a draft sufficient to proceed up the river to the offloading dock.

The bulk of offshore lightering is currently being done in the Gulf of Mexico. VLCCs of 250 MDWT and larger are completely unloaded into smaller tankers of 40 MDWT to 80 MDWT. The transfer operation takes place 20 to 50 miles off the coast. Mooring between the VLCC and the lightering tanker normally takes place with both vessels underway at slow to medium speeds and

TABLE 2.12

STATUS OF VLCC TRANSSHIPMENT TERMINALS

Location	Estimated Capacity (BD)	Comments
Caribbean:		
Curacao	1,000,000	
Aruba	500,000	
Bonaire	500,000	
Bahamas:		
Freeport	800,000	
Canada:		
Canso, N.S.	250,000	
Available Now But Not Used:		
Trinidad	300,000	Company uses lightering in Gulf vs. Trinidad Terminal
St. Croix	500,000	Requires installation of SPM to be effective
St. John's, N.B.	200,000	Presently does some. Weather not too good (fog, etc.)
St. John's, N.F.	500,000	Shut down for lack of business

headed into the prevailing sea. The lightering tanker gradually closes the gap until mooring lines can be passed and contact is made with the fenders. After mooring is complete, the VLCC can continue to maintain headway or drift during the offloading operation. The choice is normally a function of weather and sea state. Contact with industry representatives involved in lightering indicates that most transfer operations are conducted with the VLCC underway at slow to medium speed.

Industry sources report that they have conducted lightering operations in 8- to 15-foot wave heights. Others have said that an 8-foot wave height is limiting. Problems occur when the relative motion between the two vessels becomes severe enough to damage the fenders and cause extensive chafing of the mooring lines. The magnitude of the relative motion is a function of the sea characteristics and ship characteristics. A brief analysis of the importance of certain of these characteristics can be found in Appendix B, which indicates that wave length is more important than wave height and that synchronism in head seas can occur when the wave length is equal to or greater than the ship length. Synchronism (maximum relative motion) will occur when the natural period of the ship is equal to the period of encounter of the wave. A change in ship speed will alter the period of encounter and gives the operator some control over relative motion. The larger lightering ships will be less subject to disturbing relative motion than the smaller ones a greater portion of the time because the longer wave lengths (700-foot range) are relatively rare even in the coastal regions of the North Atlantic.

At the present state of the art in offshore lightering, the VLCC offloads to only one lightering vessel at a time. In the future, as experience is gained, confidence is improved, and when the economics make VLCC delays more costly, it is likely that lightering vessels will moor and offload on both sides of the VLCC improving turnaround time. Turnaround can also be improved by increasing the transfer rate which currently averages 30,000 to 40,000 barrels per hour in the United States. European rates for dedicated lightering operations have been quoted at 80,000 to 100,000 barrels per hour.

Table 2.13 shows the current status of lightering in the United States. Six companies are engaged in offshore lightering on the West Coast, Gulf Coast and Bahamas. VLCC even lighter in the Bahamas for delivery to the East Coast when transshipment facilities are congested. The major lightering operation is in the Gulf, with a thruput of approximately 450,000 barrels per day which is roughly 20 percent of all of the oil delivered to the Gulf during 1975. It is reported that the lightering vessels supply the VLCC with fuel oil and supplies for the return trip and also transfer their dirty ballast to the VLCC.

COST ANALYSIS - SHIP

Basic cost data were derived from References 13 and 14, and developed into suitable cost parameters for cost analysis of the many trade routes and transport modes used to import oil into the United States. Constant cost items and variable cost items were identified and treated separately as functions of the transport scenario. The following are examples of constant cost items which

TABLE 2.13

STATUS OF LIGHTERING IN UNITED STATES

LOCATION OF LIGHTERING OPERATION	COMPANY	LIGHTERED VESSEL		APPROX. DELIVERIES Bbl/DAY BY LIGHTER	WHEN COMMENCED	LIGHTERS		DISCHARGE PORTS	DAYS DELAY TO VLCC	LIMITING WEATHER CONDITIONS	VLCC BKR. DEL.	WORK BOAT SUPPLY FENDERS	DISCHARGE DIRTY BALLAST TO VLCC	COMMENTS
		NO.	AV. SIZE DWT			NO.	AV. SIZE DWT							
WEST COAST	A	2 PER MONTH	225,000	100,000	SPRING '76	1	79,000 DEDICATED	USUALLY SAN FRANCISCO	14-18	10-15' WAVES NO PROBLEM	YES	NO	YES	
U.S. GULF	B	38 IN 32 MONTHS	210,000	60,000	JAN '74	5-6	50,000	PORT ARTHUR & MISS. R. AREA	10-14	6-8' WAVES WIND 4-5 BEAUFORT	YES	YES	YES	
	C	ABOUT 50 IN 11 MONTHS	35-VLCC 15-SMALLER	150,000	OCT '75	MANY	45,000 TO 50,000	SEVERAL GULF PORTS	8-10	–	YES	YES	YES	LIGHTERS OFTEN EXPERIENCE QUEUEING DELAYS
	D	–	VLCC	170,000	AUG '76	2-3	80,000 DEDICATED	NEW ORLEANS	4-6	6-8' WAVES	YES	NO	NO	LIGHTERS ARE SEGREGATED BALLAST
	E	2 PER MONTH	80,000 TO 100,000	25,000	1974	1-2	15,000 TO 20,000	FREEPORT	–	4-5' WAVE HEIGHTS. SMALL LIGHTERS AFFECTED FIRST.	–	NO	–	MANY VESSELS PARTIALLY LIGHTERED THEN ENTER PORT. OCCASIONAL COMPLETE LIGHTERING. TWO TUG BOATS STAND BY WHILE LIGHTERING AT ANCHOR 7-8 MILES OFF COAST.
	F	1 OR 2 PER MONTH	120,000	45,000	JULY '76	–	50,000 TO 60,000	FREEPORT	–	–	–	–	–	COMPANY UNCERTAIN IF LIGHTERING TO BE CONTINUED. SEVERAL FACTORS INVOLVED.
BAHAMAS	G	2 PER MONTH	VLCC	100,000	MID '75	–	66,000	NEW YORK (PERTH AMBOY) SOMETIMES GULF	–	–	–	–	–	
PLANS FOR LIGHTERING	H			50,000 TO 200,000										DEPENDS ON DECISION FOR ADDITIONAL REFINING CAPACITY

are independent of the length of the trade route, and can be summed to represent the daily cost of operation for a given size of vessel. These cost items are:

- Insurance
- Manning
- Repairs
- Provisions/stores
- Miscellaneous
- Amortization (0 tax).

Variable cost items are those which depend on ship operation such as:

- Fuel at sea
- Fuel in port
- Port charges.

Constant costs for three foreign flag tankers of 120 MDWT, 250 MDWT and 500 MDWT for the years 1972, 1975, and 1980 are listed in Tables 2.14, 2.15, and 2.16. The 1972 cost data is from Reference 13, and the escalation factors are from Reference 14. The constant cost items are summed and converted to daily costs. Daily fuel costs at sea and in port are shown along with daily fuel rates and fuel costs for the three reference years. Port charges are taken from Reference 13 as a function of ship size.

The daily constant costs for the three tankers are shown in Figure 2.6 for the three reference years 1972, 1975 and 1980. The curves are used to develop freight rate cost details for tankers of different sizes.

Fuel consumption is based on a vessel speed of 16 knots and itemized as follows:

Ship Size MDWT	At Sea Fuel Consumption LT/Day	Power Plant	
		Type	Shp-Size
250	150	Turbine	32,000
120	100	Turbine	25,000
65	70	Diesel	18,000

In-port fuel consumption is assumed to be half of the at-sea value.

Port charges are shown in Figure 2.7 for the years 1975 and 1980. Costs are based on tanker deadweight and assumed to vary in a linear fashion.

It is recognized that the cost data developed in these two figures may not be reducible to straight lines and fair curves in every case

TABLE 2.14

ANNUAL OPERATING COST (120 MDWT) FOREIGN FLAG TANKER

Item	1972	Esc %	Esc Factor	1975	Esc Factor	1980
Insurance	$ 463	8	1.26	$ 583	1.47	$ 858
Manning	350	9	1.30	455	1.54	701
Repairs	200	10	1.33	266	1.61	428
Provisions/Stores	150	9	1.30	195	1.54	300
Miscellaneous	15	9	1.30	20	1.54	30
Amortization (0)	2,217	-	-	2,217	-	2,217
Total Annual Constant Costs	$3,395,000			$3,736,000		$4,534,000
Daily Constant Costs (365)	9,300			10,240		12,420
Daily Fuel at Sea	2,300[1]			7,500[3]		10,000[5]
Daily Fuel in Port	1,650[2]			3,750[4]		5,000[6]
Port Charges Per Call	11,974		1.33	15,926	1.61	25,641

[1] 100 LT/Day @ $23/LT

[2] 50 LT/Day @ $23/LT

[3] 100 LT/Day @ $75/LT

[4] 50 LT/Day @ $75/LT

[5] 100 LT/Day @ $100/LT

[6] 50 LT/Day @ $100/LT

TABLE 2.15

ANNUAL OPERATING COST (250 MDWT) FOREIGN FLAG TANKER

Item	1972	Esc %	Esc Factor	1975	Esc Factor	1980
Insurance	$ 1,079	8	1.26	$ 1,360	1.47	$ 1,999
Manning	350	9	1.30	455	1.54	701
Repairs	254	10	1.33	338	1.61	544
Provisions/Stores	175	9	1.30	228	1.54	351
Miscellaneous	25	9	1.30	33	1.54	51
Amortization (0 Tax)	4,158	-	-	4,158	-	4,158
Total Annual Constant Costs	$6,041,000			$6,572,000		$7,804,000
Daily Constant Costs (365)	16,550			18,010		21,380
Daily Fuel at Sea	3,450[1]			11,250[3]		15,000[5]
Daily Fuel in Port	1,730[2]			5,630[4]		7,500[6]
Port Charge Per Call	25,463		1.33	33,865	1.61	54,528

[1] 150 LT/Day @ $23/LT

[2] 75 LT/Day @ $23/LT

[3] 150 LT/Day @ $75/LT

[4] 75 LT/Day @ $75/LT

[5] 150 LT/Day @ $100/LT

[6] 75 LT/Day @ $100/LT

TABLE 2.16

ANNUAL OPERATING COSTS (500 MDWT) FOREIGN FLAG TANKER

Item	1972	Esc %	Esc Factor	1975	Esc Factor	1980
Insurance	$ 2,295	8	1.26	$ 2,892	1.47	$ 4,251
Manning	350	9	1.30	455	1.54	701
Repairs	300	10	1.33	399	1.61	642
Provisions/stores	225	9	1.30	293	1.54	451
Miscellaneous	40	9	1.30	52	1.54	80
Amortization (0)	7,170	-	-	7,170	-	7,170
Total Annual Constant Costs	$10,380,000			$11,261,000		$13,295,000
Daily Constant Cost (365)	28,440			30,850		36,420
Daily Fuel at Sea	5,060[1]			16,500[3]		22,000[5]
Daily Fuel in Port	2,530[2]			8,250[4]		11,000[6]
Port Charge Per call	49,022		1.33	65,199	1.61	104,970

[1]220 LT/Day @ $23/LT

[2]110 LT/Day @ $23/LT

[3]220 LT/Day @ $75/LT

[4]110 LT/Day @ $75/LT

[5]220 LT/Day @ $100/LT

[6]110 LT/Day @ $100/LT

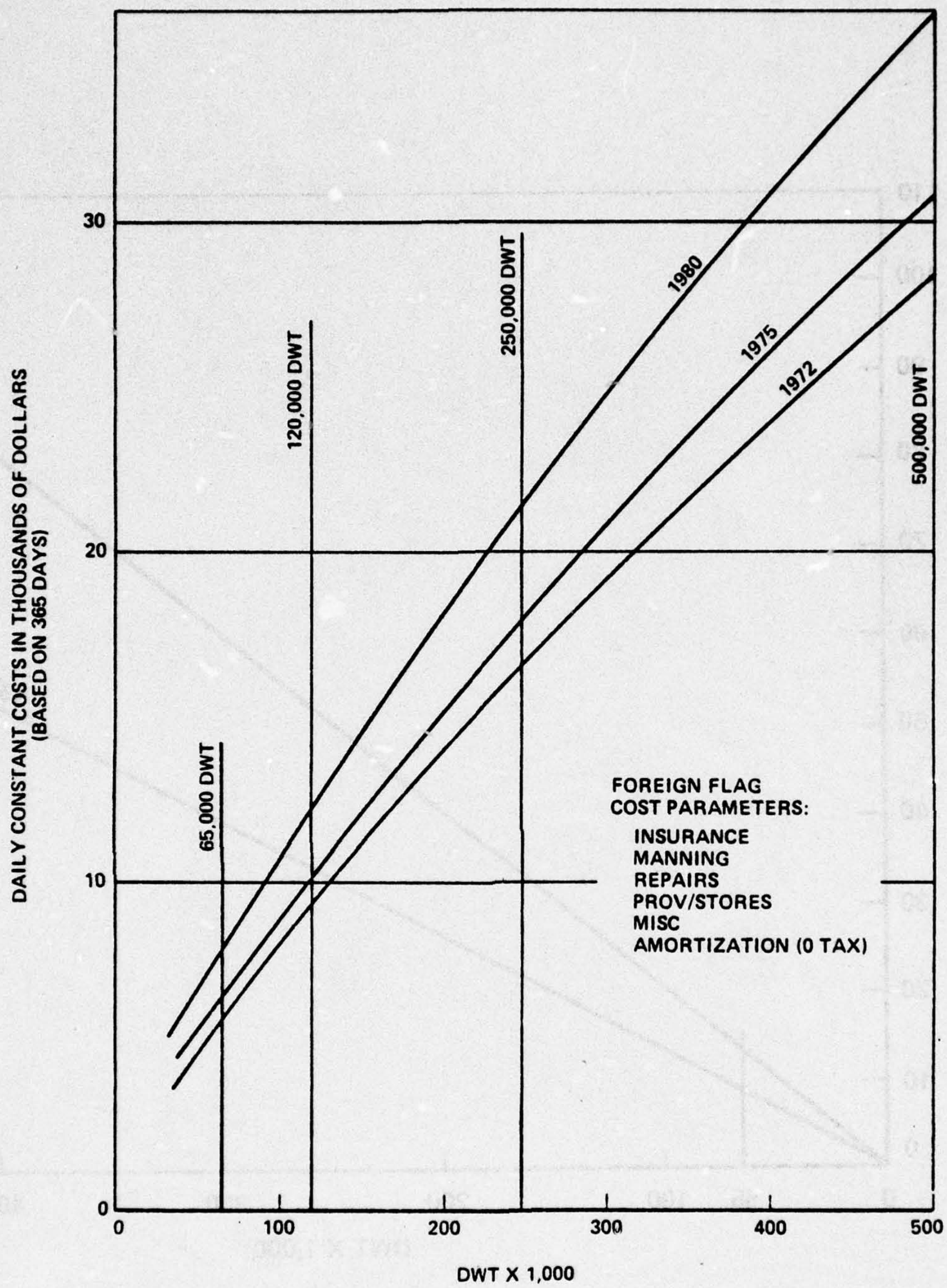


FIGURE 2.6. CONSTANT COSTS vs FOREIGN FLAG TANKER SIZE

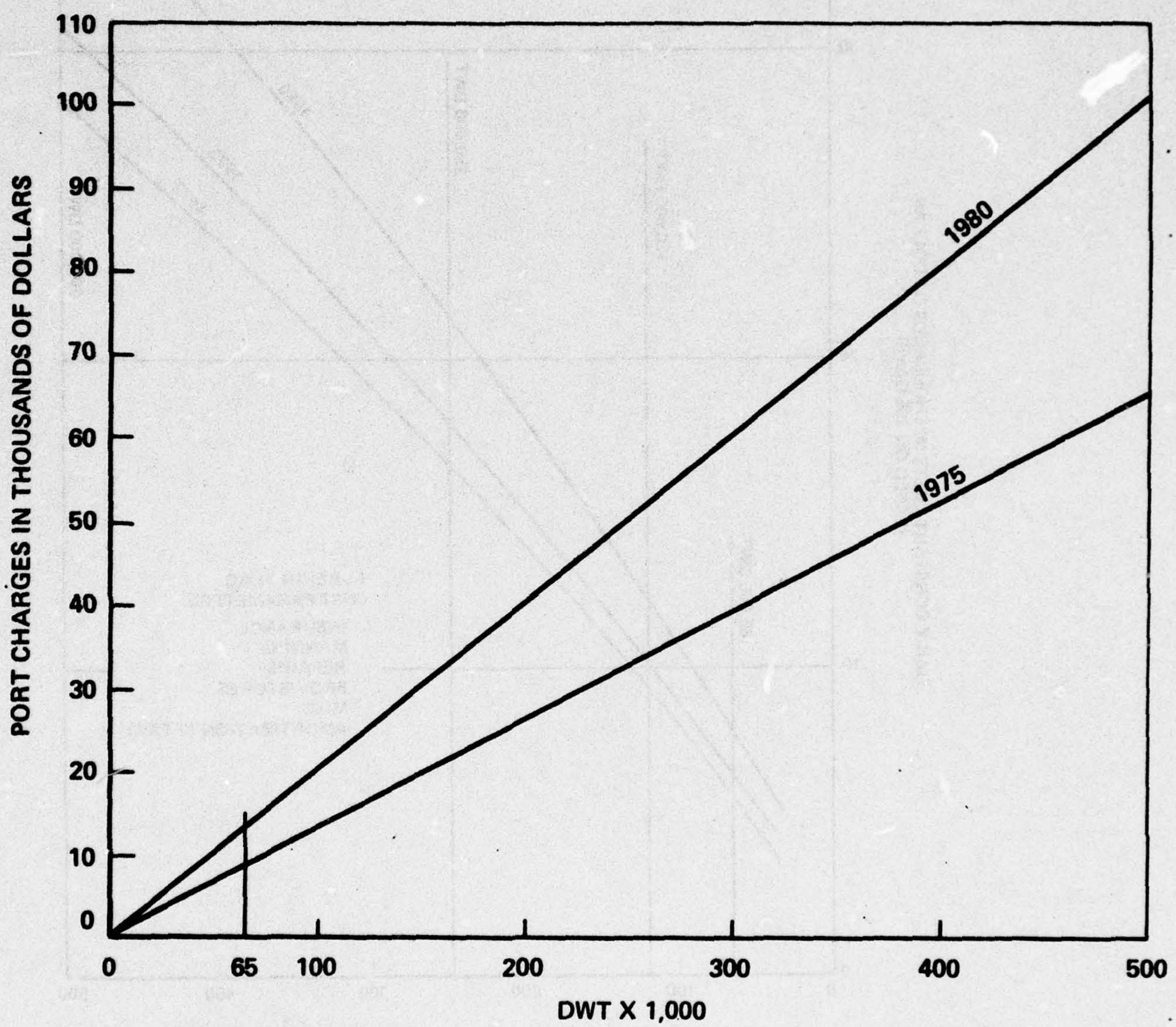


FIGURE 2.7. PORT CHARGES vs TANKER SIZE

for analyzing and comparing freight rates for the various generalized trade routes under consideration. Detailed freight rate cost sheets are shown in Appendix C for a variety of trade routes, ship sizes, and transport modes.

COST ANALYSIS - TRANSFER OPERATIONS

Transshipment

Whenever oil is transferred in a transshipment operation, a transfer charge is levied which is a function of the labor and facility costs of the transfer terminal. Both the onshore terminals located in the Bahamas and Caribbean, and the proposed offshore terminals, i.e., Loop and Seadock, are considered transshipment facilities. Current (1975) transfer rates have been obtained from references and industry sources as follows:

Onshore Terminals (1975 rates)

$1.09-$1.46 per long ton (industry sources), averaged at $1.28/LT for all onshore terminal transfer locations in the Bahamas and Caribbean.

Onshore Terminals (1980 rates)

Escalating at the rate of 15 percent over 5 years, the 1980 transfer rate would average $1.28 x 1.15 = $1.47/LT.

Offshore Terminals (1980 rates)

Escalating the transfer charge of $1.43/LT (Reference 5) over 5 years at 15 percent yields $1.43 x 1.15 = $1.64/LT in 1980. Reference 5 also identifies an additional charge of $0.30/LT as the pipeline use rate.

Lightering

Costs associated with the lightering operation are the cost of the lightering vessels, delays to the VLCC, and miscellaneous costs such as fenders and a fender boat to service the mooring operation.

Partial lightering costs are based on primary delivery by a 120 MDWT tanker to an inshore anchorage and partial lightering into barges. The 1975 cost of barge lighters is $0.41/LT based on data supplied by an industry source involved in partial lightering in Delaware Bay. This cost has been escalated at 5 percent per year to $0.52/LT by 1980, based on the supposition that barges are not as labor intensive as individual lightering tankers.

Offshore lightering is currently being conducted in the Gulf of Mexico. Primary delivery is made by a 250 MDWT VLCC. Lightering tankers are assumed to average 65 MDWT in size. Costs of these vessels are itemized in Appendix C based on a 260-mile round trip. If non-dedicated lighters are used, a fender boat must deliver the fenders to the lightering vessel before the mooring operation begins. The cost of the fenders and fender boat are estimated at $0.10/LT in 1975, and $0.12/LT in 1980.

Delays to the VLCC during the lightering operation are incorporated into the detailed VLCC costs in Appendix C as additional port time. Instead of the normal 4 days port time, VLCCs involved in lightering have been estimated at 8 days based on discussions with industry sources. Delays are the result of port congestion and lack of dock space for the lighters. There have been few delays due to weather thus far in the brief history of lightering.

COST ANALYSIS - SUMMARY

Transportation costs are summarized in the following scenarios and cost tables (Tables 2.17 through 2.22). The following abbreviations are used to designate trade routes:

PG = Persian Gulf	CAR = Caribbean
EC = East Coast of United States	BAH = Behamas
WA = West Africa	GULF = Gulf Coast of United States
NA = North Africa	

For example, the first table shows three trade routes, Persian Gulf to East Coast (PG-EC), West Africa to East Coast (WA-EC), and North Africa to East Coast (NA-EC). The primary transport vessel on these three routes is an average-size tanker of 65 MDWT. The numbers represent the freight rate in dollars per long ton ($/LT) of cargo transported. Cost details which make up the tanker freight rates shown can be found in Appendix C.

The Direct Shipment Scenario assumes that primary delivery is made in a 65 MDWT tanker direct from loading port to unloading port without either transshipment or lightering.

TABLE 2.17

DIRECT SHIPMENT COSTS

1975	PG-EC	WA-EC	NA-EC
Primary Transport (65s)	13.02	6.25	5.15
Terminal Costs	-	-	-
Lightering Costs	-	-	-
Total $/LT	13.02	6.25	5.15
1980	**PG-EC**	**WA-EC**	**NA-EC**
Primary Transport (65s)	16.72	8.05	6.63
Terminal Costs	-	-	-
Lightering Costs	-	-	-
Total $/LT	16.72	8.05	6.63

The Partial Lightering Scenario assumes that primary delivery is made by a 120 MDWT tanker to an inshore anchorage where oil is off-loaded into barges until the tanker is lightened to a 40-foot draft, at which time the tanker will proceed upriver to the off-loading dock to unload the remainder of its cargo. The 1980 costs reflect freight rates for both segregated and non-segregated 120s. The operating cost of a non-segregated tanker has been increased by 15 percent to represent the cost of a segregated tanker. This increase is due to lost cargo capacity and tank modifications.

TABLE 2.18

PARTIAL LIGHTERING COSTS

1975	PG-EC	WA-EC	NA-EC
Primary Transport (120s)	10.64	5.13	4.23
Terminal Costs	-	-	-
Lightering Costs (Barges)	0.41	0.41	0.41
Total $/LT	11.05	5.54	4.64

1975	PG-GULF	WA-GULF	NA-GULF
Primary Transport (120s)	11.05	5.54	5.46
Terminal Costs	-	-	-
Lightering Costs (Barges)	0.41	0.41	0.41
Total $/LT	11.46	5.95	5.87

1980	PG-EC		WA-EC		NA-EC	
	Non-Seg	Seg	Non-Seg	Seg	Non-Seg	Seg
Primary Transport (120s)	13.48	15.50	6.53	7.51	5.40	6.21
Terminal Costs	-	-	-	-	-	-
Lightering Costs (Barges)	0.52	0.52	0.52	0.52	0.52	0.52
Total $/LT	14.00	16.02	7.05	8.03	5.92	6.73

1980	PG-GULF		WA-GULF		NA-GULF	
	Non-Seg	Seg	Non-Seg	Seg	Non-Seg	Seg
Primary Transport (120s)	14.00	16.10	7.05	8.11	6.95	7.99
Terminal Costs	-	-	-	-	-	-
Lightering Costs (Barges)	0.52	0.52	0.52	0.52	0.52	0.52
Total $/LT	14.52	16.62	7.57	8.63	7.47	8.51

TABLE 2.18 (Cont)

1975	CAR-EC	CAR-GULF	BAH-EC	BAH-GULF
Primary Transport (120s)	2.26	2.01	1.60	1.35
Terminal Costs	-	-	-	-
Lightering Costs (Barges)	0.41	0.41	0.41	0.41
Total $/LT	2.67	2.42	2.01	1.76

1980	CAR-EC		CAR-GULF		BAH-EC		BAH-GULF	
	Non-Seg	Seg	Non-Seg	Seg	Non-Seg	Seg	Non-Seg	Seg
Pri Trans (120s)	2.91	3.35	2.59	2.98	2.07	2.38	1.77	2.04
Terminal Costs	-	-	-	-	-	-	-	-
Lit'ing (Barges)	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Total $/LT	3.43	3.87	3.11	3.50	2.59	2.90	2.99	2.56

The Full Lightering Scenario assumes that primary delivery is made in a 250 MDWT tanker to an offshore location where it is met by lightering tankers. The VLCC is completely off-loaded and the lightering tankers deliver the oil to the off-loading dock. A fender boat is used to deliver the fenders to the lightering tankers. The lightering vessels will refuel and reprovision the VLCC for its return trip. The lightering vessels will also transfer their dirty ballast to the VLCC during the off-loading operation.

TABLE 2.19
FULL LIGHTERING COSTS

1975	PG-GULF	WA-GULF	NA-GULF
Primary Transport (250s)	9.30	4.93	4.87
Terminal Costs	-	-	-
Lightering Costs (65s)	0.80	0.80	0.80
Fender Boat Costs	0.10	0.10	0.10
Total $/LT	10.20	5.83	5.77
1980	**PG-GULF**	**WA-GULF**	**NA-GULF**
Primary Transport (250s)	11.33	5.90	5.82
Terminal Costs	-	-	-
Lightering Costs (65s)	1.03	1.03	1.03
Fender Boat Costs	0.12	0.12	0.12
Total $/LT	12.48	7.05	6.97

The <u>Transshipment Scenario</u> assumes that primary delivery is made in 250 MDWT tankers to transshipment terminals in the Bahamas and the Caribbean. Smaller feeder vessels, 65 MDWT, load at the terminals and deliver oil to the United States.

TABLE 2.20

TRANSSHIPMENT COSTS TO EAST COAST

1975	PG-BAH	WA-BAH	NA-BAH
Primary Transport (250s)	8.14	8.14	8.14
Terminal Costs	1.28	1.28	1.28
Feeder Vessel Costs (65s)	1.86	1.86	1.86
Total $/LT	11.38	7.07	6.95
1980	**PG-BAH**	**WA-BAH**	**NA-BAH**
Primary Transport (250s)	10.31	4.96	4.81
Terminal Costs	1.47	1.47	1.47
Feeder Vessel Costs (65s)	2.40	2.40	2.40
Total $/LT	14.18	8.83	8.86
1975	**PG-CAR**	**WA-CAR**	**NA-CAR**
Primary Transport (250s)	7.65	3.55	3.75
Terminal Costs	1.28	1.28	1.28
Feeder Vessel Costs (65s)	2.65	2.65	2.65
Total $/LT	11.58	7.48	7.68
1980	**PG-CAR**	**WA-CAR**	**NA-CAR**
Primary Transport (250s)	9.58	4.48	4.73
Terminal Costs	1.47	1.47	1.47
Feeder Vessel Costs (65s)	3.42	3.42	3.42
Total $/LT	14.47	9.37	9.62

TABLE 2.21

TRANSSHIPMENT COSTS TO GULF

1975	PG-BAH	WA-BAH	NA-BAH
Primary Transport (250s)	8.24	3.93	3.81
Terminal Costs	1.28	1.28	1.28
Feeder Vessel Costs (65s)	1.56	1.56	1.56
Total $/LT	11.08	6.77	6.65

TABLE 2.21 (Cont)

1980	PG-BAH	WA-BAH	NA-BAH
Primary Transport (250s)	10.31	4.96	4.81
Terminal Costs	1.47	1.47	1.47
Feeder Vessel Costs (65s)	2.03	2.03	2.03
Total $/LT	13.81	8.46	8.31
1975	**PG-CAR**	**WA-CAR**	**NA-CAR**
Primary Transport (250s)	7.65	3.55	3.75
Terminal Costs	1.28	1.28	1.28
Feeder Vessel Costs (65s)	2.37	2.37	2.37
Total $/LT	11.30	7.20	7.40
1980	**PG-CAR**	**WA-CAR**	**NA-CAR**
Primary Transport (250s)	9.58	4.48	4.73
Terminal Costs	1.47	1.47	1.47
Feeder Vessel Costs (65s)	3.03	3.03	3.03
Total $/LT	14.08	8.98	9.23

The Deepwater Ports Scenario assumes that primary delivery is made in 250 MDWT tankers direct to the DWP terminal. Transfer costs are based on Reference 5. Oil is pumped from the terminal to shore via an underwater pipeline. Costs are shown for both segregated and non-segregated 250s. Segregated tanker operating costs are 15 percent higher due to tank modification and lost cargo capacity.

TABLE 2.22

DEEPWATER PORT COSTS

	PG-GULF		WA-GULF		NA-GULF	
	Non-Seg	Seg	Non-Seg	Seg	Non-Seg	Seg
Primary Transport (250s)	10.83	12.45	5.41	6.22	5.33	6.13
Transfer Costs	1.64	1.64	1.64	1.64	1.64	1.64
Pipeline Costs	0.30	0.30	0.30	0.30	0.30	0.30
Total $/LT	12.77	14.39	7.35	8.16	7.27	8.07

Table 2.23 summarizes the various delivery alternatives on the basis of final freight rate in $/LT. Delivery alternatives are compared with freight rates from the various world oil sources. In all cases lightering a 250 MDWT tanker is the least costly, followed closely by the deepwater port option. Partial lightering is a good third choice on the closer trade routes (North and West Africa), followed by direct shipment. Transshipment is the most

TABLE 2.23

FREIGHT RATE vs DELIVERY ALTERNATIVES

Delivery Method	Year	Persian Gulf		West Africa		North Africa		Caribbean		Bahamas	
		East Coast	Gulf Coast	East Coast	Gulf Coast	East Coast	Gulf Coast	East Coast	Gulf Coast	East Coast	Gulf Coast
Direct Shipment (65 MDWT)	1975	13.02	13.53	6.25	6.76	5.15	6.66	2.65	2.37	1.86	1.56
	1980	16.72	17.36	8.05	8.69	6.63	8.57	3.42	3.03	2.40	2.03
Partial Lightering (120 MDWT)	1975	11.05	11.46	5.54	5.95	4.64	5.87	2.67	2.42	2.01	1.76
	1980	14.00	14.52	7.05	7.57	5.92	7.47	3.43	3.11	2.59	2.29
Partial Lightering (120 MDWT) Seg	1975	-	-	-	-	-	-	-	-	-	-
	1980	16.02	16.62	8.03	8.63	6.73	8.51	3.87	3.50	2.90	2.56
Transshipment via Bahamas (120 MDWT)	1975	11.38	11.08	7.07	6.77	6.95	6.65	-	-	-	-
	1980	14.18	13.81	8.83	8.46	8.68	8.31	-	-	-	-
Transshipment via Caribbean (250 MDWT)	1975	11.58	11.30	7.48	7.20	7.68	7.40	-	-	-	-
	1980	14.47	14.08	9.37	8.98	9.62	9.23	-	-	-	-
Full Lightering (250 MDWT)	1975	-	10.20	-	5.83	-	5.77	-	-	-	-
	1980	12.07	12.48	6.65	7.05	5.76	6.97	-	-	-	-
Deepwater Port-Gulf (250 MDWT)	1975	-	-	-	-	-	-	-	-	-	-
	1980	-	12.77	-	7.35	-	7.27	-	-	-	-
Deepwater Port-Gulf (250 MDWT) Seg	1975	-	-	-	-	-	-	-	-	-	-
	1980	-	14.39	-	8.16	-	8.07	-	-	-	-

costly on these two routes. On the longest route (Persian Gulf), direct shipment is the most costly, followed by transshipment and partial lightering.

DELIVERY SCENARIOS

Import Quantities and Ship Calls

Import data from References 11 and 12 include the quantity of oil shipped to U.S. ports, the sources of shipment, and the number of ship calls as a function of ship size. This information has been collected for the year 1975 for two major East Coast ports (New York and Delaware), and for one Gulf port (New Orleans). These three ports will be used as samples for scaling up quantities and ship calls to include the entire East Coast and Gulf Coast.

Table 2.24 shows the scale up procedure for the U.S. Gulf. Detailed customs manifest information for New Orleans is shown in the second column. Gulf Coast values have been obtained by scaling up the New Orleans data by the ratio of total imports to the Gulf Coast in 1975 from Figure 2.2 to the total imports to New Orleans in 1975. This ratio is 4:43. Import quantities are noted in net registered tons (NRT). Ship calls are divided up into those quantities less than 70 MDWT (<70) and those greater than 70 MDWT (>70). The quantity delivered from each of the sources listed in the first column is shown as a percent of the total delivered to the Gulf Coast. Note that of the 598 ship calls to the New Orleans area, only about 9 percent were in ships greater than 70 MDWT.

Table 2.25 shows the scale up procedure for the East Coast. This data was also obtained from References 11 and 12. Procedures are identical to those just discussed for the Gulf Coast, except that Philadelphia was not considered typical of other East Coast ports because of its large refinery capacity. New York was considered typical and the New York sample was used to scale up the other East Coast ports. Philadelphia was then added to obtain the total East Coast data base shown in the last three columns.

Ship calls for 1975 are summarized in Table 2.26 for the Gulf and East Coasts. The average ship size for vessels below 70 MDWT is 40 MDWT (rounded off) and for vessels greater than 70 MDWT, it is 80 MDWT (rounded off).

Ship calls for 1980 have been increased by the ratio of regional imports in 1980 to regional imports in 1975. Table 2.27 shows that ship calls increased by 81 percent in 1980 due to increasing oil imports and assuming no retrofit regulation is in force.

Table 2.28 shows the anticipated changes in 1980 ship calls assuming that retrofit is required and the industry elects to circumvent the regulation by replacing the 1,181 tankers over 70 MDWT (80 MDWT average) in Table 2.27, with the 1,454 tankers less than 70 MDWT (65 MDWT average) shown in Table 2.28. This represents an increase in ship calls of only 2 percent over the 1980 status quo.

TABLE 2.24

GULF COAST IMPORT STATISTICS 1975

To / From	New Orleans			Gulf Coast		
	Import Quantity NRT Thousands	Ship Calls <70/>70	Percent Total Volume	Import Quantity NRT Thousands	Ship Calls <70/>70	Percent Total Volume
Venezuela	473	42/1	5	2,095	186/4	5
Caribbean	4,993	274/22	49	22,125	1,213/98	49
Bahamas	1,032	57/2	10	4,570	252/9	10
Persian Gulf	192	9/2	2	850	40/9	2
West Africa	1,302	62/5	13	5,766	275/22	13
North Africa	1,910	63/21	19	8,459	279/93	19
Europe	215	25/0	2	952	111/0	2
Miscellaneous	127	13/0	1	562	58/0	1
Totals	10,247	545/53		45,380	2,414/235	

TABLE 2.25

EAST COAST IMPORT STATISTICS, 1975

To / From	New York			Philadelphia			Other East Coast Ports			Total East Coast		
	Import Quantity NRT Thousands	Ship Calls <70/>70	Percent Total Volume	Import Quantity NRT Thousands	Ship Calls <70/>70	Percent Total Volume	Import Quantity NRT Thousands	Ship Calls <70/>70	Percent Total Volume	Import Quantity NRT Thousands	Ship Calls <70/>70	Percent Total Volume
Venezuela	4,919	211/27	36	2,286	149/4	13	12,017	515/66	36	19,222	875/97	30
Caribbean	3,070	217/9	23	3,340	167/20	20	7,499	530/22	23	13,909	914/51	22
Bahamas	1,584	92/4	12	727	35/4	4	3,869	225/10	12	6,180	352/18	10
Persian Gulf	738	24/10	5	2,289	38/42	13	1,803	59/24	5	4,831	121/76	8
West Africa	846	50/6	6	4,111	67/78	24	2,066	122/15	6	7,023	239/99	10
North Africa	774	40/7	6	3,141	66/56	18	1,891	98/17	6	5,806	204/80	9
Europe	1,277	123/1	9	679	52/4	4	3,119	300/2	9	5,075	475/7	8
Misc.	425	40/1	3	481	12/9	3	1,039	98/2	3	1,945	150/12	3
Total	13,633	797/ 65		17,055	586/ 217		33,303	1,947/ 158		63,991	3,330/ 440	

TABLE 2.26

SHIP CALLS AND SIZES, 1975 STATUS QUO

Region	Ship Calls <70 MDWT	Ship Calls >70 MDWT	Total Calls
Gulf Coast	2,414	235	2,649
East Coast	3,330	440	3,770
Total	5,774	675	6,419

TABLE 2.27

SHIP CALLS AND SIZES, 1980 STATUS QUO

Region	Ship Calls <70 MDWT	Ship Calls >70 MDWT	Total Calls
Gulf Coast	5,773	562	6,335
East Coast	4,683	619	5,302
Total	10,456	1,181	11,637

TABLE 2.28

SHIP CALLS AND SIZES, 1980 RETROFIT

Region	Ship Calls <70 MDWT	Ship Calls in 65 MDWT	Total Calls
Gulf Coast	5,773	692	6,465
East Coast	4,683	762	5,445
Total	10,456	1,454	11,910

The following two tables (Table 2.29 and 2.30) show the Gulf and East Coast regions with the addition of the West Coast, deepwater ports, and anticipated increases in lightering and transshipment. The Alaskan pipeline will be operational by 1980, however, it is not clear at this time where that oil will be delivered. The U.S. West Coast will be self-sufficient by 1980, and delivery to the U.S. East and/or Gulf Coasts is evidently not practical.

The following average ship sizes are assumed:

	Average Ship Size
Lightering vessels	65s, 80s
Transshipping vessels	40s, 80s
Direct shipment (West Coast)	80s
Direct shipment (East Coast and Gulf Coast)	40s, 80s
Deepwater port vessels	250s

TABLE 2.29

SHIP CALLS AND SIZES, 1980 STATUS QUO, INCLUDING DWP

Ship Sizes	40 MDWT	65 MDWT	80 MDWT	120 MDWT	250 MDWT	Total
Gulf Region	1,600	-	200	-	813	2,613
East Coast	4,683	-	619	-	-	5,302
West Coast	-	77	438	-	-	515
Total	6,283	77	1,257	-	813	8,430

TABLE 2.30

SHIP CALLS AND SIZES, 1980 RETROFIT, INCLUDING DWP

Ship Sizes	40 MDWT	65 MDWT	80 MDWT	120 MDWT	250 MDWT	Total
Gulf Region	1,600	246	-	-	1,016	2,862
East Coast	4,683	762	-	-	-	5,445
West Coast	-	616	-	-	-	616
Total	6,283	1,624	-	-	1,016	8,923

Table 2.31 is the Delivery Scenario Summary (non-compliance), which shows the five scenarios for the Gulf, East, and West Coasts, and the projected effects of a deepwater port operation. The two 1980 retrofit scenarios are calculated based on non-compliance by industry, except in the special case of the DWP 250s. Total ship calls by ship size is shown at the botton of the table for each scenario. The circled numbers (footnotes) in the table are used to acquaint the reader with the assumption, logic, and information sources that were used to develop this table and forecast the four 1980 scenarios. The footnotes are listed as follows:

1. Quantities of products and crude from the regional import curves, Figures 2.2, 2.3, and 2.4.

2. Breakdown of quantity between operational modes comes from the following sources:

   Lightering: discussion with industry sources
   Direct: Bureau of the Census data, References 11 and 12, Tables 2.24 and 2.25
   Transshipment: left-over quantity - compared with transshipment capacity, Table 2.12.

3. Ship calls come from Table 2.24 and 2.25, scaled up by region and year to 1980.

4. The Alaskan pipeline has not been included in the 1980 scenarios because Alaskan oil will probably not be delivered to the U.S. The West Coast will be self-sufficient by 1980, and transportation to the East Coast and Gulf Coast may not be practical.

5. Import quantities in the three modes and port calls increased by the ratio of total quantity increase between 1975 and 1980, as follows:

   Gulf Coast ratio 5.5/2.3
   East Coast ratio 4.5/3.2
   West Coast ratio 1.

6. West Coast ship calls and sizes are based on the present lightering operation in San Francisco using 65s (average) and the direct shipments to Long Beach in 80s (average). Long Beach has deepwater at the dock and can handle ships at 51-foot draft.

7. Retrofit required but industry refuses to comply except for special cases.

8. Assumes that the 562 80s used in the 1980 status quo scenario will not be retrofitted. The 80s represent about 10 percent of the fleet and 20 percent of the

TABLE 2.31
DELIVERY SCENARIO SUMMARY

		1975 STATUS QUO				1980 STATUS QUO				1980 RETROFIT 7			INCLUDING DEEPWATER PORTS: 1980 STATUS QUO				INCLUDING DEEPWATER PORTS: 1980 RETROFIT 7			
			MODE 2				MODE 5 4			MODE 8 11			MODE 10				MODE			
		1975 MMBD	LIGHTER	TRAN-SHIP	DIRECT	1980 MMBD	LIGHTER	TRAN-SHIP	DIRECT	LIGHTER	TRAN-SHIP	DIRECT	LIGHTER	TRAN-SHIP	DWP	DIRECT	LIGHTER	TRAN SHIP	DWP	DIRECT
GULF	PRODUCTS	0.2			0.2	0.5	–	–	0.5	–	–	0.5		–	–	0.5	–	–	–	0.5
	CRUDE	2.1	0.4	1.1	0.6	5.0	1.0	2.6	1.4	1.5	3.2	0.3	–	–	3.9	1.1	–	–	3.9	1.1
	TOTAL 1*	2.3	0.4	1.1	0.8	5.5	1.0	2.6	1.9	1.5	3.2	0.8	–	–	3.9	1.6	–	–	3.9	1.6
	SHIP CALLS 3			2,414-40s 235-80s				5,773-40s 562-80s			5,773-40s 692-65s 9			813-250s 11 200-80s 1,600-40s				1,016-250s 12 246-65s 9 1,600-40s		
	TOTAL			2,649				6,335			6,465			2,613				2,862		
EAST COAST	PRODUCTS	2.1	–	–	2.1	3.2	–	–	3.2	–	–	3.0	–	–	–	3.2	–	–	–	3.0
	CRUDE	1.1	0.1	0.4	0.6	1.3	0.2	0.4	0.7	0.5	1.0	–	0.2	0.4	–	0.7	0.5	1.0	–	–
	TOTAL 1	3.2	0.1	0.4	2.7	4.5	0.2	0.4	3.9	0.5	1.0	3.0	0.2	0.4	–	3.9	0.5	1.0	–	3.0
	SHIP CALLS 3			3,330-40s 440-80s				4,683-40s 619-80s			4,683-40s 762-65s 9			4,683-40s 619-80s				4,683-40s 762-65s 9		
	TOTAL			3,770				5,302			5,445			5,302				5,445		
WEST COAST	PRODUCTS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	CRUDE	0.8	0.1	–	0.7	0.8	0.1	–	0.7	0.3	–	0.5	0.1	–	–	0.7	0.3	–	–	0.5
	TOTAL 1	0.8	0.1	–	0.7	0.8	0.1	–	0.7	0.3	–	0.5	0.1	–	–	0.7	0.3	–	–	0.5
	SHIP CALLS			77-65s 438-80s				77-65s 438-80s			616-65s 9			77-65s 438-80s				616-65s 9		
	TOTAL			515 6				515 6						515						
	GRAND TOTALS	6.3 MMBD		5,744-40s 77-65s 1,113-80s		10.8 MMBD		10,456-40s 77-65s 1,619-80s 957-120s			10,456-40s 2,070-65s 957-120s			6,283-40s 77-65s 1,257-80s 957-120s 813-250s				6,283-40s 1,624-65s 1,016-250s 813-250s		
	TOTAL CALLS			6,934				12,152			12,526			8,430				8,923		

*See text for footnotes 1 thru 11

total cargo volume. Therefore, since 80s will not be used in the 1980 retrofit scenario, 20 percent of the total volume was deducted from direct shipment and applied across lightering and transshipment.

9. Ship calls in 40s show no change from 1980 status quo. The volume carried by the 80s is now carried by 65s in the 1980 retrofit scenario.

10. Assumes that all lightering and transshipment will shift to DWP in the following ratio:

Seadock	2.5 MMBD
Loop	1.4 MMBD
	3.9 DWP

The remaining 1.6 MMBD will be direct shipped.

11. Assumes all ships calling at DWP will be 250s on the average carrying 240 DWT. Of the direct shipped 1.6 MMBD, assumes that 20 percent of volume is carried in 80s and 80 percent is carried in 40s, as per the 1975 breakdown of Census data (Reference 11).

12. Assumes that DWP fleet will retrofit, but that direct shipments will not. Retrofit will reduce cargo capacity by 20 percent.

13. If the industry complies with retrofit, the ship mix will be the same as the 1980 status quo, except for a 20 percent increase in ship calls for the ships > 70 MDWT to offset the loss of cargo capacity.

Table 2.32 shows the two 1980 retrofit scenarios on the basis that industry has agreed to comply with the ruling. The ship mixes and transport mode volumes are similar to the 1980 status quo scenarios except for an increase in the number of ship calls greater than 70 MDWT. The increase in ship calls is based on a 20 percent reduction in cargo capacity due to segregated ballast tanks.

The number of ship calls for 1980 retrofit (compliance) is only 3 percent greater than the 1980 status quo (Table 2.31) and approximately equal to the 1980 retrofit (non-compliance). When DWP is included, the number of ship calls for the 1980 retrofit (compliance) is 6 percent greater than the 1980 retrofit (non-compliance). In both tables it was assumed in the 1980 retrofit DWP scenario that the 250s serving DWP would be segregated ballast because there would be no point in 65s calling at DWP rather than going straight to the dock.

TABLE 2.32

DELIVERY SCENARIO (RETROFIT COMPLIANCE)

			1980 Retrofit			1980 Retrofit Including DWP			
			Mode			Mode			
		1980 MMBD	Lighter	Trans-Ship	Direct	Lighter	Trans-Ship	DWP	Direct
Gulf	Products	0.5	-		0.5	-	-	-	0.5
	Crude	5.0	1.0	2.6	1.4	-	-	3.9	1.1
	Total	5.5	1.0	2.6	1.9	-	-	3.9	1.6
	Ship Calls		5,773 - 40s 703 - 80s			1,016 - 250s 250 - 80s 1,600 - 40s			
	Total		6,476			2,866			
East Coast	Products	3.2	-	-	3.2	-	-	-	3.2
	Crude	1.3	0.2	0.4	0.7	0.2	0.4	-	0.7
	Total	4.5	0.2	0.4	3.9	0.2	0.4	-	3.9
	Ship Calls		4,683 - 40s 774 - 80s			4,683 - 40s 774 - 80s			
	Total		5,457			5,457			
West Coast	Products	-	-	-	-	-	-	-	-
	Crude	0.8	0.1	-	0.7	0.1	-	-	0.7
	Total	0.8	0.1	-	0.7	0.1	-	-	0.7
	Ship Calls		77 - 65s 548 - 80s			77 - 65s 548 - 80s			
	Total		625			625			
	Grand Total	10.8 MMBD	10,456 - 40s 77 - 65s 2,025 - 80s			6,283 - 40s 77 - 65s 1,572 - 80s 1,016 - 250s			
	Total Calls		12,558			8,948			

III. ENVIRONMENTAL CONSIDERATIONS

REGULATION FOR PREVENTION OF POLLUTION

The history of legislation and regulation generated by concern for protection of the marine environment is relatively short. The earliest national legislation of this type was the Refuse Act of 1899 (33 U.S.C. 407). This act prohibits the throwing, discharging, or depositing of refuse waste into the navigable waters of the United States. It was not used in the prevention of oil pollution for many years and it was not until a Supreme Court decision (U.S. vs Standard Oil Co., 384 U.S. 224) defined the term "refuse" as including gasoline that a foundation for oil pollution regulation was laid. In the years following World War II, Environmental concerns were increasing and this interest is reflected by both an increasing number of statutes and an increasing frequency of amendments to existing statutes.

In the area of international law, the dawn of history occurs somewhat later than in the national sphere. The Washington Conference of 1926 was convened to consider means for international control of oil pollution. This conference produced several proposals whose general characteristics have remained unchanged since (e.g., the 50-mile prohibited discharge zone), but the agreements reached at the conference were never ratified or enforced (Reference 16). The Oil Pollution Conference of 1954 produced a convention which included many of the recommendations conceived at the Washington Conference almost 30 years earlier. The conditions for this convention's entry into force were not met until 1958, and the United States did not ratify the instrument until late 1961. Among the revisions and amendments to this convention are the 1969 Amendments, which specify discharge limits. The latest proposal is the new International Convention for the Prevention of Pollution from Ships, 1973. A comparison of the provisions of the 1954 and 1973 conventions is contained in Appendix D. This Appendix is taken from Reference 17. The mandatory requirement for segregated ballast for "new" tankers of 70,000 DWT and greater is a part of this convention. The Coast Guard advance notice to require retrofitting segregated ballast tanks on both U.S. and foreign vessels operating in U.S. waters, is a unilateral United States initiative on the same subject.

SEGREGATED BALLAST

Tankers operationally (and legally) discharge a certain quantity of oil into the marine environment every voyage. After unloading, the ship rides high out of the water with the propeller and sometimes the forefoot exposed. If the vessel were to return to sea in this condition it would be difficult to steer, have poor propulsive characreristics, and be subject to slamming. To overcome these problems it is normal to take on water ballast before starting the return trip to make the vessel more seaworthy. The water ballast amounts to about 40 percent of the cargo capacity except during heavy weather when the master may take on an additional 20 percent to make his ship handle more comfortably.

The water taken onboard as ballast mixes with the sludge and residual oil remaining in the tanks and this "dirty ballast" must be discharged before reaching port. Therefore, during the return trip the crew will clean several tanks so that clean ballast can be put in clean tanks, and the dirty ballast discharged overboard while outside of prohibited zones defined by the 1954 Convention and amended in 1962. On most ships this discharge is monitored and that portion of the dirty ballast containing the heaviest concentration of oil is transferred to a special tank called a slop tank for later discharge ashore or to be added to the cargo after settling.

Thus, under the current system, a certain amount of oil will be discharged overboard every voyage as a result of tank cleaning and ballasting. Under the proposed segregated ballast system, a portion of the ship's tanks will be segregated for clean water ballast to prevent the mixing of ballast water and cargo oil. This practically eliminates the discharge of dirty ballast and reduces the requirement for tank cleaning every voyage, except for routine inspection, prevention of sludge build-up, and prior to shipyard entry. Some dirty ballast discharge will still occur when tankers take on ballast in addition to their segregated ballast capacity during heavy weather.

ENVIRONMENTAL POLLUTION ESTIMATES

Introduction

The environmental pollution problem with which this is concerned may be stated as follows:

- What are the probable future changes in amount and location of oil discharges resulting from the implementation of the proposed regulation?

In order to satisfactorily answer this question, the study team was required to estimate current pollution and then project a future estimate based on the two alternatives that the regulation will or will not be complied with. On the most general level of analysis, types of oil discharges may be characterized as operational or accidental. Operational discharges are considered those that occur as a result of normal activities in the process of moving petroleum from its source to the ultimate consumer. Accidental discharges are the result of various types of casualties which may occur in this process. The amounts and locations of both operational and accidental discharges are affected by a large number of factors, including total volume spilled, types and sizes of ships involved, operational scenarios and the level of training and qualification of the personnel involved in various sectors of the shipping industry. The following sections will describe in detail the methods, data sources, and assumptions used in computing our estimates of current and future oil pollution in the marine environment.

Operational Discharges

The general method used for the computation of operational discharges is similar to that used in the Coast Guard FEIS on Regulations for Tank Vessels Engaged in the Carriage of Oil in Domestic Trade (Reference 15). This system was selected because of the clarity with which data sources, assumptions, and computations are displayed. For the purposes of the present analysis, we will initially define four basic categories of operational discharges and, within these, will define subcategories. The divisions to be used are as follows:

1. Tank cleaning and ballasting discharges
   a. Load On Top tankships (LOT)
   b. Non-LOT tankships (NLOT)
   c. Segregated ballast tankships (SBT)
2. Shipyard Entry (SE), requires cleaning and gas-freeing all tanks
3. Bilges and Bunkering (BB)
4. Terminal Operations
   a. Direct shipment (DS)
   b. Transshipment (TS)
   c. Lightering (L)
   d. Deepwater Ports (DWP).

The letters in parentheses above will be used to define quantities in the computational equations which follow. Additional parameters to be used are:

a, b, c - respective percentages of LOT, NLOT, and SBT type ships in service

k, l, m, n - respective percentages of total maritime petroleum imports using the DS, TS, L, and DWP options.

Total operational discharges (TOD) from tankers in the United States import trade for any given year may then be defined by the equation:

$$TOD = LOT + NLOT + SBT + SE + BB + DS + TS + L + DWP \qquad (1)$$

Base Year (1975) TOD Computation. For each of the quantities shown in Equation (1) above, we will now describe the sources, rationale, and assumptions used in its derivation. A basic factor needed for most computations is an estimate of total petroleum imports for the year in terms of millions of barrels per year (MMBY).

Total petroleum imports (TPI) 1975 = 2,300 MMBY.

This is divided into:

Crude (TPIC) = 1,460 MMBY
Products (TPIP) = 840 MMBY.

These estimates are taken from Figure 2.1 of Section II.

The amounts of normal operational underway discharges from various types of tankers (LOT, NLOT, and SBT) are derived as follows:

$$\text{LOT} = \text{LOT (Crude)} + \text{LOT (Products)} \tag{2}$$

$$\text{LOT (Crude)} = a \cdot \text{TPIC} \cdot \text{CC}\left\{\text{TC}(1-\text{ELOT}) + \text{DB} \cdot \text{CBD}\right\} \tag{3}$$

where:

a = Percentage of LOT tankers in U.S. import service
= 80%

Derived from:

Reference 15 - 80%
Reference 19 - 75%
Reference 20 - 80%.

TPIC = as defined above

CC = Crude oil clingage
= 0.4%

Derived from:
Reference 15 - 0.4%
Reference 18 - Ranges between .3 and 1.5%
Reference 19 - Ranges between .1 and 1.5%; 0.35%
Reference 20 - Ranges between .1 and .9%; 0.4%.

TC = Tanks cleaned and/or ballasted during each voyage
= 33%

Derived from:
Reference 15 - 33%
Reference 19 - 33-40%.

ELOT = Effectiveness of LOT procedures

= 90%

Derived from:

Reference 15 - 90%
Reference 18 - 99/95%
Reference 19 - 80%
Reference 20 - 90% but less when considering short hauls, heavy weather, and poor supervision.

DB = Tanks ballasted prior to departure from unloading port, i.e., dirty ballast

= 25%

Derived from:

Reference 15 - 20%
Reference 18 - 33%
Reference 19 - Ranges between 20 and 33%

CDB = Clingage discharge when pumping dirty ballast

= 15%

Derived from:

Reference 15 - 15%
Reference 19 - 15%

$$\therefore \text{LOT (Crude)} = .8 \times 1460 \times 10^6 \times .004 \{.33\ (1-.9) + .25 \times .15\}$$

$$= \underline{329{,}376 \text{ barrels}}.$$

$$\text{LOT (Product)} = a \cdot \text{TPIP} \cdot \text{PC} \{\text{TC (1-ELOT)} + \text{DB} \cdot \text{CDB}\} \qquad (4)$$

where:

TPIP = as defined above

PC = Product clingage

= .1%

Derived from:

Reference 15 - 0.075%
Reference 19 - Ranges between .1 and 1.5%.

$$\therefore \text{LOT (Product)} = .8 \times 840 \times 10^6 \times .001 \{.33\ (1-.9) + .25 \times .15\}$$

$$= \underline{47{,}376 \text{ barrels}}$$

$$LOT = LOT\ (Crude) + LOT\ (Product)$$
$$= 329{,}376 + 47{,}376$$
$$= 376{,}752 \text{ barrels}$$

$$NLOT = NLOT\ (Crude) + NLOT\ (Product) \tag{5}$$

$$SBT = SBT\ (Crude) + SBT\ (Product) \tag{6}$$

$$NLOT\ (Crude) = b \cdot TPIC \cdot CC\ (TC + DB \cdot CDB) \tag{7}$$

$$SBT\ (Crude) = c \cdot TPIC \cdot CC \cdot SBC \cdot TC \cdot TRM\ (1\text{-}ELOT) \tag{8}$$

where:

b = Percentage of non-LOT tankers in U.S. import service

= 19%

c = Percentage of segregated ballast tankers in U.S. import service

= 1%

Derived from:

References used for derivation of a

Estimate of segregated ballast tankers based on approximately six of the estimated 600 tankers in the industry having segregated ballast

SBC = Segregated ballast clingage (as a percent of normal crude or product clingage)

= 75%

Derived from:

Assumption that fewer structural members in cargo tanks of segregated ballast tankers will result in slightly reduced clingage

TRM = Tanks cleaned for routine maintenance and sediment control (as a percentage of total tanks cleaned)

= 60%

Derived from:

Reference 15 - 50%

Reference 13 - 75%

This factor serves as an estimator of pollution from tank cleaning and ballasting requirements in a segregated ballast tanker.

$$\text{NLOT (Crude)} = .19 \times 1460 \times 10^6 \times .004\ (.33 + .25 \times .15)$$

$$= \underline{407{,}778 \text{ barrels}}$$

$$\text{SBT (Crude)} = .01 \times 1460 \times 10^6 \times .004 \times .75 \times .33 \times .6\ (1-.9)$$

$$= \underline{867 \text{ barrels}}.$$

$$\text{NLOT (Product)} = b \cdot TPIC \cdot PC\ (TC + DB \cdot CDB) \qquad (9)$$

$$\text{SBT (Product)} = c \cdot TPIP \cdot PC \cdot SBC \cdot TC \cdot TRM\ (1\text{-}ELOT) \qquad (10)$$

where:

$$\text{NLOT (Product)} = .19 \times 840 \times 10^6 \times .001\ (.33 + .25 \times .15)$$

$$= \underline{58{,}653 \text{ barrels}}$$

$$\text{SBT (Product)} = .01 \times 840 \times 10^6 \times .001 \times .75 \times .33 \times .6\ (1-.9)$$

$$= 125 \text{ barrels}$$

$$\text{NLOT} = \text{NLOT (Crude)} + \text{NLOT (Product)}$$

$$= 407{,}778 + 58{,}653$$

$$= \underline{466{,}431 \text{ barrels}}$$

$$\text{SBT} = \text{SBT (Crude)} + \text{SBT (Product)}$$

$$= 867 + 125$$

$$= \underline{992 \text{ barrels}}$$

The amount of operational discharge resulting from drydocking and shipyard entry (SE) is derived as follows:

$$SE = DDF \cdot NTT \cdot MDWT \cdot \left(CC \frac{TPIC}{TPI} + PC \frac{TPIP}{TPI} \right) \qquad (11)$$

where:

DDF = Frequency of shipyard entry (as a percentage of ships entering shipyard each year)

= 50%

<u>Derived from</u>:

Reference 15 - 50% (i.e., every two years)

Reference 20 - 50%

Reference 21 - 50%

Reference 13 - 67% (i.e., 18 months)

NTT = No. of tankers in U.S. import trade

= 556 computed as follows:

Source (FEA Data)	Percent of TPI	No. of Tanker Trips per Year
Persian Gulf	33	5
North/West Africa	30	12
Caribbean/S. America	25	26
Indonesia	12	5

Taking a weighted average, we compute a mean trip frequency of 12.35 trips per year.

There were 6,934 petroleum importing ship arrivals during 1975. This number is developed in Section II, Table 2.31.

$$\text{Total long tons imported} = \frac{\text{TPI}}{7.45}$$

$$= 308.73 \text{ million}$$

$$\text{Mean ship size} = \frac{308.73 \times 10^6}{6{,}934}$$

$$= 44{,}524 \text{ DWT.}$$

Rounding off, we get 45,000 DWT.

$$\text{NTT} = \frac{308.73 \times 10^6}{12.35 \times 4.5 \times 10^4}$$

$$= \frac{30{,}873}{55.6}$$

$$= 556.$$

MDWT = Mean DWT in petroleum import trade expressed in barrels

= <u>335,250 barrels</u>

<u>Derived above</u>.

All other quantities have been previously defined.

$$\text{SE} = .5 \times 556 \times 335{,}250 \left(.004 \frac{1460}{2300} + .001 \frac{840}{2300} \right)$$

$$= \underline{270{,}684 \text{ barrels}}$$

The amount of operational discharge resulting from bilge pumping and bunkering (BB) is derived as follows:

$$BB = NTT \cdot BD \tag{12}$$

where

BD = Bilge and bunkering discharge per ship

= 112 barrels

Derived from:

Reference 19 - 117 barrels; 93 bilges, 24 bunkering (assumes 330 days operation/year)

Reference 20 - 73 barrels.

We concur with the Reference 19 method, but estimate 350 days instead of 330 days of operation each year and have conservatively halved the Reference 19 estimate of bunkering spillage.

$BB = 556 \cdot 112$

= 62,272 barrels.

The spillage from terminal operations is computed as follows:

Deriving percentages of petroleum imports using various shipment strategies, we excerpt the following information from Section II, Table 2.31:

Strategy / Area	Imports (MMBD) 1975		
	Direct Shipment	Transshipment	Lightering
East Coast	2.7	.4	.1
Gulf Coast	.8	1.1	.4
West Coast	.7	-	.1
Totals	4.2	1.5	.6
%	67	24	9

Therefore, as previously defined:

$k = 67\%$
$l = 24\%$
$m = 9\%$
$n = 0\%$.

Then, for direct shipment spillage,

$$DS = k \cdot SA \cdot DST \cdot TOS \tag{13}$$

where:

SA = Ship arrivals

= 6,934

DST = Direct shipment transfer operations

= 2

In direct shipment, there is only the initial loading and final unloading operation to consider.

TOS = Transfer operation spill

= 4.35 barrels

Derived from:
Reference 19 - 5.8 barrels.

The analysis contained in Reference 19 is considered most appropriate for the purposes of this study, but the amount of spill (0.003 percent of total volume handled) is considered slightly high and the estimate has been reduced by 25 percent.

$DS = .67 \times 6{,}934 \times 2 \times 4.35$

$= 40{,}418$ barrels.

For transshipment spillage,

$$TS = l \cdot SA \cdot TST \cdot TOS \tag{14}$$

where:

TST = Transshipment transfer operations

= 4

In transshipment, there are initial loading, interim unloading and loading, and final unloading operations to consider.

TS = .24 x 6,934, x 4 x 4.35

= <u>28,956 barrels</u>.

For lightering spillage,

$$L = m \cdot SA \cdot LT \cdot TOS \tag{15}$$

where:

LT = Lightering transfer operations

= 3

In lightering, there are initial loading, underway transfer and final unloading operations to consider.

L = .09 x 6,934 x 3 x 4.35

= <u>8,144 barrels.</u>

For deepwater port spillage,

$$DWP = n \cdot SA \cdot DWPT \cdot TOS \tag{16}$$

where:

DWPT = Deepwater port transfer operations

= 2

In deepwater port shipment, there are initial loading, and final unloading operations to consider.

DWP = 0 in 1975 since there are no DWPs in operation.

By adding the arithmetic subtotals resulting from the computations shown under Equations (2), (5), (6), (11), (12), (13), (14), (15), and (16), we compute the final 1975 total result for Equation (1):

TOD = LOT (376,752) + NLOT (466,431) + SBT (992)
+ SE (270,684) + BB (62,272) + DS (40,418)
+ TS (28,956) + L (8,144) + DWP (0)

TOD (1975) = 1,254,649 barrels.

By applying identical procedures to the data from each of the seven scenarios discussed in this report, we calculate their respective TODs to be:

Status Quo 1975	= 1,254,649 barrels
Status Quo 1980	= 2,164,819 barrels
Retrofit 1980	= 2,191,045 barrels
Status Quo 1980 (with DWP)	= 2,067,420 barrels
Retrofit 1980 (with DWP)	= 2,011,122 barrels
Retrofit 1980 (comply)	= 2,070,191 barrels
Retrofit 1980 (DWP & comply)	= 1,888,150 barrels.

The input values for Equation (1) for each scenario are detailed in Table 3.1 for purposes of comparing the composite terms. All of the variable terms for Equations (2) through (16) for each scenario are itemized in Table 3.2, and the constant values are listed in Table 3.3.

During the preceding discussion of the derivation of values for each equation, the assumptions and data sources were cited for the 1975 calculations but remain valid for each of the 1980 scenarios as well. The development of the percentages of LOT, NLOT, and SBT ships for 1980 (terms a, b, and c), however, need further explanation. The 1975 mix of 80 percent, 19 percent, and 1 percent, respectively, has not been changed for 1980, except as affected by the addition of segregated ballast ships. We recognize two categories of additional SBT ships: those which are new vessels constructed to replace tankers being retired from service, and those which are retrofitted to meet scenario requirements. The former results in a reduction of older vessels, typically non-LOT, while the large capital investment of the latter tends to be in the newer vessels with a longer useful life, typically LOT ships. It was assumed that by 1980, 2 percent (as opposed to 1 percent in 1975) of the tanker fleet would be SBT replacements, therefore NLOT would be a constant 18 percent. The impact of the scenario differences on percent SBT of vessels in fleet was calculated from Tables 2.31 and 2.32 for the last three retrofit scenarios (ship calls by tankers 70,000 DWT and over divided by total calls) to be 11 percent, 16 percent, and 29 percent, respectively.

These values, when added to the 2 percent SBT "replacements," result in 13 percent, 18 percent, and 31 percent, and when subtracted from 80 percent LOT (which are non-segregated ballast) give 69 percent, 64 percent, and 51 percent, as shown in Table 3.2. Though LOT appears to decrease in these three scenarios, it is actually entirely attributable to this recategorization to SBT due to the retrofitting of segregated ballast tanks on LOT ships.

TABLE 3.1

CALCULATION OF TOTAL OPERATIONAL DISCHARGE (TOD)

Scenario	TOD =	LOT +	NLOT +	SBT +	SE +	BB +	DS +	TS +	L +	DWP
SQ 75	1,254,649	376,752	446,431	992	270,684	62,272	40,418	28,956	8,144	0
SQ 80	2,164,819	660,895	775,146	3,480	474,542	109,088	63,433	59,205	19,030	0
R 80	2,191,045	660,895	775,146	3,480	474,365	114,240	43,590	85,001	34,328	0
SQ 80 D	2,067,420	660,895	775,146	3,480	474,365	76,160	41,804	5,867	3,300	26,403
R 80 D	2,011,122	570,022	775,146	22,621	474,299	81,312	36,486	13,973	9,316	27,947
R 80 (C)	2,070,191	528,716	775,146	31,322	474,365	114,240	65,553	61,183	19,666	0
R 80 D(C)	1,888,150	421,320	775,146	53,944	474,299	81,312	44,373	6,228	3,503	28,025

TABLE 3.2

DATA INPUT FOR CALCULATION OF TOTAL OPERATIONAL DISCHARGE (TOD)
(Variable Values)

Term	SQ 75	SQ 80	R 80	SQ 80 DWP	R 80 DWP	R 80 (Comply)	R 80 DWP (Comply)
a = Percent of LOT type ships in service	80	80	80	80	69[1]	64[1]	51[1]
b = Percent of NLOT type ships in service	19	18	18	18	18[2]	18	18[2]
c = Percent of SBT type ships in service	1	2	2	2	13	18	31
k = Percent of total imports by DS	67	60	40	57	47	60	57
l = Percent of total imports by TS	24	28	39	4	9	28	4
m = Percent of total imports by L	9	12	21	3	8	12	3
n = Percent of total imports by DWP	0	0	0	36	36	0	36
TPIC = Total crude import (million barrels)	1,460	2,592	2,592	2,592	2,592	2,592	2,592
TPIP = Total product imports (million barrels)	840	1,350	1,350	1,350	1,350	1,350	1,350
NTT = Number of tankers in U.S. imports	556	974	1,020	680	726	1,020	726
MDWT = Mean DWT tanker in import trade (barrels)	335,250	327,800	312,900	496,350	439,550	312,900	439,550
SA = Number of ship arrivals	6,934	12,152	12,526	8,430	8,923	12,558	8,948

[1] Non-SBT LOT fleet reduced when LOT ships retrofit.

[2] Primary increase in SBT fleet is due to retrofitted LOT ships.

TABLE 3.3

DATA INPUT FOR CALCULATION OF TOTAL OPERATIONAL DISCHARGE (TOD)
(Constant Values)

Term		Value
CC	Crude oil clingage	.4%
TC	Percent tanks cleaned/ballasted per trip	33%
ELOT	Effectiveness of LOT procedures	90%
DB	Dirty ballast	25%
CDB	Clingage discharge when pumping DB	15%
PC	Product clingage	.1%
SBC	Segregated ballast clingage	75%
TRM	Tanks cleaned for routine maintenance	60%
DDF	Frequency of drydocking	50%
BD	Bilge and bunkering discharge (barrels)	112
DST	Direct shipment transfer operations	2
TOS	Transfer operation spills	5.8
TST	Transshipment transfer operations	4
LT	Lightering transfer operations	3
DWPT	Deepwater port transfer operations	2

Effect of the 1969 Amendments on Operational Discharges

The 1969 Amendments (Reference 25) specify for all tankers above 500 DWT that the discharge of cargo oil/oily mixture will be prohibited except under the following conditions:

- The tanker is proceeding en route
- The instantaneous rate of discharge of oil content does not exceed 60 liters per mile
- The total quantity of oil discharged on a ballast voyage does not exceed 1/15,000 of the total cargo-carrying capacity
- The tanker is more than 50 miles from the nearest land.

It further specifies that no discharge of bilge oil will be permitted except under these conditions:

- The ship is proceeding en route
- The instantaneous rate of discharge of oil content does not exceed 60 liters per mile
- The oil content of the discharge is less than 100 parts per 1,000,000 parts of the mixture
- The discharge is made as far as practicable from land.

To determine the maximum effect on operational discharges by meeting the provisions of the 1969 Amendments, we assumed no NLOT tankers would be operating. Since the capability to comply with the volume of discharge (1/15,000 of DWT) mandates the efficiency of a system such as LOT, 100 percent compliance means that all ships will practice LOT, including segregated ballast ships.

The Amendments define oil as "crude oil, fuel oil, heavy diesel oil, and lubricating oil," i.e., black oil not products. Therefore, the volume limitation applies only to the crude imports (TPIC) portion of the TOD equation. The Amendments are specifically directed toward reducing the quantity of operational discharges on the ballast voyage, not the transfer operation spills or the bilge and bunkering discharges. Therefore, summarized in Table 3.4 are the totals of tank cleaning, dirty ballast, and shipyard entry discharges for each 1980 scenario (LOT, NLOT, SBT, and SE) calculated by Equations (3), (4), (7), (8), (9), (10), and (11), and compared with the maximum allowable under the 1969 Amendments (TPIC ÷ 15,000).

Accidental Discharges

Accidental oil discharges can occur from a variety of ship casualties ranging from a cracked plate to a catastrophic collision. Tanker casualty data is published by Lloyds of London and ship casualty and pollution files are available at Coast Guard headquarters. References 15, 22, and 23 give estimates of accidental outflows for the world's tanker fleet as a function of

TABLE 3.4

EFFECT OF 1969 AMENDMENT ON OPERATIONAL DISCHARGES
(Barrels Per Year)

	Without 1969 Amendment		With 1969 Amendment	Discharge Reduction
Scenario	Crude	Product	Crude	Crude
SQ 80	1,693,548	220,515	97,333	1,596,215
R 80	1,693,392	220,494	97,333	1,596,059
SQ 80 (DWP)	1,693,392	220,494	97,333	1,596,059
R 80 (DWP)	1,629,865	202,223	97,333	1,532,532
R 80 (Comply)	1,601,076	208,473	97,333	1,503,743
R 80 (DWP & Comply)	1,526,009	198,700	97,333	1,428,676

casualty type. This information is shown in Table 3.5. Structural failures and groundings contribute to more than half of the total coutlow. Outflow estimates from three different references are shown in the table. The annual accidental outflow volume appears to be relatively steady over the 5-year period from 1969 to 1974, at about 200,000 long tons per year. The active tanker fleet size has also been relatively steady. In 1970 there were 3,391 tankers in the world fleet larger than 10,000 DWT. In 1975 there were 3,659, but about 500 of these were laid up; thus, the active fleet in 1975 numbered about 3,159 vessels. So, for a period of 5 years, both the tanker fleet size and the volume of accidental outflow have remained about the same.

Casualty Statistics. Tanker casualty statistics are displayed in Reference 23. During this 5-year time period (1969 to 1973), there were 422 polluting incidents from tankers greater than 10,000 DWT. These incidents resulted in a total outflow of 951,317 LT. Averaging these two figures on a yearly basis, gives us 84.4 incidents and 190,263 LT per year.

According to Reference 15, the total world oil movement in 1975 was $1{,}507.6 \times 10^6$ tons and the total tanker capacity was 291.4×10^6 DWT. Assuming 500 ships laid up in 1975 with an average size of 90 MDWT, yields an inactive deadeweight of 45×10^6 DWT and an active capacity of 246.4×10^6 DWT. Reducing this figure by 5 percent to obtain cargo deadweight, gives a total fleet cargo capacity of about 235×10^6 CDWT.

The average number of trips per year for the world fleet in 1975 is then:

TABLE 3.5

ESTIMATES OF ANNUAL OIL POLLUTION BY TANKER CASUALTIES

Source / Type of Casualty \ Units of Volume	Reference 15 Metric Ton/Annum (1969-1973)	Reference 22 Long Ton Per 2 Years (1969-1970)	Reference 23 Long Ton Per 5 Years (1969-1973)
Structural Failure	70,000	212,367	339,181
Grounding	50,000	124,022	230,806
Collision	40,000	34,271	185,088
Explosion	20,000	34,046	94,803
Other	10,000	638	54,911
Breakdowns	6,000	16,400	29,940
Rammings	3,000	4,657	13,645
Fires	1,000	4,319	2,935
Total	200,000	430,720	951,317

$$\text{Number trips per year} = \frac{1,507.6}{235}$$

$$= 6.42.$$

Assuming that the number of polluting incidents each year is related to the size of the active tanker fleet, we can obtain the number of polluting incidents for 1975 by:

$$\text{Polluting incidents in 1975} = 84.4 \; \frac{3,159}{3,391}$$

$$= 78.$$

If the total active tanker fleet in 1975 numbers 3,159 ships, then the total number of calls is:

$$\text{Total tanker calls} = 6.42 \times 3,159$$

$$= 20,281.$$

The number of polluting incidents per call would then be:

$$\text{Incidents per call} = \frac{78}{20,281}$$

$$= .0038.$$

Derivation of Accidental Discharges. Referring back to the casualty data in References 23 and 24, we can derive the volume of outflow per polluting incident as a function of vessel size. Table 3.6 displays this data. The data was assembled from 1969-1973 casualty records. Lacking any more recent information and based on the steady levels in fleet size and outflow volumes over the 1969-1973 time period, we shall assume that the casualty data of Reference 23 is applicable to 1975.

The total volume spilled during the 5-year sample for the 90,000 to 149,999 DWT range was 150,922 LT. However, a single accident contributed 120,300 LT or 80 percent of the total volume. Since this single casualty badly biased the data, it was deleted from the parameters displayed in Table 3.6, for the average 120 MDWT tanker.

The data in Table 3.6 indicates that the tankers with the highest potential for large outflows are the average size 40 MDWT, 120 MDWT, and 250 MDWT tankers. The 40s are used mainly in direct shipment of products, as transshipping feeder vessels, and as lightering vessels; and as a result, they make many trips over short distances in coastal waters. They also represent some of the oldest vessels in the fleet.

TABLE 3.6

VESSEL SIZE vs OUTFLOW

DWT Range	No. of Incidents	Outflow LT	Outflow/Incident	Average Tanker Represented	Incidents/Calls	Outflow/Call
10,000-29,999	260	388,394	2,039	40 MDWT	.0038	7.7
30,000-49,999	83	310,852				
50,000-69,999	37	37,037	1,001	65 MDWT	.0038	3.8
70,000-89,999	27	26,733	990	80 MDWT	.0038	3.8
90,000-149,999	20	30,622	1,531	120 MDWT	.0038	5.8
150,000-up	25	37,851	1,514	250 MDWT	.0038	5.8

Many of the 120s are used in inshore lightering operations where they are also exposed to confined waters and congestion. This is a bad combination for ships of this size and may explain the relatively large outflow ratio for the 120s. The 80s and VLCCs have the best record.

The information in Table 3.6 can now be applied to the scenarios displayed in Section II and displayed in Table 2.31. The last column of Table 3.6 lists the outflow per call and Table 2.31 gives the calls as a function of ship size for the seven scenarios. Therefore, accidental outflows for each scenario can be established. This data is developed in Table 3.7.

Table 3.7 shows the accidental discharges for the tanker fleet importing oil into the United States. It does not include those VLCCs on the primary leg of a transshipment or lightering operation, but it does include those transshipping and lightering vessels on the secondary leg.

The 1975 status quo accidental discharge rate is 68,445 LT or 33 percent of the world total of 209,890 LT. This seems rather high considering that the United States only imports 20 percent of the world's total oil exports. One possible explanation of this might be that U.S. pollution and casualty data in and around U.S. waters is more complete than the average world data, so, in fact, the world total contains a higher proportion of U.S.-involved incidents just due to better recordkeeping.

The scenario discharge figures are probably best used on a comparative basis. Note the expected increase in accidental discharge by 1980 of 94 percent. This is due mainly to a dramatic increase in import volume with a similar increase in the number of ship calls. Increases are strictly linear and do not include the effects of future Coast Guard actions in regulatory areas, traffic control, design, etc. A requirement to retrofit in 1980 will actually increase the accidental discharge volume by 4 percent due to the increases in number of tankers in the 65 MDWT range.

The addition of deepwater ports in the two scenarios in Table 3.7 indicates a reduction in accidental discharge rate by bringing larger vessels into the fleet and reducing the number of smaller ships in the 40 MDWT range. The reduction in the two 1980 status quo scenarios due to DWP in approximately 35 percent. A similar reduction is evident between the two 1980 retrofit scenarios which is 32 percent due to DWP.

Transportation Modes. Transportation modes have not been considered except as the mode effects the numbers and sizes of vessels in the system. Consideration of the lightering operation vs the transshipment operation would indicate that lightering is the more accident prone operation just because at-sea mooring and transfer implies greater hazard than transfer at a dock or terminal. At the present time there are no statistics to prove this since no spills have been recorded in the lightering operation.

Segregated ballast tankers represent less than 1 percent of the fleet and no casualty statistics are available on these ships. If the segregated

TABLE 3.7

ACCIDENTAL DISCHARGES vs SCENARIOS

Tanker Size MDWT	Outflow / Call	1975 Status Quo Calls	Accidental Discharge LT	1980 Status Quo Calls	Accidental Discharge LT	1980 Retrofit Calls	Accidental Discharge LT	1980 Status Quo + DWP Calls	Accidental Discharge LT	1980 Retrofit + DWP Calls	Accidental Discharge LT	1980 Retrofit + Comply Calls	Accidental Discharge LT	1980 Retrofit + DWP + Comply Calls	Accidental Discharge LT
40	7.7	5,744	44,229	10,456	80,511	10,456	80,511	6,283	48,379	6,283	48,379	10,456	80,511	6,283	48,379
65	3.8	77	293	77	293	2,070	7,866	77	293	1,624	6,171	77	293	77	293
80	3.8	1,113	4,229	1,619	6,152	–	–	1,257	4,777	–	–	2,025	7,695	1,572	5,974
120	5.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
250	5.8	–	–	–	–	–	–	813	4,715	1,016	5,843	–	–	1,016	5,893
		6,934	48,751	12,152	86,956	12,526	88,377	8,430	58,164	8,923	60,443	12,558	88,499	8,948	60,539

ballast tanks are wing tanks which protect a percentage of the bilge and side areas from spills due to groundings and collisions, these vessels may have better accidental discharge records than vessels not so equipped. However industry sources have commented that if retrofit is required, they will elect to modify existing tanks so that the SBT tanks are on the centerline for reasons of economics and trim control. If this procedure is followed, there will be no benefit from SBT as far as accidental discharge is concerned.

Discharge Summary

Both operational and accidental discharges are summarized in Table 3.8 for the seven transport scenarios. Analyzing the figures in Table 3.8, it is evident that there will be a 74 percent increase in total discharges by 1980 just due to the increases in import volume and numbers of ships. If retrofit is required by 1980, the increase in total discharge will be 76 percent, or a 2 percent increase just due to SBT.. The addition of DWP to the 1980 scenarios is the most effective way to reduce total discharge. The reduction in the number of ships and the increases in ship size results in a reduction of 11 percent, when comparing the 1980 status quo scenarios and a reduction of 14 percent when comparing the 1980 retrofit scenarios.

Location and Volume of Discharges

Due primarily to the fact that direct shipment, lightering and transshipment are currently being employed in the same locations as expected for 1980, it is not projected that the location of either operational or accidental discharges will change. The effect, however, will be to the volume discharged, attributable mainly to the substantial increase in imports and the number of ships.

Displayed on the charts of the Atlantic Ocean in Figures 3.1 and 3.2 are the calculated volumes of discharge in barrels per day for each of the trade routes for 1975 and 1980 (status quo). Since accidental discharges are confined almost exclusively to the congested coastal waters, harbors, and their entrances, their volumes of 995 and 2,692 barrels per day are not plotted on such small-scale charts. (Ten major structural failures skewed the 1969-1970 data for spills at sea. Excluding these, only 15 percent of the accidental discharge volume occurred outside coastal waters (22.)

The locations of the operational spills in Figures 3.1 and 3.2 are approximate, but do consider the nearness of land and the distance covered while cleaning tanks before decanting slops. The tankers leaving the lower East Coast and Gulf for West Africa and the Persian Gulf are generally well clear of the Lesser Antilles before begining discharging. The other trans-Atlantic tankers generally wait one to five days before beginning their cleaning and discharging operations. Those tankers steaming for the Caribbean from Delware Bay area usually begin discharging around the Sargasso Sea and south of Bermuda.

The operational discharge volumes, in barrels per day, shown in Figures 3.1 and 3.2 were calculated by multiplying the volume imported along

TABLE 3.8

SUMMARY OF ENVIRONMENTAL DISCHARGES

	Barrels Per Year		
	Operational	Accidental	Total
Status Quo 1975	1,254,649	363,195	1,617,844
Status Quo 1980	2,164,819	647,822	2,812,641
Retrofit 1980	2,191,045	658,409	2,849,454
Status Quo 1980 + DWP	2,067,420	433,322	2,500,742
Retrofit 1980 + DWP	2,011,122	450,300	2,461,422
Retrofit 1980 + Comply	2,070,191	659,318	2,727,509
Retrofit 1980 + DWP + Comply	1,888,150	451,016	2,339,166

FIGURE 3.1. 1975 OPERATIONAL DISCHARGE
(Barrels Per Day)

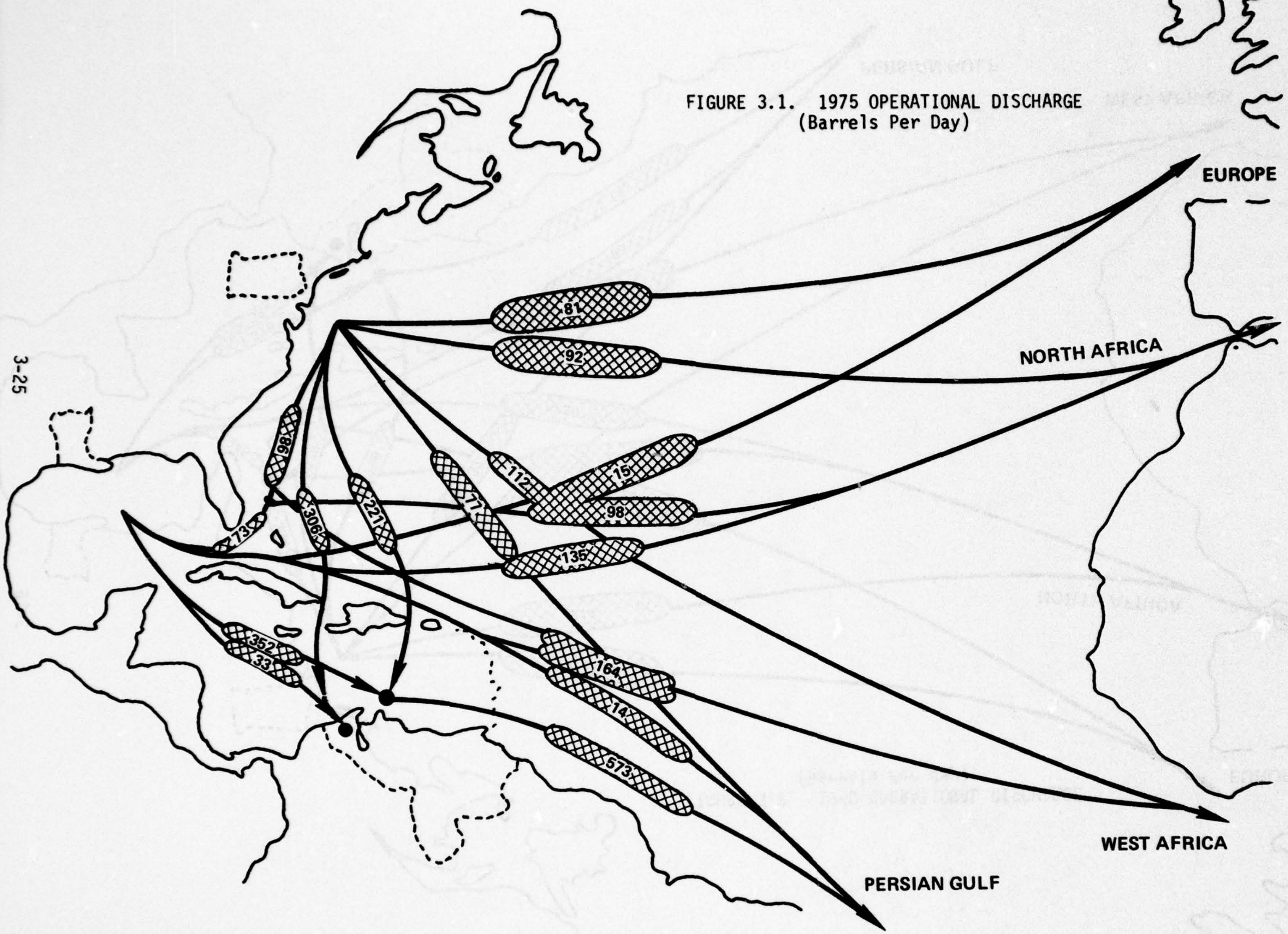
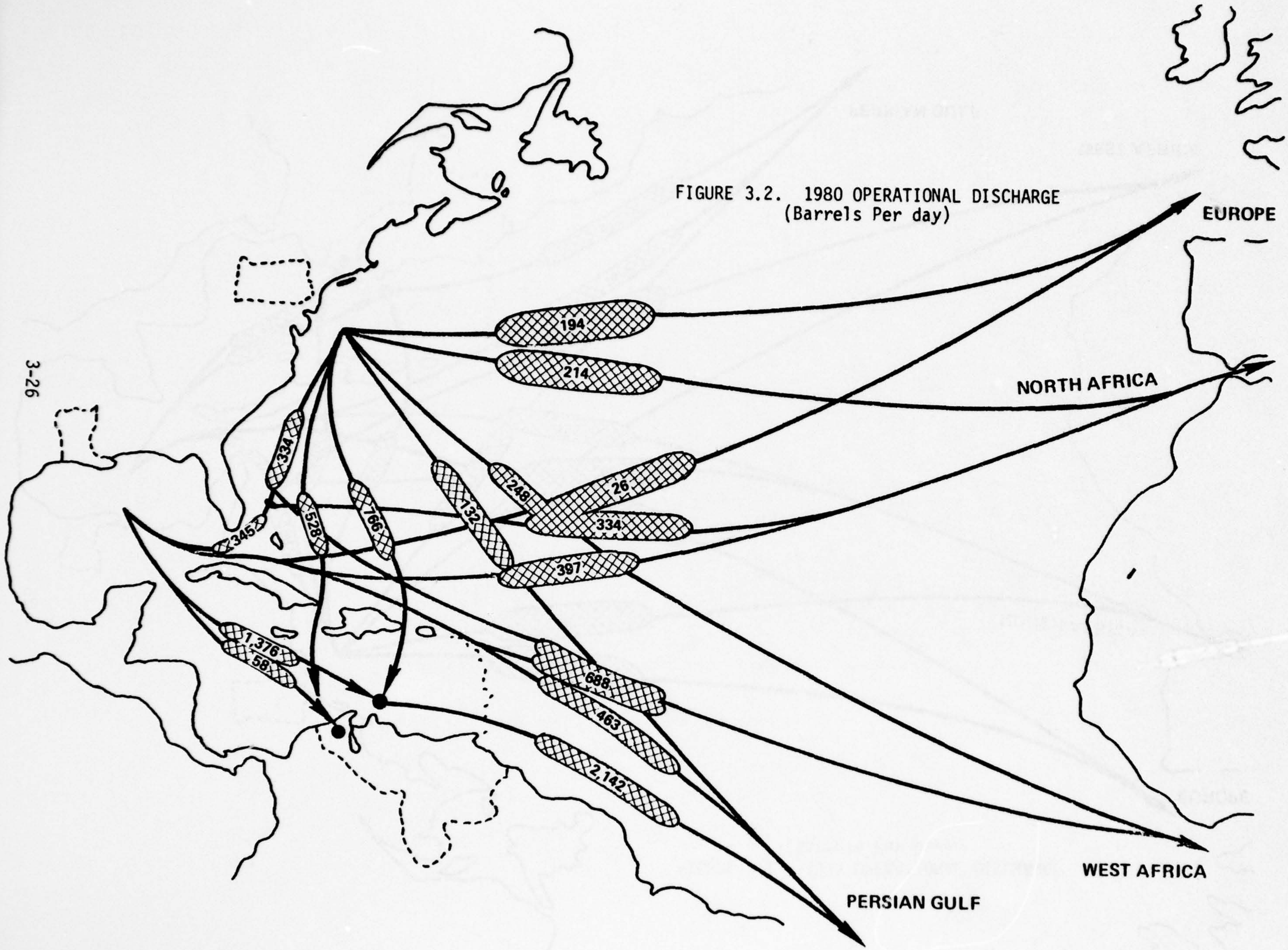


FIGURE 3.2. 1980 OPERATIONAL DISCHARGE
(Barrels Per day)



each route by the spill rate for the respective year, expressed in barrels spilled per million barrels imported. Each spill rate was determined by dividing the TOD by the TPI from Table 3.2 for each year, resulting in 318 and 549 barrels spilled per million barrels imported for 1975 and 1980, respectively.

IV. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

TRANSPORT MODES AND COSTS

The primary purpose of this study was to investigate the alternate transportation modes suggested by industry for circumventing the Coast Guard's proposed SBT ruling. In essence, industry has indicated that rather than pay the costs of retrofit and suffer the resulting cargo penalty, they would re-route those vessels subject to SBT from direct service into U.S. ports and re-route that import volume through transshipping terminals and offshore lightering operations.

An analysis of the 1975 U.S. transportation system indicates that only about 16 percent of the ships were greater than 70 MDWT and subject to the SBT ruling. Transshipping already accounts for a large portion of the oil imported to U.S. ports and offshore lightering is a relatively new operation that is increasing rapidly in popularity as experience is gained in underway mooring and transfer.

The costs (freight rates) of the various transport modes tend to regulate the thruput. Lightering has the lowest freight rate by a substantial margin over its closest current competitor. The DWP operation appears to offer costs that are competitive with lightering, but no DWP will be operational for several years and during those years it is possible that lightering will become a major transport mode, and industry interest and backing of DWPs will decline except in those areas where port congestion is a factor.

Transshipping is one of the most expensive transport modes due to terminal costs and several terminals are presently inactive. Direct shipment costs vary as a function of ship size. The smaller ships (usually less than 80 MDWT) operate in the direct shipment modes due to draft restrictions in U.S. ports. In some cases, on the shorter trade routes, direct shipment is less costly than transshipping.

Conclusions

If the proposed SBT regulations were to be imposed in the next year or two, the following would probably take place:

- Industry would reroute the 16 percent of the fleet affected through transshipping and lightering operations.

- Very few, if any, vessels would be retrofitted - the exceptions may be found in some vessels in the TAPS trade and a few dedicated lightering vessels.

- The scope of lightering operations would increase more rapidly than normal.

- The number of ships calling at U.S. ports would increase by about 4 percent.

- If SBT were required on the VLCCs calling at DWPs, VLCC costs would increase by 15 percent, which would make DWPs less attractive on a cost basis when compared with lightering.

SBT will have very little effect on either the 1975 or 1980 U.S. oil import transportation system. The main force that drives the system is oil demand. By 1980, oil imports will increase by 89 percent, creating very real problems in relation to terminal facilities in port congestion. The number of port calls along the Gulf Coast will increase by 150 percent if no deepwater ports are available. If DWPs are operational by 1980, ship calls in 1980 will remain essentially unchanged from 1975 and port congestion in the Gulf will be a continuing problem.

Recommendations

The following items represent both present and future problem areas. Further study is recommended to offset potentially hazardous polluting situations:

- An expected increase in U.S. port calls of 89 percent by 1980 has the potential for major increases in casualties and accidental spills, and requires a new look at methods of traffic control and ways of reducing in-port turnaround time.

- DWPs should be reevaluated on their potential for reducing port congestion, accident rates and accidental spills.

- It is anticipated that offshore lightering will become a major operation in the next year or two and lightering in the North Atlantic appears to be feasible. Studies should be started immediately to investigate the safety aspects of underway mooring and oil transfer to include a marine engineering analysis of the present mooring operation, relative motion between ships, ship's speed, headings, transfer equipment, safety rules and regulations, etc. The industry has taken the initiative and prepared lightering operations manuals and conducted both small-scale and full-scale lightering tests. Their spill record thus far has been outstanding, but as the operation expands and more ships and operators are involved, there is the need for an exhaustive study to supplement the work done by industry and to ensure that lightering remains a safe and cost-effective operation for the benefit of the U.S. consumer.

- A more exhaustive study of the 1980 U.S. oil import system should be made to verify the results of this 2-month study and to lay out the transportation systems and port receiving systems in greater detail. There is a possibility of a breakdown between the two in the future, and a thorough study will highlight problem areas, hopefully, in time for corrective action to be taken.

OIL DISCHARGED TO THE ENVIRONMENT

The proposed SBT regulation will have very little effect on operational oil discharges because retrofit will not be accomplished by industry and those ships visiting U.S. ports will be less than 70 MDWT. These smaller ships will deliver the same total volume of oil and operationally discharge the same amount of oil.

Assuming that SBTs are required in 1980, there will be only a 1 percent reduction in operational discharges while accidental discharges will increase by 4 percent due to increased calls and a different ship mix. The addition of DWPs in 1980 has little effect on operational discharges; however, it has a significant affect on accidental discharges, reducing the discharge volume from this cause by 32 percent due to decreases in port calls and a different mix of ships.

Conclusions

- SBT will not reduce either operational or accidental discharges.

- The volume of operational discharges is over twice the volume of accidental discharge, except in the two DWP scenarios where it is about three times greater.

- Accidental discharges may increase dramatically by 1980 due to the 89 percent increase in port calls and the resulting increased traffic density and congestion.

Recommendations

- Study the feasibility of industry-offered alternatives to SBT - crude washing and supervised LOT.
- Investigate the effectiveness of shore-based dirty ballast facilities.
- Investigate casualty and pollution incident data to determine if there are any relationships between transport mode (direct, transshipment, lightering) and spill volume and frequency.

APPENDIX A

DETAILS CONCERNING OIL IMPORTS AND SHIP MIXES

INTRODUCTION

This appendix is concerned with three items, i.e.,

- Details of the Census data,
- Details of the engineers data, and
- Detailed computations of the distributions of total imports across origin, ship size, and unloading port.

These discussions supplement the material contained in Section II, on oil imports and ship mixes.

BUREAU OF CENSUS DATA

The latest year for which this material was available was 1975. For this year the information was in the form of computer printout with column headings as shown in Table A.1.

Several comments are necessary concerning the printout. First, it is obviously complete, since every entering ship must supply the required information. Second, it is programmed serially, first by customs, district, then by the engineer channel in the district where the dock is located, and finally within channels by draft of ship. Third, "bulk cargo" is not divided into crude petroleum, petroleum products, iron ore, molasses, etc.

Since the printout was approximately 18 inches high containing thousands of items, it was decided to copy[1] only vessel entrances which met all of the following requirements:[2]

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[1] A separate computer run of the required information was not obtainable in the time available.

[2] See Table A.1.

TABLE A.1.

ORGANIZATION OF DATA IN ENGINEERS ANNUALS

<u>Type Service</u>

1. Linear or berth
4. Tanker
5. Irregular or tramp

<u>Rig</u>

1. Motor dry cargo, steam dry cargo
2. Motor tanker, steam tanker
3. Tug
4. Barge (other than tanker), scow
5. Tanker barge
6. Other, including yacht, gas, sloop, schooner, sailboat, houseboat, rowboat, research vessel

<u>Ballast or Cargo</u>

1. Vessel entered direct from foreign ports in ballast
2. Vessel entered direct from foreign ports with bulk cargo
3. Vessel entered direct from foreign ports with general cargo
4. Vessel entered via other domestic ports in ballast
5. Vessel entered via other domestic ports with bulk cargo
6. Vessel entered via other domestic ports with general cargo

<u>Country and Subdivision or U.S. Port</u>

Individuals first foreign country entering direct from (origin of inbound voyage) in terms of Schedule C code. Where "country from" has marked coastal differences a further distinguishing sub-country code is added-otherwise sub-country code is always "0". If entering via domestic ports, indicates last U.S. port vessel cleared in terms of Schedule D' code.

<u>Type Vessel</u>

0. Vessels from other domestic ports, Navy operated vessels, vessels in for repairs or crew changes, and all other types excluded by reason of FT 975 coverage

1. All vessels except tanker entered direct from foreign ports
2. Tankers entered direct from foreign ports

<u>Type Cargo</u>

0. All vessels coded "0" under type vessel
1. Bulk or general cargo
3. Ballast

<u>Trip</u>

0. No. foreign cargo discharges at this port
1. Foreign cargo discharged at this port
9. Vessels under 26 net registered tons

- Was in one of three customs districts

  --New York
  --Philadelphia
  --New Orleans

- Rig 2, i.e., motor or steam tanker
- Ballast on cargo 2, i.e., vessel entered directly from foreign port with bulk cargo
- Trip 1, i.e., foreign cargo discharged at this port.

For each vessel entrance meeting these requirements, two items were copied, i.e., net registered tonnage and country of origin. Subdivisions of the country of origin were:

- Caribbean

  All Caribbean islands plus Mexico, but not Venezuela or the Bahamas

- Bahamas

  No sub-origins

- Venezuela

  Includes small numbers from Columbia, Peru, Brazil and Argentina

- Europe

  Italy and U.S.S.R. dominate slightly, but also includes some from Sweden, Denmark, Portugal, Netherlands, Belgium, Spain, Romania, Turkey, France and Gibralter

- North Africa

  Almost all Algeria, some Libya and Tunisia

- West Africa

  Almost all Nigeria; small number from Spanish Sahara, Angola, Liberia, S. Africa, and Mozambique (assume this comes around the Cape of Good Hope)

- Persian Gulf

  Major origins are Kuwait, Bahrain, Saudi Arabia and Iran; minor origins are Yeman and Oman

- Miscellaneous

  Canada, Indonesia, Philippines, Maylasia, etc.

The New York customs district includes not only the immediate New York and New Jersey docks, but also docks up the Hudson to Albany. Philadelphia includes all Delaware River docks from Trenton to the sea. New Orleans includes from the Gulf entrances up the Mississippi to river ports such as Memphis, Vicksburg, etc., and other nearby areas such as Morgan City, La.

Note the assumption that all "bulk cargo" is crude petroleum or products. Intuitively this was felt to be justified, but the magnitude of the error was not investigated.

CORPS OF ENGINEERS DATA

There appeared to be considerable difference in the areas and supplementary ports included in customs districts and engineer districts. This was particularly true of New Orleans. Also, the Engineer's data does not indicate vessel type so considerable barge traffic may be included. Finally, there is the ambiguity with the term "bulk cargo" as used by Census, whereas the Engineer data segregates petroleum and petroleum products from other bulk cargo. For these reasons, there is a discrepancy between the New York and Delaware Bay values from the two sources.[3] The means used to reconcile this discrepancy was explained in Section II when total imports were discussed.

The commodity classifications used in the Engineer data are listed in Table A.2.

Considerable changing of units is needed in using the two data sources. All data was translated to millions of barrels per day. Thus, in using Table 2.5 note that:

$$10^6\left(\frac{\text{bbl}}{\text{day}}\right) = \left[\frac{\text{NRT}(10^3)}{\text{year}}\right]\left(\frac{1}{10^3}\right)\left(\frac{1}{0.4}\right)\left(7.3\ \frac{\text{bbl}}{\text{ton}}\right)\left(\frac{1}{365\ \frac{\text{days}}{\text{year}}}\right)$$

$$=\left(\frac{1}{20{,}000}\right)\left[\frac{\text{NRT}(10^3)}{\text{year}}\right]$$

and, when using Tables 2.7 and 2.8,

---

[3] New Orleans values were not obtained for the Engineer data.

TABLE A.2
COMMODITY CLASSIFICATION AS USED BY U.S. ARMY
CORPS OF ENGINEERS

Code No.	Item Name
	Group 13 - Crude Petroleum
1311	Crude Petroleum
	Group 29 - Petroleum Products
2911	Gasoline, including natural gasoline
2912	Jet fuel
2913	Kerosene
2914	Distillate fuel oil
2915	Residual fuel oil
2916	Lubricating oils and greases
2917	Naptha, mineral spirits, solvents, not elsewhere classified (nec)
2918	Asphalt, tar and pitches
2921	Liquified petroleum gases, coal gases, natural gas, and natural gas liquids
2991	Petroleum and coal products, not elsewhere classified

AD-A034 840 OPERATIONS RESEARCH INC SILVER SPRING MD F/G 13/2
IMPLICATIONS OF THE U. S. COAST GUARD SEGREGATED BALLAST RETROF--ETC(U)
OCT 76 R DAYTON, P DANIELS, L STOEHR N00014-76-C-0918
UNCLASSIFIED ORI-TR-1096 USCG-M-06-77 NL

2 OF 2
AD-A
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END
DATE
FILMED
3-7-77
NTIS

$$10^6 \left(\frac{bbl}{day}\right) = \left[\frac{\text{Short Tons } (10^3)}{\text{year}}\right]\left(\frac{1}{10^3}\right)\left(\frac{2{,}240}{2{,}000}\right)\left(7.3\ \frac{bbl}{ton}\right)\left(\frac{1}{365\ \frac{days}{year}}\right)$$

$$= 2.24 \times 10^{-5} \left[\frac{\text{Short Tons } (10^3)}{\text{year}}\right]$$

DISTRIBUTION COMPUTATIONS

The data available on the distribution of origin, destination, and ship size is given in Table A.3. No distributions are available for the Atlantic, excluding New York and Philadelphia, or the Gulf Coast excluding New Orleans.

TABLE A.3

AVAILABLE DISTRIBUTION DATA

District No.	Port	See Table, Section II
A	New Orleans	2.4
B	New York	2.2
C	Philadelphia	2.3

The problem then was to extend the percentages of tankers of varying sizes from varying origins as given in distributions A, B and C, to the entire Atlantic and Gulf Coast ports. After this was done, those extended percentages could be applied to the total imports into the Atlantic and Gulf Coast.

Using the values in Tables 2.2, 2.3, and 2.4 of Section II, two computations were made for each origin and unloading port combination:

- The fraction of unloading ships of more than and less than 30,000 net registered tons
- The fraction of the tonnage of petroleum carried by ships of more than and less than 30,000 net registered tons.

The resulting values are shown in Table A.4.

Note that 30,000 net registered tons equals 75,000 deadweight tons. This is slightly greater than the 70,000 DWT in the proposed rule. Hence, the Table C.4 values for the "greater than" lines are a slight inestimation for amounts greater than 70,000 DWT (28,000 NRT). This arose because of the manner in which the data was collected.

TABLE A.4

FRACTION OF TANKERS LESS THAN AND GREATER THAN 30,000 NET REGISTERED TONS AND FRACTION OF TONNAGE CARRIED BY THESE TANKERS DISTRIBUTED BY ORIGIN AND UNLOADING PORT

				1	2	3	4	5	6	7	8	-
Distribution	Port	Item	Weight	Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Misc.	All Origins
A	New Orleans	No. of Ships	Less Than	.956	.966	.997	1.000	.905	.985	.909	1.000	.957
			Greater Than	.044	.034	.023	0	.095	.015	.091	0	.043
		Tonnage	Less Than	.915	.936	.936	1.000	.844	.976	.838	1.000	.914
			Greater Than	.085	.064	.064	0	.156	.024	.162	0	.086
B	New York	No. of Ships	Less Than	.970	.990	.953	1.000	.936	.946	.853	.976	.963
			Greater Than	.030	.010	.047	0	.064	.054	.147	.024	.037
		Tonnage	Less Than	.937	.979	.910	1.000	.870	.886	.769	.928	.919
			Greater Than	.063	.021	.090	0	.130	.114	.231	.072	.081
C	Philadelphia	No. of Ships	Less Than	.909	.898	1.000	.982	.615	.516	.575	.761	.777
			Greater Than	.091	.102	0	.018	.385	.484	.425	.239	.223
		Tonnage	Less Than	.827	.812	1.000	.952	.484	.383	.455	.616	.628
			Greater Than	.173	.188	0	.048	.516	.617	.545	.384	.372

Distribution A in Table A.4 was applied directly to the Gulf Coast ports. Distributions B and C were combined to get an Atlantic Coast distribution (Distribution D).

As an example of the method used to define distribution D, consider the ship fraction (the analysis applied equally well to the tonnage fraction). For each origin, let

$S_{cn} \rightarrow$ number of tankers having size < 30,000 NRT unloading at New York

$S_{cp} \rightarrow$ number of tankers having size < 30,000 NRT unloading at Philadelphia

$S_{tn} \rightarrow$ total number of tankers unloading at New York

$S_{tp} \rightarrow$ total number of tankers unloading at Philadelphia

$S_o \rightarrow S_{tn} + S_{tp}$.

The desired distribution D fraction is:

$$\frac{S_{cn} + S_{cp}}{S_{tn} + S_{tp}} = \frac{S_{cn} + S_{cp}}{S_o}$$

$$= \frac{S_{cn}}{S_o} + \frac{S_{cp}}{S_o}$$

$$= \frac{S_{cn}}{S_{tn}} \cdot \frac{S_{tn}}{S_o} + \frac{S_{cp}}{S_{tr}} \cdot \frac{S_{tp}}{S_o} .$$

The fractions $\frac{S_{cn}}{S_{tn}}$ and $\frac{S_{cp}}{S_{tp}}$ are given in Table A.4 in the rows labeled New York, No. of Ships, Less Than, and Philadelphia, No. of Ships, Less Than, respectively. Values of $\frac{S_{tn}}{S_o}$ and $\frac{S_{tp}}{S_o}$ were obtained from the number of ships listed in Tables 2.2 and 2.3 of Section II .[4]

The results of these computations are shown in Table A.5.

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[4] Taking the Caribbean as an example, $S_{tn} = 226$; $S_{tp} = 187$ (see Table 2.6) $S_o = 226 + 187 = 413$; $\frac{S_{tn}}{S_o} = \frac{226}{413} = 0.547$; and $\frac{S_{tp}}{S_o} = \frac{187}{413} = 0.453$.

TABLE A.5

FRACTION OF TANKERS LESS THAN AND GREATER THAN 30,000 NET REGISTERED TONS AND FRACTION OF TONNAGE CARRIED BY THESE TANKERS (ATLANTIC COAST PORTS)

		1	2	3	4	5	6	7	8	-
Item		Caribbean	Bahamas	Venezuela	Europe	North Africa	West Africa	Persian Gulf	Misc.	All Origins
No. of Ships	Less Than	.942	.963	.969	.994	.704	.636	.658	.903	.876
	Greater Than	.058	.037	.031	.006	.296	.364	.342	.097	.124
Tonnage	Less Than	.880	.926	.938	.983	.560	.469	.532	.762	.757
	Greater Than	.120	.074	.062	.017	.440	.531	.486	.283	.243

Before distributions A (Gulf Coast) and D (Atlantic Coast) could be applied to the total tonnages of imported petroleum shown in Table 2.11 it was necessary to distribute these total tonnage among origins. This distribution was done in proportion to the ratio of origin tonnage to the total tonnage.

Consider the Gulf Coast case. The total imports are 2.07×10^6 bbl/day. The Distribution A tonnage ratio for all origins is 0.914 (line 3, Table A.4). That is, for all Gulf Coast ports, 91.4% of the petroleum tonnage arrives in tankers having NRT < 30,000.

Let $t_i \rightarrow$ tonnage from origin i in ships NRT < 30,000, and $T_i \rightarrow$ tonnage from origins i in all ships.

$$\text{Then, } \frac{t_1 + t_2 + t_3 \ldots + t_8}{T_1 + T_2 + T_3 \ldots + T_8} = 0.914$$

Note that the t and T values in this equation are New Orleans values, not the total Gulf Coast values. Ratios using these are assumed to apply to the total values also. Then,

$$\frac{t_1 + t_2 + \ldots t_8}{\Sigma T_i} = 0.914$$

$$\frac{t_1}{\Sigma T_i} + \frac{t_2}{\Sigma T_i} + \ldots + \frac{t_8}{\Sigma T_i} = 0.914$$

$$\frac{t_1}{T_1} \cdot \frac{T_1}{\Sigma T_i} + \frac{t_2}{T_2} \cdot \frac{t_2}{\Sigma T_2} + \ldots + \frac{t_8}{T_8} \cdot \frac{T_8}{\Sigma T_8} = 0.914$$

$$R_1 \frac{T_1}{\Sigma T_i} + R_2 \frac{T_2}{\Sigma T_2} + \ldots + R_8 \frac{T_8}{\Sigma T_8} = 0.914 \qquad \text{(A)}$$

The R_i values in equation A are the values for tonnage for Distribution A (line 3, Table A.4).

The $\frac{T_i}{\Sigma T_i}$ can be obtained from Table 2.5, Section II.

If each term in Equation A is multiplied by the true total Gulf Value of 2.07×10^6 bbl/day, each term is true total amount from that origin.

Similar computations can be done for the Atlantic ports using the Atlantic Coast totals of 3.23×10^6 bbl/day, the tonnage ratio values of distribution D from Table A.5, and the total tonnages from Table 2.5, in Section II.[5]

[5] Tonnages are the sum of New York and Philadelphia Values.

APPENDIX B

LIGHTERING-SEA CHARACTERISTICS CAUSING MOTION

The lightering operation has the potential for many delays. The most serious delays at the present time are port congestion and the lack of dock space. Long delays due to weather and/or sea state have not been reported by those engaged in lightering in the Gulf. Should the SBT regulation create a lightering operation in the North Atlantic off the Delaware Coast, this situation may change.

Discussions with industry personnel engaged in lightering indicate that wave height is the sea characteristic most often quoted. Some have stated that they have operated successfully in seas as high as 15 feet, and others report that an 8-foot sea is probably limiting. References 6, 7, and 8 were reviewed, but lacked definitive sea state information. The main problem attributed to the sea was the relative motion between the lighter and the VLCC which caused excessive wear of the fenders and chafing of mooring lines.

The purpose of this appendix is to attempt to put this problem in perspective and to identify the more important ship and wave characteristics which produce motion.

The mooring operation between lighter and VLCC is normally performed while underway. In most cases offloading is also performed while underway at slow to medium speed. The vessels normally head into the sea to eliminate roll motion. Theoretically head seas will produce only pitch, heave and surge. Regular seas will produce more motion than irregular seas, and the sea characteristics which excite the natural frequency of the vessel (synchronism) will produce maximum motion and must be avoided.

Synchronism occurs when the natural period of the ship is equal to the period of encounter of the wave. Ship motion will be a maximum under this condition. The potential for synchronism exists when the wave length, L_W, is equal to ship length, L, or greater. The normal range for severe motion and wet decks is

$$\frac{L_W}{L} = 1\text{-}2.5.$$

We can demonstrate synchronism with an example. Assume a lightering tanker of 720 feet and 50,000 DWT fully loaded, with a displacement of 64,000 LT. The displacement-length ratio in this condition is 171. Entering Figure B.1 (Reference 9) with this displacement-length ratio we can read a pitch period to length ratio of about 0.325. This gives the natural pitch period of the ship of 8.7 seconds. Entering Figure B.2 (Reference 9) with a period-length ratio of 0.325 we can read the speed-length ratio at $L_W/L = 1$ of about 0.45. This indicates that the speed in head seas which will cause synchronism is 12 knots. At a speed of 12 knots in a 720-foot wave, the period of encounter is 8.7 seconds, which is in synchronism with the ship's natural pitch period, and will produce maximum pitching motion. Motion can be reduced by increasing speed (supercritical condition) or reducing speed (subcritical condition). Again referring to Figure B.2, note that operation in waves which are less than the length of the ship will produce only moderate motion and wave lengths less than 0.75 L will produce relatively little response at any speed.

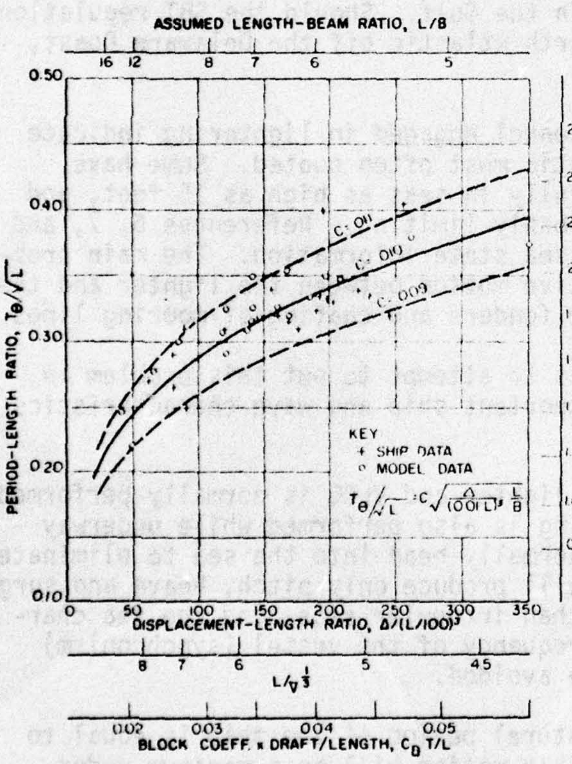

Figure B.1. Variation of Natural Pitching Period with Ship Characteristics

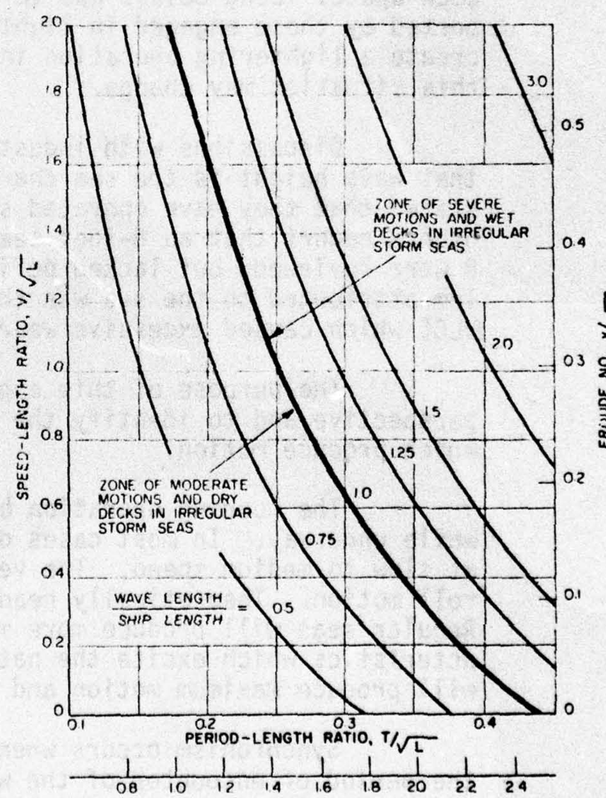

Figure B.2. Ship and Wave Characteristics

As previously stated, the wave lengths to avoid are those equal to the ship length and greater. The probability of encountering a wave of 720 feet in the North Atlantic off the coast of Delaware is not very high. A harmonic wave in deep water with a length of 720 feet has a period of about 12 seconds. Reference 10 indicates that a wave with a period greater than 11 seconds and with a height equal to or greater than 8 feet will only be encountered about 2 percent of the time during the winter months of January, February and March. The percentage during the remaining months of the year is almost unreadable.

Based on this brief analysis of ship and wave characteristics, it appears that a North Atlantic lightering operation is feasible (insofar as sea state is concerned) with minimum weather delays. Larger lighters would improve the relative motion situation and smaller ones would make it worse. The VLCC which is significantly larger than the lighter can probably be considered stationary when analyzing relative motion. The most important wave characteristic is length (not height) and large relative motions may occur when the wave length is equal to the ship's length or longer, unless speed is used to change the encounter frequency and ease the motion.

APPENDIX C

COST CALCULATIONS FOR VARIOUS TRADE ROUTES AND TRANSPORT MODES

COST CALCULATIONS

1975 OIL DELIVERIES TO THE U.S. EAST COAST (65 MDWT)

VESSEL SIZE - MDWT	65	65	65	65	65
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	Motor	Motor	Motor	Motor	Motor
VOYAGE	PG-EC	WA-EC	NA-EC	CAR-EC	BAH-EC
ROUND TRIP DISTANCE (miles)	24,000	10,600	8,400	3,600	2,000
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	70	70	70	70	70
FUEL CONSUMPTION IN PORT - T/D	35	35	35	35	35
FUEL COST - $/TON	75	75	75	75	75
TIME AT SEA - DAYS	62.5	27.6	21.9	9.4	5.2
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	66.5	31.6	25.9	13.4	9.2
TRIPS PER YEAR (350 ÷ TIME)	5.26	11.08	13.5	26.1	38.0
OPERATING COSTS - $/OPER. DAY	6,779	6,779	6,779	6,779	6,779
OPERATING COSTS - $/VOYAGE	450,804	214,216	175,576	90,833	62,367
FUEL COST AT SEA - $/DAY	5,250	5,250	5,250	5,250	5,250
FUEL COST AT SEA - $/VOYAGE	328,125	114,900	114,975	49,350	27,300
FUEL COST IN PORT - $/DAY	2,625	2,625	2,625	2,625	2,625
FUEL COST IN PORT - $/VOYAGE	10,500	10,500	10,500	10,500	10,500
PORT CHARGES - $/CALL	9,000	9,000	9,000	9,000	9,000
PORT CHARGES - $/VOYAGE	18,000	18,000	18,000	18,000	18,000
TOTAL VOYAGE COSTS - $	807,429	387,616	319,051	168,683	118,167
CARGO AS % OF DWT	95	95	95	98	98
CARGO CARRIED - TONS	62,000	62,000	62,000	63,700	63,700
UNIT COST - $/T	13.02	6.25	5.15	2.65	1.86

COST CALCULATIONS

1975 OIL DELIVERIES TO THE U.S. GULF COAST (65 MDWT)

VESSEL SIZE - MDWT	65	65	65	65	65
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	Motor	Motor	Motor	Motor	Motor
VOYAGE	PG-Gulf	WA-Gulf	NA-Gulf	CAR-Gulf	BAH-Gulf
ROUND TRIP DISTANCE (miles)	25,000	11,600	11,400	3,000	1,400
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	70	70	70	70	70
FUEL CONSUMPTION IN PORT - T/D	35	35	35	35	35
FUEL COST - $/TON	75	75	75	75	75
TIME AT SEA - DAYS	65.10	30.21	29.70	7.81	3.65
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	69.10	34.21	33.70	11.81	7.65
TRIPS PER YEAR (350 ÷ TIME)	5.07	10.23	10.40	29.64	47.75
OPERATING COSTS - $/OPER. DAY	6,779	6,779	6,779	6,779	6,779
OPERATING COSTS - $/VOYAGE	468,429	231,910	228,452	80,060	51,859
FUEL COST AT SEA - $/DAY	5,250	5,250	5,250	5,250	5,250
FUEL COST AT SEA - $/VOYAGE	341,775	158,603	155,925	41,003	19,163
FUEL COST IN PORT - $/DAY	2,625	2,625	2,625	2,625	2,625
FUEL COST IN PORT - $/VOYAGE	10,500	10,500	10,500	10,500	10,500
PORT CHARGES - $/CALL	9,000	9,000	9,000	9,000	9,000
PORT CHARGES - $/VOYAGE	18,000	18,000	18,000	18,000	18,000
TOTAL VOYAGE COSTS - $	838,704	419,013	412,877	149,563	99,522
CARGO AS % OF DWT	95	95	95	98	98
CARGO CARRIED - TONS	62,000	62,000	62,000	63,700	63,700
UNIT COST - $/T	13.52	6.76	6.66	2.37	1.56

COST CALCULATIONS

1975 OIL DELIVERIES TO THE U.S. GULF COAST (120 MDWT)

VESSEL SIZE - MDWT	120	120	120	120	120
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	ST/MO	ST/MO	ST/MO	ST/MO	ST/MO
VOYAGE	PG-Gulf	WA-Gulf	NA-Gulf	CAR-Gulf	BAH-Gulf
ROUND TRIP DISTANCE (miles)	25,000	11,600	11,400	3,000	1,400
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	100	100	100	100	100
FUEL CONSUMPTION IN PORT - T/D	50	50	50	50	50
FUEL COST - $/TON	75	75	75	75	75
TIME AT SEA - DAYS	65.10	30.21	29.70	7.81	3.65
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	69.10	34.21	33.70	11.81	7.65
TRIPS PER YEAR (350 ÷ TIME)	5.07	10.23	10.4	29.64	45.75
OPERATING COSTS - $/OPER. DAY	10,674	10,674	10,674	10,674	10,674
OPERATING COSTS - $/VOYAGE	737,573	365,050	359,714	126,060	81,656
FUEL COST AT SEA - $/DAY	7,500	7,500	7,500	7,500	7,500
FUEL COST AT SEA - $/VOYAGE	488,250	226,500	222,750	58,575	27,375
FUEL COST IN PORT - $/DAY	3,750	3,750	3,750	3,750	3,750
FUEL COST IN PORT - $/VOYAGE	15,000	15,000	15,000	15,000	15,000
PORT CHARGES - $/CALL	15,926	15,926	15,926	15,926	15,926
PORT CHARGES - $/VOYAGE	31,852	31,852	31,852	31,852	31,852
TOTAL VOYAGE COSTS - $	1,272,675	638,402	629,316	231,487	155,883
CARGO AS % OF DWT	96	96	96	96	96
CARGO CARRIED - TONS	115,200	115,200	115,200	115,200	115,200
UNIT COST - $/T	11.05	5.54	5.46	2.01	1.35

COST CALCULATIONS

1975 OIL DELIVERIES TO THE U.S. EAST COAST (120 MDWT)

VESSEL SIZE - MDWT	120	120	120	120	120
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	ST/MO	ST/MO	ST/MO	ST/MO	ST/MO
VOYAGE	PG-EC	WA-EC	NA-EC	CAR-EC	BAH-EC
ROUND TRIP DISTANCE (miles)	24,000	10,600	8,400	3,600	2,000
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	100	100	100	100	100
FUEL CONSUMPTION IN PORT - T/D	50	50	50	50	50
FUEL COST - $/TON	75	75	75	75	75
TIME AT SEA - DAYS	62.5	27.6	21.9	9.4	5.2
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	66.5	31.6	25.9	13.4	9.2
TRIPS PER YEAR (350 ÷ TIME)	5.26	11.08	13.5	26.1	38.0
OPERATING COSTS - $/OPER. DAY	10,674	10,674	10,674	10,674	10,674
OPERATING COSTS - $/VOYAGE	709,840	337,298	276,456	143,032	98,200
FUEL COST AT SEA - $/DAY	7,500	7,500	7,500	7,500	7,500
FUEL COST AT SEA - $/VOYAGE	468,750	207,000	164,250	70,500	39,000
FUEL COST IN PORT - $/DAY	3,750	3,750	3,750	3,750	3,750
FUEL COST IN PORT - $/VOYAGE	15,000	15,000	15,000	15,000	15,000
PORT CHARGES - $/CALL	15,926	15,926	15,926	15,926	15,926
PORT CHARGES - $/VOYAGE	31,852	31,852	31,852	31,852	31,852
TOTAL VOYAGE COSTS - $	1,225,442	591,150	487,558	260,384	184,052
CARGO AS % OF DWT	96	96	96	96	96
CARGO CARRIED - TONS	115,200	115,200	115,200	115,200	115,200
UNIT COST - $/T	10.64	5.13	4.23	2.26	1.60

COST CALCULATIONS

1975 OIL DELIVERIES TO THE BAHAMAS (250 MDWT)

VESSEL SIZE - MDWT	250	250	250		
FLAG - U.S. or FOREIGN	F	F	F		
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T		
PROPULSION - STEAM OR MOTOR	ST	ST	ST		
VOYAGE	PG-BAH	WA-BAH	NA-BAH		
ROUND TRIP DISTANCE (miles)	23,200	10,000	9,600		
SPEED (Knots 16) - MPD	384	384	384		
ANNUAL OPERATING DAYS	350	350	350		
FUEL CONSUMPTION AT SEA - T/D	150	150	150		
FUEL CONSUMPTION IN PORT - T/D	75	75	75		
FUEL COST - $/TON	75	75	75		
TIME AT SEA - DAYS	60.4	26.0	25.0		
TIME IN PORT - DAYS	4	4	4		
TOTAL VOYAGE TIME - DAYS	64.4	30.0	29.0		
TRIPS PER YEAR (350 ÷ TIME)	5.43	11.67	12.07		
OPERATING COSTS - $/OPER. DAY	18,771	18,771	18,771		
OPERATING COSTS - $/VOYAGE	1,208,852	563,130	544,359		
FUEL COST AT SEA - $/DAY	11,250	11,250	11,250		
FUEL COST AT SEA - $/VOYAGE	679,500	292,500	281,250		
FUEL COST IN PORT - $/DAY	5,625	5,625	5,625		
FUEL COST IN PORT - $/VOYAGE	22,500	22,500	22,500		
PORT CHARGES - $/CALL	33,000	33,000	33,000		
PORT CHARGES - $/VOYAGE	66,000	66,000	66,000		
TOTAL VOYAGE COSTS - $	1,976,852	944,130	914,109		
CARGO AS % OF DWT	96	96	96		
CARGO CARRIED - TONS	240,000	240,000	240,000		
UNIT COST - $/T	8.24	3.93	3.81		

COST CALCULATIONS

1975 OIL DELIVERIES TO THE CARIBBEAN (250 MDWT)

VESSEL SIZE - MDWT	250	250	250		
FLAG - U.S. or FOREIGN	F	F	F		
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T		
PROPULSION - STEAM OR MOTOR	ST	ST	ST		
VOYAGE	PG-CAR	WA-CAR	NA-CAR		
ROUND TRIP DISTANCE (miles)	21,400	8,800	9,400		
SPEED (Knots 16) - MPD	384	384	384		
ANNUAL OPERATING DAYS	350	350	350		
FUEL CONSUMPTION AT SEA - T/D	150	150	150		
FUEL CONSUMPTION IN PORT - T/D	75	75	75		
FUEL COST - $/TON	75	75	75		
TIME AT SEA - DAYS	55.7	22.9	24.5		
TIME IN PORT - DAYS	4	4	4		
TOTAL VOYAGE TIME - DAYS	59.7	26.9	28.5		
TRIPS PER YEAR (350 ÷ TIME)	5.86	13.01	12.28		
OPERATING COSTS - $/OPER. DAY	18,771	18,771	18,771		
OPERATING COSTS - $/VOYAGE	1,120,629	504,940	534,974		
FUEL COST AT SEA - $/DAY	11,250	11,250	11,250		
FUEL COST AT SEA - $/VOYAGE	626,625	257,625	275,625		
FUEL COST IN PORT - $/DAY	5,625	5,625	5,625		
FUEL COST IN PORT - $/VOYAGE	22,500	22,500	22,500		
PORT CHARGES - $/CALL	33,000	33,000	33,000		
PORT CHARGES - $/VOYAGE	66,000	66,000	66,000		
TOTAL VOYAGE COSTS - $	1,835,754	851,065	899,099		
CARGO AS % OF DWT	96	96	96		
CARGO CARRIED - TONS	240,000	240,000	240,000		
UNIT COST - $/T	7.65	3.55	3.75		

COST CALCULATION

1975 OIL DELIVERIES TO THE U.S. GULF
LIGHTERING OPERATION WITH 250 MDWT

VESSEL SIZE - MDWT	250	250	250		
FLAG - U.S. or FOREIGN	F	F	F		
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T		
PROPULSION - STEAM OR MOTOR	ST	ST	ST		
VOYAGE	PG-Gulf	WA-Gulf	NA-Gulf		
ROUND TRIP DISTANCE (miles)	25,000	11,600	11,400		
SPEED (Knots 16) - MPD	384	384	384		
ANNUAL OPERATING DAYS	350	350	350		
FUEL CONSUMPTION AT SEA - T/D	150	150	150		
FUEL CONSUMPTION IN PORT - T/D	75	75	75		
FUEL COST - $/TON	75	75	75		
TIME AT SEA - DAYS	65.10	30.21	29.70		
TIME IN PORT - DAYS	10	10	10		
TOTAL VOYAGE TIME - DAYS	75.10	40.21	39.70		
TRIPS PER YEAR (350 ÷ TIME)	4.66	8.70	8.82		
OPERATING COSTS - $/OPER. DAY	18,771	18,771	18,771		
OPERATING COSTS - $/VOYAGE	1,409,702	754,782	745,209		
FUEL COST AT SEA - $/DAY	11,250	11,250	11,250		
FUEL COST AT SEA - $/VOYAGE	732,375	339,863	334,125		
FUEL COST IN PORT - $/DAY	5,625	5,625	5,625		
FUEL COST IN PORT - $/VOYAGE	56,250	56,250	56,250		
PORT CHARGES - $/CALL	33,000	33,000	33,000		
PORT CHARGES - $/VOYAGE	33,000	33,000	33,000		
TOTAL VOYAGE COSTS - $	2,231,327	1,183,895	1,168,584		
CARGO AS % OF DWT	96	96	96		
CARGO CARRIED - TONS	240,000	240,000	240,000		
UNIT COST - $/T	9.30	4.93	4.87		

COST CALCULATIONS

1980 OIL DELIVERIES TO THE U.S. GULF COAST (65 MDWT)

VESSEL SIZE - MDWT	65	65	65	65	65
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	Motor	Motor	Motor	Motor	Motor
VOYAGE	PG-Gulf	WA-Gulf	NA-Gulf	CAR-Gulf	BAH-Gulf
ROUND TRIP DISTANCE (miles)	25,000	11,600	11,400	3,000	1,400
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	70	70	70	70	70
FUEL CONSUMPTION IN PORT - T/D	35	35	35	35	35
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	65.10	30.21	29.70	7.81	3.65
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	69.10	34.21	33.70	11.81	7.65
TRIPS PER YEAR (350 ÷ TIME)	5.07	10.23	10.40	29.64	47.75
OPERATING COSTS - $/OPER. DAY	8,343	8,343	8,343	8,343	8,343
OPERATING COSTS - $/VOYAGE	576,501	285,414	281,159	98,531	63,824
FUEL COST AT SEA - $/DAY	7,000	7,000	7,000	7,000	7,000
FUEL COST AT SEA - $/VOYAGE	455,700	211,470	207,900	54,670	25,550
FUEL COST IN PORT - $/DAY	3,500	3,500	3,500	3,500	3,500
FUEL COST IN PORT - $/VOYAGE	14,000	14,000	14,000	14,000	14,000
PORT CHARGES - $/CALL	13,000	13,000	13,000	13,000	13,000
PORT CHARGES - $/VOYAGE	26,000	26,000	26,000	26,000	26,000
TOTAL VOYAGE COSTS - $	1,072,201	536,884	529,059	193,201	129,374
CARGO AS % OF DWT	95	95	95	98	98
CARGO CARRIED - TONS	61,750	61,750	61,750	63,700	63,700
UNIT COST - $/T	17.36	8.69	8.57	3.03	2.03

COST CALCULATIONS

1980 OIL DELIVERIES TO THE U.S. EAST COAST (65 MDWT)

VESSEL SIZE - MDWT	65	65	65	65	65
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	Motor	Motor	Motor	Motor	Motor
VOYAGE	PG-EC	WA-EC	NA-EC	CAR-EC	BAH-EC
ROUND TRIP DISTANCE (miles)	24,000	10,600	8,400	3,600	2,000
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	70	70	70	70	70
FUEL CONSUMPTION IN PORT - T/D	35	35	35	35	35
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	62.5	27.6	21.9	9.4	5.2
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	66.5	31.6	25.9	13.4	9.2
TRIPS PER YEAR (350 ÷ TIME)	5.26	11.08	13.5	26.1	38.0
OPERATING COSTS - $/OPER. DAY	8,343	8,343	8,343	8,343	8,343
OPERATING COSTS - $/VOYAGE	554,810	263,639	216,084	111,796	76,756
FUEL COST AT SEA - $/DAY	7,000	7,000	7,000	7,000	7,000
FUEL COST AT SEA - $/VOYAGE	437,500	193,200	153,300	65,800	36,400
FUEL COST IN PORT - $/DAY	3,500	3,500	3,500	3,500	3,500
FUEL COST IN PORT - $/VOYAGE	14,000	14,000	14,000	14,000	14,000
PORT CHARGES - $/CALL	13,000	13,000	13,000	13,000	13,000
PORT CHARGES - $/VOYAGE	26,000	26,000	26,000	26,000	26,000
TOTAL VOYAGE COSTS - $	1,032,310	496,839	409,384	217,596	153,156
CARGO AS % OF DWT	95	95	95	98	98
CARGO CARRIED - TONS	61,750	61,750	61,750	63,700	63,700
UNIT COST - $/T	16.72	8.05	6.63	3.42	2.40

COST CALCULATIONS

1975 and 1980 OFFSHORE LIGHTERING OPERATIONS

	-----------1980-----------			1980	1975
VESSEL SIZE - MDWT	40	65	80	65	65
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	Motor	Motor	Motor	Motor	Motor
VOYAGE	Lighter	Lighter	Lighter	Lighter	Lighter
ROUND TRIP DISTANCE (miles)	260	260	260	260	260
SPEED (Knots 12.3) - MPD Av.	295	295	295	295	295
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION PER VOYAGE	-	-	-	-	-
FUEL CONSUMPTION IN PORT - T/D	64 LT	80 LT	91 LT	80 LT	80 LT
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	1	1	1	-	-
TIME IN PORT - DAYS	2	2	2	-	-
TOTAL VOYAGE TIME - DAYS	3	3	3	5	5
TRIPS PER YEAR (350 ÷ TIME)	116.67	116.67	116.67	70	70
OPERATING COSTS - $/OPER. DAY	6,257	8,343	9,646	8,343	6,779
OPERATING COSTS - $/VOYAGE	18,771	25,029	28,939	41,715	33,895
FUEL COST AT SEA - $/DAY	-	-	-	-	-
FUEL COST PER VOYAGE*	6,400	8,000	9,100	9,500	7,125
FUEL COST IN PORT - $/DAY	-	-	-	-	-
FUEL COST IN PORT - $/VOYAGE	-	-	-	-	-
PORT CHARGES - $/CALL	8,500	13,000	17,000	13,000	9,000
PORT CHARGES - $/VOYAGE	8,500	13,000	17,000	13,000	9,000
TOTAL VOYAGE COSTS - $	33,671	46,029	55,039	64,215	50,020
CARGO AS % OF DWT (Inc. fuel & sup. for VLCC)	96	96	96	96	96
CARGO CARRIED - TONS	38,400	62,400	76,800	62,400	62,400
UNIT COST - $/T	0.88	0.74	0.72	1.03	0.80

*Fuel cost per voyage included all fuel costs, i.e., at-sea, in-port, berthing, unberthing, delays, unloading, etc.

COST CALCULATIONS

1980 OIL DELIVERIES TO THE U.S. EAST COAST (120 MDWT)

VESSEL SIZE - MDWT	120	120	120	120	120
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	ST/MO	ST/MO	ST/MO	ST/MO	ST/MO
VOYAGE	PG-EC	WA-EC	NA-EC	CAR-EC	BAH-EC
ROUND TRIP DISTANCE (miles)	24,000	10,600	8,400	3,600	2,000
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	100	100	100	100	100
FUEL CONSUMPTION IN PORT - T/D	50	50	50	50	50
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	62.5	27.6	21.9	9.4	5.2
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	66.5	31.6	25.9	13.4	9.2
TRIPS PER YEAR (350 ÷ TIME)	5.26	11.08	13.5	26.1	38.0
OPERATING COSTS - $/OPER. DAY	12,931	12.931	12,931	12,931	12,931
OPERATING COSTS - $/VOYAGE	859,912	408,620	334,913	173,275	118,965
FUEL COST AT SEA - $/DAY	10,000	10,000	10,000	10,000	10,000
FUEL COST AT SEA - $/VOYAGE	625,000	276,000	219,000	94,000	52,000
FUEL COST IN PORT - $/DAY	5,000	5,000	5,000	5,000	5,000
FUEL COST IN PORT - $/VOYAGE	20,000	20,000	20,000	20,000	20,000
PORT CHARGES - $/CALL	24,000	24,000	24,000	24,000	24,000
PORT CHARGES - $/VOYAGE	48,000	48,000	48,000	48,000	48,000
TOTAL VOYAGE COSTS - $	1,552,912	752,620	621,913	335,275	238,965
CARGO AS % OF DWT	96	96	96	96	96
CARGO CARRIED - TONS	115,200	115,200	115,200	115,200	115,200
UNIT COST - $/T	13.48	6.53	5.40	2.91	2.07

COST CALCULATIONS

1980 OIL DELIVERIES TO U.S. GULF (120 MDWT)

VESSEL SIZE - MDWT	120	120	120	120	120
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	ST/MO	ST/MO	ST/MO	ST/MO	ST/MO
VOYAGE	PG-Gulf	WA-Gulf	NA-Gulf	CAR-Gulf	BAH-Gulf
ROUND TRIP DISTANCE (miles)	25,000	11,600	11,400	3,000	1,400
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	100	100	100	100	100
FUEL CONSUMPTION IN PORT - T/D	50	50	50	50	50
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	65.10	30.21	29.70	7.81	3.65
TIME IN PORT - DAYS	4	4	4	4	4
TOTAL VOYAGE TIME - DAYS	69.10	34.21	33.70	11.81	7.65
TRIPS PER YEAR (350 ÷ TIME)	5.07	10.23	10.4	29.64	45.75
OPERATING COSTS - $/OPER. DAY	12,931	12,931	12,931	12,931	12,931
OPERATING COSTS - $/VOYAGE	893,532	442,370	435,775	152,715	98,922
FUEL COST AT SEA - $/DAY	10,000	10,000	10,000	10,000	10,000
FUEL COST AT SEA - $/VOYAGE	651,000	302,100	297,000	78,100	36,500
FUEL COST IN PORT - $/DAY	5,000	5,000	5,000	5,000	5,000
FUEL COST IN PORT - $/VOYAGE	20,000	20,000	20,000	20,000	20,000
PORT CHARGES - $/CALL	24,000	24,000	24,000	24,000	24,000
PORT CHARGES - $/VOYAGE	48,000	48,000	48,000	48,000	48,000
TOTAL VOYAGE COSTS - $	1,612,532	812,470	800,775	298,815	203,422
CARGO AS % OF DWT	96	96	96	96	96
CARGO CARRIED - TONS	115,200	115,200	115,200	115,200	115,200
UNIT COST - $/T	14.00	7.05	6.95	2.59	1.77

COST CALCULATIONS

1980 OIL DELIVERIES TO U.S. EAST COAST AND
GULF COAST, LIGHTERING OPERATIONS WITH 250 MDWT

VESSEL SIZE - MDWT	250	250	250	250	250
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	ST	ST	ST	ST	ST
VOYAGE	WA-EC	NA-EC	PG-Gulf	WA-Gulf	NA-Gulf
ROUND TRIP DISTANCE (miles)	10,600	8,400	25,000	11,600	11,400
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	150	150	150	150	150
FUEL CONSUMPTION IN PORT - T/D	75	75	75	75	75
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	27.6	21.9	65.1	30.21	29.7
TIME IN PORT - DAYS	8	8	8	8	8
TOTAL VOYAGE TIME - DAYS	35.6	29.9	73.1	38.21	37.7
TRIPS PER YEAR (350 ÷ TIME)	9.83	11.71	4.79	9.16	9.28
OPERATING COSTS - $/OPER. DAY	22,317	22,317	22,317	22,317	22,317
OPERATING COSTS - $/VOYAGE	794,485	667,278	1,631,373	852,733	841,351
FUEL COST AT SEA - $/DAY	15,000	15,000	15,000	15,000	15,000
FUEL COST AT SEA - $/VOYAGE	414,000	328,500	976,500	453,150	445,500
FUEL COST IN PORT - $/DAY	7,500	7,500	7,500	7,500	7,500
FUEL COST IN PORT - $/VOYAGE	60,000	60,000	60,000	60,000	60,000
PORT CHARGES - $/CALL	51,000	51,000	51,000	51,000	51,000
PORT CHARGES - $/VOYAGE	51,000	51,000	51,000	51,000	51,000
TOTAL VOYAGE COSTS - $	1,319,485	1,106,778	2,718,873	1,416,883	1,397,851
CARGO AS % OF DWT	96	96	96	96	96
CARGO CARRIED - TONS	240,000	240,000	240,000	240,000	240,000
UNIT COST - $/T	5.50	4.61	11.33	5.90	5.82

COST CALCULATION

1980 OIL DELIVERIES TO THE U.S. EAST COAST
LIGHTERING OPERATIONS WITH 250 MDWT

VESSEL SIZE - MDWT	250	250	250	250	250
FLAG - U.S. or FOREIGN	F	F	F	F	F
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T	T	T
PROPULSION - STEAM OR MOTOR	ST	ST	ST	ST	ST
VOYAGE	PG-EC	WA-EC	NA-EC	PG-EC	PG-EC
ROUND TRIP DISTANCE (miles)	24,000	10,600	8,400	24,000	24,000
SPEED (Knots 16) - MPD	384	384	384	384	384
ANNUAL OPERATING DAYS	350	350	350	350	350
FUEL CONSUMPTION AT SEA - T/D	150	150	150	150	150
FUEL CONSUMPTION IN PORT - T/D	75	75	75	75	75
FUEL COST - $/TON	100	100	100	100	100
TIME AT SEA - DAYS	62.5	27.6	21.9	62.5	62.5
TIME IN PORT - DAYS	5	5	5	8	10
TOTAL VOYAGE TIME - DAYS	67.5	32.6	26.9	70.5	72.5
TRIPS PER YEAR (350 ÷ TIME)	5.19	10.74	13.01	4.96	4.83
OPERATING COSTS - $/OPER. DAY	22,317	22,317	22,317	22,317	22,317
OPERATING COSTS - $/VOYAGE	1,506,398	727,534	600,327	1,573,349	1,617,988
FUEL COST AT SEA - $/DAY	15,000	15,000	15,000	15,000	15,000
FUEL COST AT SEA - $/VOYAGE	937,500	414,000	328,500	937,500	937,500
FUEL COST IN PORT - $/DAY	7,500	7,500	7,500	7,500	7,500
FUEL COST IN PORT - $/VOYAGE	37,500	37,500	37,500	60,000	75,000
PORT CHARGES - $/CALL	51,000	51,000	51,000	51,000	51,000
PORT CHARGES - $/VOYAGE	51,000	51,000	51,000	51,000	51,000
TOTAL VOYAGE COSTS - $	2,532,398	1,230,034	1,017,327	2,621,849	2,681,483
CARGO AS % OF DWT	96	96	96	96	96
CARGO CARRIED - TONS	240,000	240,000	240,000	240,000	240,000
UNIT COST - $/T	10.55	5.13	4.24	10.92	11.17

COST CALCULATIONS

1980 OIL DELIVERIES TO THE BAHAMAS (250 MDWT)

VESSEL SIZE - MDWT	250	250	250		
FLAG - U.S. or FOREIGN	F	F	F		
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T		
PROPULSION - STEAM OR MOTOR	ST	ST	ST		
VOYAGE	PG-BAH	WA-BAH	NA-BAH		
ROUND TRIP DISTANCE (miles)	23,200	10,000	9,600		
SPEED (Knots 16) - MPD	384	384	384		
ANNUAL OPERATING DAYS	350	350	350		
FUEL CONSUMPTION AT SEA - T/D	150	150	150		
FUEL CONSUMPTION IN PORT - T/D	75	75	75		
FUEL COST - $/TON	100	100	100		
TIME AT SEA - DAYS	60.4	26.0	25.0		
TIME IN PORT - DAYS	4	4	4		
TOTAL VOYAGE TIME - DAYS	64.4	30.0	29.0		
TRIPS PER YEAR (350 ÷ TIME)	5.43	11.67	12.07		
OPERATING COSTS - $/OPER. DAY	22,317	22,317	22,317		
OPERATING COSTS - $/VOYAGE	1,437,215	669,510	647,193		
FUEL COST AT SEA - $/DAY	15,000	15,000	15,000		
FUEL COST AT SEA - $/VOYAGE	906,000	390,000	375,000		
FUEL COST IN PORT - $/DAY	7,500	7,500	7,500		
FUEL COST IN PORT - $/VOYAGE	30,000	30,000	30,000		
PORT CHARGES - $/CALL	51,000	51,000	51,000		
PORT CHARGES - $/VOYAGE	102,000	102,000	102,000		
TOTAL VOYAGE COSTS - $	2,475,215	1,191,510	1,154,193		
CARGO AS % OF DWT	96	96	96		
CARGO CARRIED - TONS	240,000	240,000	240,000		
UNIT COST - $/T	10.31	4.96	4.81		

COST CALCULATIONS

1980 OIL DELIVERIES TO CARIBBEAN (250 MDWT)

VESSEL SIZE - MDWT	250	250	250		
FLAG - U.S. or FOREIGN	F	F	F		
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T		
PROPULSION - STEAM OR MOTOR	ST	ST	ST		
VOYAGE	PG-CAR	WA-CAR	NA-CAR		
ROUND TRIP DISTANCE (miles)	21,400	8,800	9,400		
SPEED (Knots 16) - MPD	384	384	384		
ANNUAL OPERATING DAYS	350	350	350		
FUEL CONSUMPTION AT SEA - T/D	150	150	150		
FUEL CONSUMPTION IN PORT - T/D	75	75	75		
FUEL COST - $/TON	100	100	100		
TIME AT SEA - DAYS	55.7	22.9	24.5		
TIME IN PORT - DAYS	4	4	4		
TOTAL VOYAGE TIME - DAYS	59.7	26.9	28.5		
TRIPS PER YEAR (350 ÷ TIME)	5.86	13.01	12.28		
OPERATING COSTS - $/OPER. DAY	22,317	22,317	22,317		
OPERATING COSTS - $/VOYAGE	1,332,325	600,327	636,035		
FUEL COST AT SEA - $/DAY	15,000	15,000	15,000		
FUEL COST AT SEA - $/VOYAGE	835,500	343,500	367,500		
FUEL COST IN PORT - $/DAY	7,500	7,500	7,500		
FUEL COST IN PORT - $/VOYAGE	30,000	30,000	30,000		
PORT CHARGES - $/CALL	51,000	51,000	51,000		
PORT CHARGES - $/VOYAGE	102,000	102,000	102,000		
TOTAL VOYAGE COSTS - $	2,299,825	1,075,827	1,135,535		
CARGO AS % OF DWT	96	96	96		
CARGO CARRIED - TONS	240,000	240,000	240,000		
UNIT COST - $/T	9.58	4.48	4.73		

COST CALCULATIONS

1980 OIL DELIVERIES TO GULF DEEPWATER PORT
OR LIGHTERING OPERATION WITH 250 MDWT

VESSEL SIZE - MDWT	250	250	250		
FLAG - U.S. or FOREIGN	F	F	F		
TYPE - TANKER/OBO/DEDICATED LIGHTER	T	T	T		
PROPULSION - STEAM OR MOTOR	ST	ST	ST		
VOYAGE	PG-Gulf	WA-Gulf	NA-Gulf		
ROUND TRIP DISTANCE (miles)	25,000	11,600	11,400		
SPEED (Knots 16) - MPD	384	384	384		
ANNUAL OPERATING DAYS	350	350	350		
FUEL CONSUMPTION AT SEA - T/D	150	150	150		
FUEL CONSUMPTION IN PORT - T/D	75	75	75		
FUEL COST - $/TON	100	100	100		
TIME AT SEA - DAYS	65.10	30.21	29.70		
TIME IN PORT - DAYS	4	4	4		
TOTAL VOYAGE TIME - DAYS	69.10	34.21	33.70		
TRIPS PER YEAR (350 ÷ TIME)	5.07	10.23	10.40		
OPERATING COSTS - $/OPER. DAY	22,317	22,317	22,317		
OPERATING COSTS - $/VOYAGE	1,542,104	763,465	752,083		
FUEL COST AT SEA - $/DAY	15,000	15,000	15,000		
FUEL COST AT SEA - $/VOYAGE	976,500	453,150	445,500		
FUEL COST IN PORT - $/DAY	7,500	7,500	7,500		
FUEL COST IN PORT - $/VOYAGE	30,000	30,000	30,000		
PORT CHARGES - $/CALL	51,000	51,000	51,000		
PORT CHARGES - $/VOYAGE	51,000	51,000	51,000		
TOTAL VOYAGE COSTS - $	2,599,604	1,297,615	1,278,583		
CARGO AS % OF DWT	96	96	96		
CARGO CARRIED - TONS	240,000	240,000	240,000		
UNIT COST - $/T	10.83	5.41	5.33		

APPENDIX D

COMPARISON OF MAJOR FEATURES OF INTERNATIONAL CONVENTIONS FOR PREVENTION OF POLLUTION FROM SHIPS

Excerpted from A Review of the 1973 Marine Pollution Convention, professional paper by RADM R.I. Price, USCG and CAPT F.P. Schubert, USCG. Presented at the IMCO International Symposium on Prevention of Pollution from Ships, Acapulco, Mexico, March 22-31, 1976.

Major Features	1954 (as amended in 1962)	1973
Enforcement mechanism	1. No comparable provision.	1. Requires that the monitoring and control system be in operation and a permanent record made anytime oily effluent is being *discharged, except for clean or segregated* ballast.
Construction and equipment requirements to control operational discharges of oily mixtures	1. No comparable provision	1. Segregated ballast is mandatory for new tankers of 70,000 DWT and greater, and is optional for tankers of less than 70,000 DWT. Note that "new tankers" are defined by calendar dates and are therefore not dependent upon entry into force of this *Convention*. 2. Retention of Oil on Board (LOT) is mandatory for all tankers. 3. Mandatory installation of effluent monitor and control system, provision of slop tanks, and provision of oil/water interface detectors. Effluent must comply with discharge criteria or be transferred to reception facility. 4. Other ships require sludge tank installations, oil-water separators and/or filters dependent upon ship size.
Reception facilities	1. Provision to promote according to need of ships using ports.	1. Expanded provision to undertake to ensure availability and adequacy at oil loading ports, repair ports, and at other ports according to the needs of ships.
Oil Record Book	1. *Establishes basic requirement* to provide oil record book and requires entries for specific operations.	1. Expands requirements to provide entries for more specific operations and in greater detail to aid in enforcement.
Construction requirements to limit the amount of oil discharge in case of *accidents*	1. No comparable provision.	1. Establishes damage assumptions and methods of calculation of the amount of hypothetical oil outflow for tankers. 2. Establishes tank arrangement and size limitations for the cargo tanks of tankers. 3. Establishes subdivision and damage stability criteria to be applied to tankers to increase survivability in the event of accident.
Additional annexes for substances other than oil. Annex II is mandatory and annexes III, IV and V may be adopted at the option of *contracting States*	1. No comparable provision.	1. Annex II details mandatory requirements for construction of chemical tankers and discharge criteria for residues of noxious liquid substances carried in bulk. 2. Annex III contains regulations for the prevention of pollution by harmful substances carried at sea in packaged form, or in freight containers, portable tanks, or road and rail tank cars. 3. Annex IV contains regulations for the prevention of pollution by sewage from ships. 4. Annex V contains regulations for the prevention of pollution by garbage from ships.

Major Feature	1954 (as amended in 1962)	1973
Applicability as regards carriage of oil	1. Seagoing tankers over 150 gross tons. 2. Other seagoing ships over 500 tons.	1. All tankers over 150 gross tons. 2. All other ships over 400 gross tons, including novel craft and fixed and floating platforms
Dispute settlement	1. Referred to International Court of Justice unless all parties agree to arbitration	1. Compulsory arbitration by specially formed tribunals upon application of any party to dispute.
Amendment procedure	1. Effective only upon specific acceptance via IMCO Assembly and Contracting States.	1. Speedier method for Annexes and appendices via IMCO Committee and tacit acceptance procedures.
Survey and certification	1. No comparable provision.	1. Survey at 5-year intervals and at intermediate (mid-period) intervals. 2. Equipment must be approved by Administration (monitors, filters, separators, interface detectors). 3. Administration issues Certificate attesting to compliance by its ships, which certificate shall be accepted except when there are clear grounds to believe the ship is not in compliance.
Definition of oil	1. Limited to crude, fuel, heavy diesel, and lubricating oils. 2. Does not include bilge slops and fuel and lube oil purification residues.	1. Includes all petroleum oils except petrochemicals (which are regulated by Annex II).
Discharge criteria in Prohibited Zones (this term does not appear in the 1973 convention which uses a distance-from-land criterion)	1. Prohibits discharges by all ships in concentrations in excess of 100 parts per million within the prohibited zones. 2. Prohibited zone generally 50 miles or greater from nearest land for tankers. Prohibited zone applies to other ships unless proceeding to a port not provided with adequate reception facilities.	1. Prohibited discharges which leave visible tracts unless it can be established by installed instruments that the concentration discharged was less than 15 parts per million. 2. For tanker cargo slops, discharge is prohibited within 50 miles from nearest land. For other ships' slop, and other tanker slop, discharge is prohibited within 12 miles from the nearest land.
Discharge criteria outside the Prohibited Zones	1. No restriction on discharges from a ship less than 20,000 gross tons. Vessels over 20,000 gross tons are limited to discharges whose concentrations are 100 parts per million or less, unless when, in the opinion of the master, circumstances make it unreasonable or impractical to retain the higher-concentrated slops onboard.	1. Tankers must meet all the following conditions: a. ship is proceeding enroute b. discharge is limited to 60 liters per mile instantaneous rate c. total quantity discharged is limited to 1/15,000 of cargo last carried for existing tankers and 1/30,000 of cargo last carried for new tankers d. tanker bilges, except pump rooms shall be treated the same as other ships. 2. Other ships must meet all of the following conditions: a. ship is proceeding enroute b. oil content of the effluent must not exceed 100 parts per million.

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