ECONOMIC EVALUATION OF ALTERNATE POLLUTION CONTROL POLICIES FOR TANKERS

BY

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ABSTRACT

The routine operations of tankers discharge a considerable amount of oil into the sea. This oil is the residue from tank cleaning as well as the discharge of oily ballast water while at sea.

There are a number of policies available to control operational discharges of oil by tankers. This study describes current practices and alternate policies, and provides a method and data base to evaluate the cost-effectiveness of these policies. This method and data base are used to evaluate the cost-effectiveness of applying the provisions of the "1973 Convention for the Prevention of Pollution from Ships" to the tankers engaged in the future Alaskan oil trade.

The main conclusion is that the value of oil saved by pollution control will more than cover the costs of pollution control measures. However, the use of segregated ballast tankers is economically justified only if it is impossible to enforce the retention of oily wash on board the ship. If effective enforcement is practiced, then the incremental cost of segregated ballast ships is not covered by the value of the small amount of additional oil saved.

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CHAPTER I

INTRODUCTION

1.1 OBJECTIVES OF THE STUDY

In recent years many countries in the world have expressed concern over oil pollution from tankers. This concern may have been promoted by some spectacular tanker oil spills; or it may come from a more global concern over marine pollution by oil and its effect on the world's ecology. Whatever the case, tanker oil pollution control has become an important issue.

Like many industries, in particular like other shipping industries, the tanker industry pollutes the marine environment. According to a background report on tanker pollution prepared in 1975 for the U.S. Congress, "recent estimates are that one third of all oil pollution of the world's oceans is caused by activities generally characterized as marine transportation. Tankers understandably are the single largest contributor of such pollution.... Oil pollution from tankers originates from two principal sources: (1) Tanker accidents and (2) Normal tanker operations such as tank cleaning deballasting and other operational reasons for periodically discharging overboard."[1]

This study is primarily concerned with operational discharges of oil from tankers. Its basic objectives are to provide background information and to develop a methodology to be used in the economic evaluation of alternate policies to control these operational discharges. The particular objectives may be detailed as follows:

a) To bring together available information on the various means for controlling operational discharges of oil from tankers, their economic cost and effectiveness; and to describe the alternate control policies currently contemplated.

b) To develop a method to assess the economic cost and effectiveness of alternate control policies on a given trade.

c) To apply this method to estimate the economic cost and effectiveness of alternate control policies in the case of the future Alaska crude oil trade between Valdez, Alaska, and the U.S. West Coast.

1.2 REASON FOR AND IMPORTANCE OF THE STUDY

Controlling operational discharges of oil from tankers is important to many of the world's countries. An economic evaluation of alternate control policies is essential to promote efficient and practical policies. The major control techniques have already been evaluated individually in economic terms but available results are widely dispersed. In addition, the studies done in this area were primarily attempting to develop specific data on specific techniques so that no general method has been developed for the economic evaluation of complex policies involving different techniques and standards. This study proposed such method and provides the necessary inputs, using available information. Besides, the application of the method in the particular case of the Alaska trade will provide results of interest for all of those (not only in Canada and the United States) concerned with tanker pollution. These points are not developed in detail.

1.2.1 Controlling Operational Discharges from Tankers: An Important Issue.

When a tanker has discharged its cargo at the port, it takes ballast water into some of its tanks to ensure proper immersion and seakeeping characteristics on the return trip. The water mixes with the residues of oil in the tank to form what is called the dirty ballast. This dirty ballast must be discharged to the sea prior to arriving in a port unless special procedures are adopted. In addition, tankers typically wash some of their cargo tanks on the return trip. The oily washwaters are also discharged overboard unless alternative procedures are followed.

Understandably, the resulting oil pollution primarily affects the regions surrounding tanker trade routes. The chronic nature of this pollution is considered by some to have a more deleterious effect on local coastal and estuarine ecosystems than acute dosing (U.S. Congress, p. 31).

"Weather, winds and currents, as well as migratory habits of marine life can also spread and propagate initial damages" (U.S. Congress, p. 31) so that it is the global marine ecosystem which is ultimately affected;especially as millions of tons of oil already reach the oceans from other sources.

In a comprehensive report on marine pollution by oil, the U.S. National Academy of Sciences concluded:

> A basic question that remains unanswered is: At what level of petroleum hydrocarbon input to the ocean might we find irreversible damage occuring? The sea is an enormously complex system about which our knowledge is very imperfect. The ocean may be able to accommodate petroleum hydrocarbon inputs far above those occurring today. On the other hand, the damage level may be within an order of magnitude of present inputs to the sea. Until we can come closer to answering this basic question, it seems wisest to continue our efforts in the international control of inputs and to push forward research to reduce our current level of uncertainty.[2]

TABLE 1 which is based on the above report, shows estimates of the various oil pollution inputs to the world's oceans. It is clear from these estimates that tanker operational discharges are a major source of marine pollution by oil and therefore deserve special consideration in the control of such pollution.

In summary, the control of tanker operational discharges is important in the following respects:

1) Tanker operational pollution is a major source of pollution for some regions of the world.

2) The control of such pollution is one of the major means to control the global oil pollution input to the world's oceans.

The appropriate control policy really depends upon which of these two aspects is emphasized. If the objective is to reduce the global oil pollution input, the evaluation of alternate policies should be made on a worldwide basis; and the policy selection should be made in view of what can be done to reduce the worldwide oil pollution input from other sources. The "best" policy might be to do nothing as regards tanker operational discharges, and to devote available resources to the control of other sources of oil pollution.

On the other hand, if the objective is to reduce oil pollution damages from tanker operational discharges, some positive actions are needed to control these discharges. These actions will reduce the global oil input to the world's oceans. But this is incidental and of limited relevance when selecting an appropriate policy, as better measures of the impact of alternate policies on environmental conditions can be achieved by evaluating each policy on a region by region basis. This study attempts to show how this can be done in practice.

TABLE 1

ESTIMATES OF OIL POLLUTION INPUTS TO THE WORLD'S OCEANS FROM ALL SOURCES

SOURCE	INPUT RATE (Millions of tons per year)	PERCENT OF TOTAL
Natural seeps	0.600	9.8
Offshore production	0.080	1.3
Coastal refineries	0.200	3.3
Atmosphere	0.600	9.8
Coastal municipal wastes	0.300	4.9
Coastal, non refining industrial wastes	0.300	4.9
Urban runoff	0.300	4.9
River runoff	1.600	26.2
Marine transportation -non tankers	0.450	7.4
- tanker accidents	0.200	3.3
- tanker operational discharges	1.380	22.6
Total Input	6.113	

Source: U.S. National Academy of Sciences, 1975, p. 6

It may be argued that the ultimate objective should not be to reduce the global oil pollution input to the world's oceans, or to reduce oil pollution damages from tanker operational discharges, but, more generally, to reduce damages from marine oil pollution.

To achieve the more general objective of reducing damages from marine oil pollution, it would be suitable to have an integrated approach involving all sources of marine oil pollution and all aspects of such pollution (inputs, location, frequency, effects....). Such an approach will not be practicable, however, until enough information is available as regards the control of marine oil pollution from each particular source. The optimal policy to control particular sources of marine oil pollution may become 'suboptimal' when the focus shifts to the control of marine oil pollution as a whole. Whatever the focus, however, the investigation of alternate policies to control tanker operational pollution is essential.

1.2.2 Importance of the Economic Evaluation of Alternate Control Policies

Alternate policies are available to control operational pollution from tankers. It is known that the most effective ones would cost billions of dollars. The magnitude of this cost makes it clear that some policies would have a significant impact on the balance of payment and economy of many countries. Decisions regarding the control of tanker operational discharges are important, therefore, to individual countries. An economic evaluation of alternate control policies, indicating the size and distribution of the costs and benefits should greatly help those countries in making decisions about pollution control.

Decisions regarding the control of tanker pollution are made primarily through a process of international negotiations under the auspices of the Inter-Governmental Maritime Consultative Organization (IMCO), a United Nations agency established in 1959. The economic evaluation of alternative control policies is essential to IMCO as it may significantly improve the organization's decisions in the following two respects:

1) The economic evaluation of alternate control policies should promote efficient decisions, that is decisions which cannot be modified without increasing the costs to the international community more than the benefits.

2) The economic evaluation of alternate control policies should promote practical decisions, that is, decisions which can be ratified and implemented without excessive delay.

The first point is quite obvious. But the second may require some explanation, as the practicality of control policies is primarily a matter of international politics, the economic dimension being only one factor among others.

The practicality of a given policy depends upon such factors as the attitude and influence of the public and industry in the various countries concerned. It also depends upon the global negotiating context in which decisions regarding tanker pollution control are made: These decisions are generally not made in isolation, but as part of a 'policy package' relating to a wider issue, such as the pollution from ships or the law of the sea, so that the practicality of a single decision really depends upon the content of the whole package. Such 'policy packages' are not necessarily defined in a formal way. They may grow up naturally as several international issues, being discussed in different places, come to interfere with each other, and individual countries start to compromise and to engage in trading of support practices.[3]

It is clear, therefore, that the economic evaluation of alternate tanker pollution control policies may not be exclusively relied upon to predict the practicality of these policies. However, such an evaluation influences the attitudes of individual countries in a predictable direction. It also reduces the range of possible outcomes, as it becomes clear that some policies are economically impractical. Accordingly, the economic evaluation could facilitate and improve predictions as to the chances of effective implementation of the contemplated policies and, therefore, as to their practicality.

1.2.3 Reasons for the study

The nature of the costs and benefits generated by tanker pollution control made it appropriate to use a cost-effectiveness framework, which will be described in Chapter 4 to evaluate alternate control policies.

Prior to the 1973 IMCO Conference, which resulted in the '1973 Convention for the Prevention of Pollution from ships' (subsequently referred as the 1973 Convention), several technical studies[4] were carried out under the auspices of IMCO on the cost and effectiveness of the major techniques for preventing tanker operational discharges. These studies were a very valuable input to the 1973 conference as they provided a data base from which a general assessment of alternate policies could be made.

The 1973 conference and other events, such as the considerable increase in the value of oil, the appearance of a large tanker surplus, the development of new techniques to prevent tanker operational pollution, and a number of tanker explosions which were probably caused by tank cleaning operations brought about further studies on the subject.[5]

While these studies and the IMCO studies contain much valuable information, they may not be readily used for evaluating alternate control policies in economic terms. There are two reasons:

a) The first reason is simply that available information and data are extremely dispersed.

b) The second reason is that these studies are primarily technical in nature, as new techniques and equipments had to be tested and investigated prior to estimating their cost and effectiveness. The main focus was not on the economic evaluation itself. These studies essentially provide a data base on the cost and effectiveness of individual techniques to control tanker operational pollution but do not provide any precise assessment of complex control policies, involving multiple techniques and standards.

Accordingly, this study may be viewed as a complement to the above studies. It attempts to bring together available information, and to develop and illustrate a method for the economic evaluation of alternate policies. It does not attempt, however, the economic analysis of controls on tanker operational discharges as such analysis has been carried out by other.[6] The main points of the analysis may be summarized as follows:

1) The economically optimal control policy should minimize the total social cost associated with tanker pollution, that is, the sum of the social cost of pollution plus the social cost of pollution control.

2) Complete bans or uniform regulations for all vessels on all the routes are not likely to be the optimal policy. Indeed, the greater the pollution problem on a given trade route, the stricter the standards which

should apply on this route; on the other hand, lower standards should apply on those routes and ships where it is more costly to reduce pollution.

According to the first point, this study accounts explicitly for enforcement costs which are clearly part of the social cost of pollution prevention. This aspect has been consistently disregarded in the previously mentioned studies. Yet, Burrows, Rowley and Owen showed in an interesting article that the inclusion of these costs may affect the results and conclusion of the economic evaluation.[7]

According to the second point, this study focuses on individual trades and allows for different vessel types. This introduces a great flexibility in policy definition as the proposed standards and techniques may vary with trade and vessel characteristics. In addition, this permits an assessment of alternate policies on a trade by trade basis, or on a few typical trades, rather than on a broad worldwide basis, and therefore, to achieve a better measure of cost-effectiveness.

1.2.4 The relevance of the Alaska Trade

Major petroleum reserves were discovered in 1968 in Prudhoe Bay on the Alaska North Slope. Increasing U.S. energy needs, and the proclamation of U.S. energy self-sufficiency as a national goal, led to the decision to develop these reserves to supply U.S. western states. This decision resulted in the construction of the Trans-Alaska pipe-line from the North Slope south to Valdez, Alaska. The pipe-line is scheduled to begin operations in the third quarter of 1977.

From Valdez the pipe-line's throughput will be shipped by tanker to the U.S. West Coast ports. At the time the decisions were made, they were the object of many controversies. The tanker pollution problem was a major point of concern.

The U.S. Coast Guard is the regulatory body responsible for establishing and enforcing U.S. tanker regulations. These regulations apply to U.S. tankers and to foreign tankers in U.S. waters. In October 1975, the Coast Guard made public a set of regulations applying to U.S. tankers engaged in domestic trade. These will apply to vessels engaged in the Alaska trade.[8]

The preparation and publication of these regulations brought about many comments and reactions from the oil and shipping industry, the environmental groups, the concerned governmental agencies, the U.S. Congress, and individual coastal states.

Thus, during the last five years, tanker pollution control on the Alaska trade has been very much debated. Various control policies have been proposed. These are described in the Final Environmental Impact Statement issued by the U.S. Coast Guard prior to the publication of the U.S. domestic trade regulations, and in the comments attached to the statement.[9]

The Coast Guard based its regulations on the 1973 IMCO Convention, on the ground that this convention, although not perfect, offered "the potential for effectively controlling oil pollution inputs from tanker operations and reducing them to acceptable levels" and "deserved wholehearted U.S. support" (U.S. Coast Guard, p. 6). The resulting increase in transportation costs was estimated to be less than 0.2 cents per gallon of crude or less than 0.6 per cent of the CIF price of crude oil (U.S. Coast Guard, Table 9). It is further estimated that the new regulations should reduce operational pollution inputs from tankers engaged in U.S. domestic trade by 90 perccent (U.S. Coast Guard, Table 6). The cost and effectiveness of alternate sets of standards have not been estimated.

This study will permit to compare the U.S. Coast Guard policy to control tanker operational discharges with alternate policies. The Coast Guard views the recent regulations as one step in a continuing process. Future decisions should be made easier by this study.

The impact of a given control policy on operational pollution really depends upon the specific conditions prevailing on the trade (climate, biota, density of traffic,....) It is the author's view, however, that the impacts of a given control policy on costs, as well as on the characteristics of operational discharges (volume of oil discharged per trip, concentration of the discharges,....) do not differ substantially between the Alaska trade and other medium to long-haul crude oil trades. Accordingly, the conclusions that will be drawn for the Alaska trade should be of use and relevance for other trades.

1.3 LIMITATIONS OF THE STUDY

1.3.1 Methodological limitations

Tanker operational pollution and tanker accidental pollution are interdependent. For example, the use of an effective safety feature preventing explosions during tank cleaning may enable the crew to use better cleaning methods that would be dangerous otherwise, with significant benefits for operational pollution. Operational pollution from ballasting operations and tanker safety are also interdependent. Ballast is taken into the tanks to provide suitable seakeeping characteristics. A reduction in the amount of ballast reduces operational pollution from ballast discharge but it increases the risk of accident. On the other hand, special tanker designs may reduce operational discharges from ballasting operations and, at the same time reduce accidental discharges in case of collision or grounding.

As accidental and operational pollution are interdependent, they cannot be dealt with separately when evaluating tanker pollution control policies. To evaluate the impact of some control policy on operational, and then on accidental pollution, however, consists of two very distinct tasks involving very distinct methods and data bases.

This study is only concerned with those control policies which primarily affect operational pollution and does not propose any evaluation method or estimate as regards any secondary effects these policies might have on accidental pollution.

1.3.2 Data limitations

The conditions in which tankers operate, as well as the operating practices of individual ship's masters are very diverse. The cost and effectiveness of most tanker pollution control policies depend to a large extent upon these conditions and practices.

Previous studies provide and use "typical" figures that are considered to be representative of the wide diversity of situations worldwide. While such an approximation is made necessary by the lack of data and the need to keep calculations manageable, it is a potential source of controversies and a definite source of uncertainty as regards the results of the calculations. This must be added to the fact that all data are subject to considerable inherent uncertainty with regard to future conditions, as the oil and tanker industries are evolving in a very unpredictable world.

It is reasonable, however, to consider that conditions and practices are not too diverse and that future conditions are not too unpredictable when focusing on a specific trade. Thus cost-effectiveness estimates should not be too controversial or uncertain. This is another reason for focusing on specific trades. The only problem in this regard is that data relating to specific trades are often unavailable so that the usual "typical" figures have to be used instead. These figures which are considered to be representative of conditions prevailing worldwide are not necessarily valid on specific trades so that the results are still subject to much uncertainty.

For all these reasons, a sensitivity analysis would be a very useful complement to this study as it could show the areas where additional information is most needed. Besides, such analysis would indicate the most significant variables affecting the cost-effectiveness of alternate control policies.

1.3.3 Other limitations

This study is also incomplete in the following respects: An important aspect of the economic evaluation relates to the distribution of the costs and benefits. While the evaluation of alternate policies on a trade basis conveys much information as to the distributive impact of alternate policies among regions it does not really say who is going to bear the economic cost of pollution abatement unless such aspects as fleet ownership, port policies and national policies are investigated. These investigations are not attempted in this study.

This study contemplates only a few typical policies which are being or have been supported or implemented by concerned groups. As a result, it is possible that promising alternatives will be overlooked. However, this study is concerned with the illustration of the proposed evaluation methodology rather than with the systematic evaluation of alternate policies. Indeed, the policies contemplated here are sufficiently diverse to permit a proper illustration of the general methodology.

Similarly, the evaluation of alternate control policies on several trades with entirely different characteristics would be very instructive, but is beyond the task of the present study.

1.4 OUTLINE OF THE STUDY

This study is in four parts; the first part presents available data and information on the control of operational pollution, and the cost and effectiveness of available techniques. The second part describes the cost-effectiveness framework used for economic evaluation purposes and outlines the methodology used to arrive at the cost-effectiveness estimates. The economic evaluation of alternate policies on the Alaska trade is done in the third part. The last part contains a brief summary as well as the main conclusions of the study.

FOOTNOTES

CHAPTER 1

[1]U.S. Congress, Office of Technology Assessment, Oil Transportation by Tankers: An Analysis of Marine Pollution and Safety Measures (Washington D.C., 1975) p.1.

[2]U.S. National Academy of Sciences, Petroleum in the Marine Environment (Washington, D.C., January 1975).

[3]For a captivating description of the international politics of tanker pollution control, see Zacher M. (University of British Columbia), the Politics of International Environmental Regulation; The case of oil pollution control, (to be published)

[4]See IMCO, Report on Study 1. Segregated Ballast Tankers, Report by the United States, 1972

IMCO, Report on part 2 of study 1, Segregated Ballast aboard Product tankers and smaller crude carriers, Report by the United States, 1973

IMCO, Report on Study 3, Retention on board, Report by the United Kingdom, 1973

IMCO, Report on study 4, Clean Ballasting before sailing from Discharging Port (by P. Theobald), Report by France, 1973

IMCO, Report on study 5, Retaining dirty ballast on board for Port Disposal, Report by Israel, 1973

[5]See U.S. Department of Commerce, Maritime Administration, Port Collection and Separation facilities for oily wastes, Report by Frederic R. Harris, Inc., Washington D.C., 1973.

[6]U.S. Department of Commerce Maritime Administration, Tanker Tank Cleaning Research Program, Report by MSA Research Corporation, Washington, D.C. 1974.

Maybourn, R. Crude Oil Washing, Proceedings of the IMCO Symposium on Prevention of Pollution from ships, Acapulco, March 1976.

Gray, W.O., Segregated Ballast and Related Aspects of Tanker design. Proceedings of the IMCO Symposium on Prevention of pollution from ships, Acapulco, March 1976.

IMCO, Introduction of segregated ballast in existing Tankers, Report by Greece, Italy and Norway to the IMCO Marine Environment Protection committee, May 1976.

[6]See in particular Heaver, T.D. and Waters, W.G., An Economic Analysis of controls on the discharges of oil at sea. Proceedings of the Canadian Transportation Research Forum, Quebec City, May 1974.

[7]Burrows and others, "Operational dumping and the pollution of the sea by oil: An evaluation of preventive measures" Journal of Environmental Economics and Management, 1: 202-218, 1974.

[8]By U.S. law, U.S. Domestic trade is open to U.S. vessels only.

[9]U.S. Coast Guard, Final Environmental Impact Statement: Regulations for tank vessels engaged in the carriage of oil in domestic trade. (Washington D.C. August 1975)

CHAPTER 2

TANKER OPERATIONAL POLLUTION CONTROL

2.1 GENERAL

Tanker operational oil pollution mainly arises through the disposal of the oil and water mixtures generated during tank cleaning and ballasting operations.

Tankers, like other ships also develop oily-water mixtures in their machinery bilges and these mixtures create pollution problems. While these bilge discharges are a source of pollution, they are not dealt with in this study as they are not specific to tankers. Tankers are only responsible for a limited fraction of bilge discharges (as shown in table (2)).

Tanker operations also generate air and sea pollution by oil through cargo evaporation and fuel combustion.[1] TABLE 2 indicates that cargo evaporation actually represents a significant amount of oil relative to the total amount of oil discharged operationally by tankers. While this is not considered as a significant source of marine pollution, it may create serious air pollution problems in harbour areas. Regarding fuel combustion, available estimates[2] suggest that the amount of unburned oil emitted as a result of fuel combustion is negligible. In any event, these last two sources of pollution have been given very little attention and there does not seem to be any attempt to control them. Accodingly, they are not considered here.

TABLE 2

SHIP OPERATIONAL DISCHARGES

OF OIL

SOURCE

SOURCE	ESTIMATED OIL INPUT TONS/YEAR
Tanker cleaning and ballasting[a] (including drydocking)	1,330,000
Tanker machinery bilges[a]	50,000
Machinery bilges from other ships[a]	450,000
Tanker cargo evaporation losses[b]	300,000
Fuel combustion[b] (unburned fuel)	negligible

[a]Source: National Academy of Sciences, 1975, p.6.

[b]These estimates are derived from U.S. Department of Commerce, Maritime Administration, Survey of ship discharges, 1974.

Focusing now on tank cleaning and ballasting operations, it must be noted that, while all oil tankers have to perform these operations routinely, the ballasting and cleaning requirements and methods differ widely depending on whether the vessel is a crude oil tanker, a product tanker carrying refined oil products, or a combination carrier (or OBO tanker) alternating oil and other bulk products, such as ore or grain. This study focuses mainly on crude oil tankers, since the crude oil traffic represents more than 80 per cent of all oil traffic.[3] However, the pollution control techniques available for product or OBO tankers can be applied to crude oil tankers (the reverse being not true). These techniques are dealt with here, therefore, and the specific problems posed by OBO and product vessels discussed although in rather more general terms.

2.2 THE CASE OF NO POLLUTION CONTROL

A typical operational scheme for a tanker not practicing pollution control procedures would be as follows.

(1) Starting after or during cargo unloading at the port, the appropriate quantity of ballast water is loaded directly into cargo tanks so as to ensure safe operation of the ship and proper propeller immersion. The ballast water mixes with the oily residues in the tanks to form dirty ballast.

(2) A suitable number of tanks are cleaned while at sea with the oily washwaters being discharged to the sea.

(3) In order to avoid considerable pollution of harbour waters at the loading port, the dirty ballast is dumped while at sea.[4] At the same time, the proper quantity of clean ballast water is taken into cleaned tanks so that the trip may be completed in good conditions.

(4) The clean ballast, which is generally suitable for disposal in harbour waters is discharged at the port prior to or during cargo loading.

(5) On the return trip, the tanker is filled with cargo; tank cleaning or ballasting is no longer needed.

2.2.1 Clingage

The commonly used term of "clingage" refers to the total amount of oil left in the vessel after discharge. It includes the cargo retained on tank surfaces, the sludge deposits on tank bottoms and inside structures and the oil remaining in the piping system after cargo discharge.

The clingage may be as low as .1% of deadweight (DWT) for light oils and as high as 1.5% of DWT for very heavy products such as residual fuel oil.[5] For crude oils, a typical figure is .4% of DWT, or 800 tons, on a 200,000 DWT tons VLCC;[6] but it can vary highly depending on the following factors.

(a) Type of oil--A high wax content will yield waxy sediments. A high viscosity or a high pour point will make it difficult to strip the tanks at the end of cargo discharge.

(b) Internal structure of the tanks--Smooth surfaces limit the build-up of residues. The clingage tends to be relatively smaller in center tanks than in the structurally more complex wing tanks.

(c) Type of tank coating--This affects the adherence of the oil on tank surfaces.

(d) Stripping capability and conditions--The drainage of the tanks may be more or less effective depending on the type of stripping pumps, and the conditions (temperature, vessel trim....) during discharge.

(e) Stripping procedure--Generally the procedure used to strip the cargo maximizes the amount of oil discharged ashore and, therefore, minimizes the amount retained in the ship. In particular, the larger cargo lines are drained into a tank where the stripping pumps are employed to send as much of the oil as possible ashore. Some ships, however, deliberately curtail the stripping procedure particularly when tanker time is considered to be at a greater primium than the receipt of the last possible ton of cargo.

(f) Trip conditions--The amount of waxy deposits is a function of time the cargo is in the ship and the temperature of the cargo. Long voyages and low temperatures result in higher clingage values.

2.2.2 Ballasting Operations

Ballast is needed to provide the ship with proper manoeuvrability and stability characteristics, to avoid structural damages under severe weather conditions, and to ensure general crew comfort. Ballasting practices vary widely from ship to ship as they depend upon the ship's characteristics, such as size and proportions, and the shipmaster's experience.

According to various sources,[7] the volume of ballast carried aboard the ship under current practice may be as low as 20% and as high as 65% of the ship's deadweight capacity.[8] However, there appears to be two basic conditions, one for normal weather (Beaufort 5 or less) and the other for rough weather. On the average, the amount of ballast will be roughly between 35% and 40% of the deadweight capacity under good weather conditions and between 50% and 60% when heavy weather is expected (with the lower figure under each case generally corresponding to the larger ships).

All this ballast is not carried in dirty cargo tanks. Most ships are provided with special tanks primarily fitted to reduce the maximum stresses but capable of carrying some clean ballast, known as the segregated ballast. The segregated ballast capacity typically represents 10-12% of the deadweight capacity on a conventional VLCC and 15-20% on smaller ships. As a result the dirty ballast will amount to 20-25% of the deadweight capacity under good weather conditions and 35-40% when rough weather is expected, whatever the ship size.

It has been estimated[9] that 80% of the clingage remaining in the tank is discharged to the sea when dirty ballast is discharged overboard in the absence of pollution control procedures. In addition, most of the oil left in the ship's piping system will be washed out upon deballasting. This oil may represent up to 90% of the total clingage for light oil tankers[10] while according to one expert[11] a typical figure would be 10 per cent for crude oil tankers.

TABLE (3) summarizes the above figures and shows the average oil discharge from deballasting operations for a conventional crude oil tanker not practicing pollution control procedures. Given that none of the relevant parameters (clingage value, dirty ballast requirements...) is significantly affected by tanker size, it is clear from the calculations described in TABLE (3) that the average oil discharge from deballasting operations is roughly proportional to tanker size. Accordingly, the calculations are only made here for a basic size of 100,000 deadweight tons. They show that a 100,000 DST tanker discharges 105 to 148 tons of oil (per trip) in the average, during deballasting, unless pollution control procedures are followed. A 200,000 DWT tanker would discharge twice as much.

TABLE 3

AVERAGE DISCHARGE DURING DEBALLASTING OPERATIONS FOR A 100,000 DWT CRUDE OIL TANKER NOT PRACTICING POLLUTION CONTROL PROCEDURES

	GOOD WEATHER	BAD WEATHER
Clingage		
- Tanks	360 tons	360 tons
- Piping system	40 tons	40 tons
- Total	400 tons	400 tons
Capacity of dirty Ballast tanks (DBT) as a percentage of deadweight capacity	20-25%	35-40%
Average oil discharge during deballasting operations		
- piping system	40 tons/trip	40 tons/trip
- dirty ballast	65 tons/trip	108 tons/trip
(80% per cent of clingage in DBT)		
- Total	105 tons/trip	148 tons/trip

2.2.3 Tank Cleaning Operations

The need for cleaning cargo tanks arises for the following reasons:

a) To prepare the cargo tanks intended for clean ballast.

b) To prevent or minimize the accumulation of cargo sediments.

c) To allow routine tank inspection and maintenance in safe-for-men conditions.

d) To prepare the cargo tanks for a new cargo (change of cargo)

e) To prepare the ship for shipyard repair and periodical overhaul (tanker drydocking).

2.2.3.1 Tanker Drydocking

A ship entering drydock for repair or overhaul has to be completely free of oily residues. Ships not practicing pollution control procedures will be cleaned entirely while at sea and the oily washwaters will be discharged overboard.

According to Theobald,[12] "although it has been claimed that with modern paintings ships will drydock once very 13 months or even every 2 years, the experience so far shows that on account of breakdowns, incidents and other contingencies, ships undergo a repair work on average every year." Therefore, assuming as previously that the clingage represents .4% of the deadweight, a 100,000 DWT crude oil tanker not practicing pollution control procedures will discharge on the average 400 tons of oil per year due to drydocking requirements.

2.2.3.2 Change of Cargo

In general, product tankers can not mix the next cargo with the residues of the previous one. (This is also true for OBO tankers shifting from crude oil to another bulk product. In such cases, the tanks previously used for oil have to be cleaned during the ballast voyage, prior to loading the new cargo). This means that the clingage (100 to 1,500 tons of oil for a 100,000 DWT tanker) is discharged overboard unless control procedures are adopted. On the other hand, it is not necessary on crude oil tankers to clean all the tanks prior to loading because it is possible to mix a crude oil cargo with residues from another one. As a result, on crude oil tankers the number of tanks to be cleaned on a routine voyage will not exceed that required for sediment control, routine maintenance and clean ballast.

2.2.3.3 Routine cleaning on crude oil tankers

According to the above section on ballasting operations, the tank capacity to be washed for clean ballast purposes represents under current practice, 20-25% of the deadweight capacity in good weather and 35-40% when rough weather is expected. Some additional tanks may also have to be cleaned for sediment control or routine maintenance. "Where sediment buildup does not create severe operational problems, washing for sediment control may be concentrated on the last few voyages before scheduled shipyard repair".[13]

The most common practice, however, is to wash several tanks on each ballast voyage so that all tanks are washed every five to six voyages. Since center tanks are most easily cleaned, they are generally washed in rotation for clean ballast. Typically one additional pair of wing tanks, representing 5-10% of the deadweight capacity is also washed, primarily for residue control and routine maintenance but it is used for clean ballast in case of bad weather. On vessels not practicing pollution control procedure, the totality of the clingage remaining in the tank is discharged to the sea when the tank is washed. TABLE 4 describes the resulting pollution: A 100,000 DWT tanker discharges 108 to 135 tons of oil (per trip), on the average, during cleaning, unless pollution control procedures are followed.

2.2.4 The case of No Pollution Control: Summary

Product tankers (and OBO vessels shifting from crude oil to another bulk product) have to get rid of the oil left in the tanks and piping system. Depending on the clingage this represents between 100 and 1,500 tons of oil for a 100,000 DWT tanker. These are simply dumped overboard in the absence of pollution control procedures.

A crude oil tanker sailing for drydock also has to get rid of all its oily residues. Typically, the resulting discharges for a 100,000 DWT crude oil tanker not practicing pollution control procedures contains something in the order of 400 tons of oil. This happens approximately once a year.

On a routine voyage, however, crude oil tankers discharge only a fraction of their clingage at sea even in the absence of pollution control procedures. TABLE 5 summarizes these routine discharges for a 100,000 DWT crude oil tanker. According to this TABLE, depending on the weather, 50 to 75% of the clingage (or 200 to 300 tons of oil for 100,000 DWT tanker) will be discharged on the ballast voyage unless control procedures are adopted. Bad weather increases the discharge of oil by about one third.

2.3 TECHNIQUES FOR CONTROLLING TANKER OPERATIONAL POLLUTION: A GENERAL REVIEW

There are two basic ways to reduce tanker operational discharges of oil. The first one consists of processing the oily water mixtures generated

TABLE 4

AVERAGE DISCHARGE DURING TANK CLEANING OPERATIONS
FOR A 100,000 DWT CRUDE OIL TANKER NOT
PRACTICING POLLUTION CONTROL PROCEDURES

	Good Weather	Bad Weather
Total clingage in tanks	360 tons	360 tons
Tank Capacity to be cleaned (% of DWT)		
- Clean Ballast	20-25%	35-40%
- Residue control and routine maintenance	5-10%	0%
- Total	25-35%	35-40%
Average oil discharge during tank cleaning (100% of clingage in cleaned tanks)	108 tons/trip	135 tons/trip

TABLE 5

OPERATIONAL OIL DISCHARGE PER TRIP FOR A 100,000 DWT CRUDE OIL TANKER NOT PRACTICING POLLUTION CONTROL PROCEDURES

	Good Weather	Bad Weather
Total clingage (.4% of DWT)	400 tons/trip	400 tons/ trip
Oil discharge from deballasting operations		
- piping system	40 tons/trip	40 tons/trip
- dirty ballast tanks	65 tons/trip	108 tons/trip
- total	105/tons/trip	148 tons/trip
Oil discharge from cleaning operations	108 tons/trip	135 tons/trip
Total operational oil discharge	213 tons/trip	283 tons/trip

by ballasting and cleaning operations in order to reduce the oil content of these mixtures before discharge.

The second way addresses the problem at its source. It basically consists of reducing the amounts of dirty ballast and washwaters to be handled or the amount of oil that may enter in contact with water. In other words, it reduces potential pollution.

2.3.1 Treatment of oily mixtures

Dirty ballast and oily washwaters may be treated either on the shore or on the ship, or on both. Treatment on the shore involves special facilities where the oil is separated from the water by some chemical or physical process.

Most ships, however are equipped to treat their oil mixtures directly on board through the "retention-on-board" system (ROB). Under this system, the mixtures are allowed to settle for a sufficient time so that the oil separates from the water. Thus, only relatively clean water is drawn off from the bottom of the settling tanks. The retained oil, and its residual saltwater may then be discharged ashore for further treatment and processing. In fact, however, since the residual mixture of crude oil and saltwater is generally compatible with a new cargo of crude oil, most crude oil tankers use a variant of the ROB system, called the "Loan-on-Top" system (LOT) under which the retained residues are blended into the new cargo loaded on top of the residues.

2.3.2 Reducing potential tanker operational pollution

The most obvious way to reduce the potential pollution from ballasting operations is to reduce total ballast requirements; lighter tanker ballasting practices are indeed seriously contemplated by present tanker operators.[14]

Alternatively, dirty ballast requirements may be reduced by equipping the ship with additional segregated ballast capacity. This technique has been given considerable attention since 1970. The 1973 IMCO Convention for the Prevention of pollution from ships requires its implement= ation for new tankers over 70,000 DWT tons. The implementation on existing vessels is presently discussed at IMCO.[15] A third way would be to "back-carry" an adequate amount of oil to serve as ballast. Given the present tanker surplus capacity, this is presently considered as one possible short-term solution to the ballast pollution problem.

Clearly, these techniques would also reduce tank cleaning require- ments as the number of tanks to be cleaned for clean ballast would be reduced. However, even assuming that the clean ballast problem is completely eliminated, tanker operators would still be faced with the problem of cleaning for residue control, routine maintenance, shipyard repair and change of cargo. As a result, other techniques have been sought to reduce cleaning requirements. A recently developed technique has proven to be very effective in this regard. This is the crude washing technique[16] under which crude oil is used as the washing fluid to wash cargo tanks during cargo discharge. Acting as a solvant, crude oil dissolves sludge and sediments and allows their movement out of the tank with the cargo being discharged.

Crude washing is generally sufficient for controlling sediment build-up and preparing the tanks for routine maintenance. Since some free oil remains in the tanks after crude washing, water washing is still required for clean ballast or drydocking. In this case, however, it may be kept to a minimum due to the absence of sludge and sediments. Finally, the oil content of dirty ballast and washwaters will be small after crude washing due to the reduced clingage. This makes subsequent treatment easier.

There are other techniques to reduce the clingage. Smoother tank designs, special tank coatings and more efficient tank stripping at the unloading port may also achieve this result,and, therefore, reduce the frequency of water cleaning and the contamination of whatever oily mixtures are generated.

Finally, an attractive technique to reduce the amount of oily washwater to be handled is to use a closed washing system which recirculates the washwater, thus reducing the amount to be handled by up to 10 times. A similar result may be achieved by using stripping pumps instead of eductors[17] to strip tank washings from the tanks being washed. This will eliminate the need for contaminating the large amounts of fresh seawater which are required to drive the eductors.

It must be noted that the use of crude washing or closed washing techniques may affect tanker safety because they create an explosion hazard. In fact, these techniques may only be used on tankers equipped with a special anti-explosion system called inert gas system.

2.3.3 Other techniques

The above two basic approaches to reduce tanker operational pollution can clearly be combined. For example, this may involve the use of ROB procedures and shore treatment facilities together with crude washing and segregated ballast techniques. One particular technique, however, is in itself a combination of both approaches. It consists of cleaning the tanks at the unloading port before ballasting, using a shorettreatment facility to handle the oily washwaters. An interesting feature of this technique, which is currently implemented in a major mediterranean port,[18] is that it reduces or eliminates the need for dirty ballast.

Other techniques have been imagined but these are generally not considered as practical at this time. For example, there have been experiments of breeding micro-organisms which will attack and break down oil mixed with water. The feasibility of this approach is still quite uncertain and it is not considered here. The possibility of fitting the tanks wwith flexible impermeable membranes to isolate oil from tank surfaces has also been considered. This would eliminate the dirty ballast problem and reduce cleaning requirement to the occasional cleaning of the membranes. However, due to the complex internal structure of the tanks, technical difficulties made this approach inappropriate.[19]

It must be noted to conclude this section, that the above techniques may be, and are already in practice, combined in a number of ways. The next sections will examine current practices, problems and proposals, which will make it possible to isolate relevant alternatives for further investigation.

2.4. Current practices[20]

The disposal of oil from tankers had been a matter of international concern for many years. Yet, the first international conference to produce an international treaty on the topic was only held in 1954. This treaty, the"International Convention for the Prevention of Pollution of the Sea by Oil' entered into force in 1958. In 1962, IMCO convened another international conference to strengthen the 1954 regulations. The 1954 Convention, as amended in 1962, became international law in 1967. It is still existing law on the subjecttof tanker operational pollution.

It is widely recognized in government as well as in industry circles that this law has had no significant impact on tanker pollution. This is for the following reasons.

a) The 1954 convention and 1962 amendments are only concerned with so-called persistent or heavy oils, that is, crude oil, fuel oil, heavy diesel oil and lubricating oil. There is no limitation on the discharge of non persistent light oils.

b) As regards persistent oils, the 1954 convention, as amended in 1962, permits any discharge having an oil content less than 100 parts per million (100 ppm). More importantly, all tankers built prior to entry into force (1967) and all new tankers under 20,000 gross tons are permitted to dump unlimited quantities of oil outside of specified prohibited zones (50 to 100 miles from land).

c) For new tankers above 20,000 gross tons compliance with the law may be achieved in two ways: (1) the oily water mixtures are discharged into some shore facility or (2) the oily mixtures are handled through the LOT system, using an oil-in-water monitor to keep the oil content of the discharge below the 100 ppm limit. Accordingly, compliance with the law is generally not possible since the required shore facilities are usually lacking or inadequate and since only a few ships are equipped with a reliable monitor (monitors are not required under current law).

d) The use of a shore facility involves additional costs and delays. Even when such facility is available, it is always financially preferable to handle oily mixtures while at sea. Until implementation of the LOT system, most common practice was simply to dump at sea. Given available technology, it was, and it is still, extremely difficult to prove violation of the 100 ppm limit. In any case, sanctions are rarely severe as they are left to the discretion of the flag-state administration. Coastal and port states are powerless unless the violation is proved to have occurred in their territorial waters (12 miles from the shore).

In the early 60's it became evident to the oil and shipping industry that, in view of the dramatic growth in tanker traffic, the ever increasing tanker size and the rising public concern over pollution matters, something had to be done to control effectively tanker operational pollution. To prevent individual countries taking severe and costly measures to protect their marine environment, the industry began to promote the use of the LOT system.

In 1969 the IMCO assembly adopted amendments to the 1954 Convention. The amendments established standards within which the use of LOT would be possible. By specifying a limitation on total quantity of oil discharged by ballast voyage (1/15000 of deadweight) it made the use of ROB procedures compulsory in practice. By prohibiting any discharge within 50 miles from land, it made enforcement easier since it was no longer necessary to measure the oil content to prove violation within the 50 miles zone. A detailed oil record book was also required which would further simplify enforcement as routine inspections of the vessel and oil record book made it possible to prove definite violations.

Finally, outside of the 50 miles zone, no dumping of oil was permitted and the 100 ppm limit for larger tankers was replaced by a "60 liters of oil per mile" limit for all tankers, which prevented a vessel to discharge large quantities of oil while at anchor.

Despite the fact that most tankers are now practicing retention on board procedures,[21] the 1969 amendments have not come into force yet. This is due to the following reasons:

- A large number of signatures are needed before the 1969 amendments are effective twelve months later (at least 32 nations must ratify).

- The process of implementation of international conventions has always been slow, because of governmental and parliamentary inertia.

- The use of LOT is impossible in some cases (short voyages, drydocking, cargo change) so that the 1969 amendments imply the costly use of expensive shore facilities.

- Some countries are not satisfied with the LOT system because it is subject to international and accidental failures, and therefore viewed as uneffective to protect the marine environment.

In view of the previous facts, it is now appropriate to look in some detail at the LOT system. This will permit a better understanding of current proposals.

2.5 THE LOT SYSTEM

2.5.1 The LOT procedure

The basic LOT procedure may be described as follows:

1) At the port, the appropriate quantity of ballast water is loaded into dirty tanks and the remaining oil in the piping system is flushed into these tanks.

2) A suitable number of tanks are cleaned with water. The oily washwater is sent to a holding tank called the slop tank. In the slop tank, the oil separates from the water and the relatively clean water is drawn regularly from the bottom of the tank so that there is always enough capacity left in the tank.

3) New ballast is taken into clean tanks and the clean part of the

settled dirty ballast is drawn from the bottom of the dirty ballast tanks. The oily layer on the top of the dirty ballast is sent to the slop tank for further separation.

4) The oily residues or slops transferred to the slop tank are allowed to separate out, and again the relatively clean water is discharged to the sea.

5) At the loading port, the clean ballast is pumped out and the new cargo is loaded on top of the slops. Alternatively, the slops may be discharged to a slop reception facility on the shore.

2.5.2 The effectiveness of the LOT system

If enough time is provided for the oily mixtures in the slop and dirty ballast tanks to separate out, it is generally agreed that the correct operation of LOT results in only one to five per cent of the oil contained in dirty ballast and washwaters being discharged to the sea. In other words, LOT is 95 to 99 per cent effective when used properly after sufficient settling time.[22]

The actual effectiveness of the LOT system is generally lower than indicated by the above figures. This is generally due to one or more of the following problems.

2.5.2.1 The short-haul problem

It is estimated that depending on weather and clingage conditions two to four days are necessary for a proper LOT operation.[23] On some trades such as those taking place within the Mediterranean or Baltic Seas, the ballast voyage requires less than 4 days unless the vessel is slowed down or diverted at a cost in time and money. In such cases, the separation process may not always be completed within the time available so that large quantities of oil are discharged with the settled water.

2.5.2.2 Destination of the slops

On most routine voyages, the slops are simply destined to be mixed with the next cargo. If, however, this is impossible for some reason, the ship has to get rid of its slops somewhere.

This is particularly relevant for tankers preparing for drydock or a change of cargo since they must be ultimately free of slops. This may also be a problem for vessels on the spot market as those are often required to arrive free of slops at the loading port.

In such cases, small tankers usually dump their slops in a non-prohibited zone while larger vessels are required under the existing law to use a slop reception facility at the port. Quite often, however, the facility is inadequate or simply not available so that the ship must go to another port or wait. To save time and money, many ships simply prefer to dump their slops while at sea. In this regard, Theobald indicated in 1972 that in repair harbours south of Brest more than 50 per cent of all tankers used to dump all their slops while at sea.[24]

2.5.2.3 Problems for tankers on routine long-haul trips

Even on routine long-haul voyages, the actual effectiveness of the LOT system is not as high as could be theoretically expected. In 1971 major oil companies investigated all tankers loading at two major loading terminals over a 6 months period. Virtually all vessels were operating on long-haul trades and purporting to perform LOT. But the investigation showed that, in fact, roughly "one-third of tankers inspected appeared to have performed LOT adequately, one-third were suspected of indifferent performance and the remaining third had made no attempt to retain their residues"[25]

Therefore the tankers surveyed were discharging, as a global average, about 50 per cent of the oil contained in dirty ballast and washwaters instead of the one to five per cent theoretically expected. This global performance was due to one or more of the following causes:

a) Human errors under difficult conditions--Under difficult conditions of sludge and wax accumulation or in unsuitable weather conditions adequate cleaning and separation are made longer and more arduous. As the men get tired, short cuts become more attractive and errors are made easily. If discharge is attempted before the separation process is complete so that the oil water interface is imprecise or inaccurately detected, serious pollution may occur.

b) Deliberate discharges--LOT may not only be arduous to operate it may also cost money and time. The cost is however not necessarily the same for all ships. Neither is the desirability to avoid pollution. As a consequence, under the same operating conditions, some ships will be less reluctant than others to discharge their oily residues. The "willingness to retain" will be determined by the following factors.

b1) Refinery policy--Some refineries are not equipped to handle oil with some salt water content and are reluctant therefore to accept slop contaminated crude. In such a case, the ship tends to minimize the amount of slops to be mixed with normal cargo. However, as some major oil fields get depleted saltwater is now found quite often in normal cargo so that most refineries are now equipped to handle salt contaminated cargo. In addition, with the dramatic increase in the price of oil, the value of the slops has greatly increased. As this material is not included in the bill of lading the refinery at most pays the freight on it, which makes it a very profitable material for this refinery. As a result most refineries no longer emphasize slop minimization.

b2) Company policy--Some companies are more disposed than others to insist upon the effective use of LOT in the instructions given to the ships they control. This may come from a genuine concern for the environment or from the desire to maintain a good image in the public and to inhibit the efforts of environmentalist lobbying groups.

In this regard it is generally considered that some oil companies are more anxious to preserve their image than specialized shipping firms because they are generally the first to suffer from the public's resentment. This is actually one of the reasons why integrated oil interests have set up a routine loading port inspection at the terminals which they operate. The inspection applies to oil company owned ships as well as to chartered ships and permits the identification of ships which definitely do not use LOT effectively by comparing the content of the slop tank with a theoretical minimum derived from a simple formula.[26] Repeated low performances give rise to protestation to the ship, its owner or its charterer, as appropriate. This puts a definite pressure on ships controlled by oil companies while other ships may more easily ignore the protest.

In this regard, according to Holdsworth, the oil company route inspection scheme showed that in 1975 oil companies owned ships were retaining roughly 50 per cent more slops than other ships (.45 per cent of the deadweight capacity versus .30 per cent on the average). Assuming no significant differences in operating conditions between both types of ships and assuming that oil company owned ships always operate LOT properly, that is, they are roughly 95 per cent effective, the other ships would be approximately 65 per cent effective on the average. Given that oil companies owned tankers only represent one-third of the world's tanker fleet a global estimate would be that LOT is only 75 per cent effective in practice on route long-haul trips. To compare the National Academy of Sciences used a 90 per cent figure to reach its worldwide oil input estimates.[27] The oil company operated routine inspection scheme partly explains why oil company ships tend to achieve better LOT performances than other ships. Another explanation is that good LOT performances have become financially desirable for ships controlled by integrated oil interests since they generate profits at the refinery. On the contrary, the LOT performance is at best financially indifferent for independent shipping firms if the freight is paid on the slops and definitely undesirable if this freight is not piad.

b3) Pollution prevention rules and enforcement--Current international law provides very little incentive to use LOT properly. Some countries, however, have already implemented the 1969 amendments which essentially require the proper use of LOT and prohibit any discharge within 50 miles from land. Ships sailing under the flag or in the waters of these countries will tend to be more reluctant to discharge their slops than other ships. This also holds for the 1973 convention which, inter alia, reproduces the 1969 amendments. The actual impact of the 1969 amendments and 1973 convention on LOT performances will depend ultimately upon the enforcement policies of the ratifying countries.

2.5.3 Improving LOT performances

It is generally considered in oil and shipping industry circles that whenever LOT can be properly used and enforced, it is the most practical and least expensive solution to the operational pollution problem. According to this view LOT should be the cornerstone of any control policy: other means such as segregated ballast tanks and shore treatment facilities are just useful to supplement LOT and simplify its operation. Hence, all steps should be taken to improve the effectiveness of LOT and promote its correct use. This would keep individual countries from imposing unnecessarily costly measures and protect the good tanker operators against irresponsible ones.[28]

To improve LOT performances, the industry and some governments have undertaken various programs to make the operation of LOT easier. These involve the development of control and monitoring equipment, such as oil-water separators, oil content monitors and oil-water interface detectors. The separation process may also be speeded up through improved pumping systems and slop tank design which prevent the formation of difficult-to-break oil-water emulsions. All these equipments and improvements constitute what may be referred to as the improved LOT (or ROB) system. Under this improved LOT system, unintentional discharges during LOT operations should be virtually eliminated. It must be noted, however, that fully reliable control and monitoring equipment is still not available.

It is generally considered in the oil and shipping industry that voluntary inspection schemes at oil company operated ports only have limited results since the industry has no compelling sanction in most cases. In addition, a majority of crude loading ports are now under governmental control. For these reasons, the industry supports any move towards governmental enforcement and in particular towards the effective implementation of the 1969 amendments (or 1973 Convention). This may take some time, however, and it is felt in the industry that further progress should be made in the interim period to prevent stringent unilateral regulations by individual countries. Thus, another voluntary scheme has been recently developed under which the owner and charterer may agree as part of their contract, to conduct all operations under their respective control in accordance with good ROB standards.[29] This requires in particular the charterer to pay the owner any incurred deadfreight or loss of time, as well as the freight on the slops. Thus, there should be no financial incentive for the chartered vessel to discharge its slops (and provided the ROB or LOT operation is easy enough, no incentive at all).

TABLE 6

Average Oil Pollution Inputs for a 100,000 DWT
Crude Oil Tanker Using LOT or ROB procedures
on medium to Long-haul trades

	Good Weather	Bad Weather
EFFECTIVE ENFORCEMENT		
Conventional LOT	95% effective 10.5 tons/trip	90% effective 28 tons/trip
Improved LOT	97% effective 6.4 tons/trip	97% effective 8.5 tons/trip
NO EFFECTIVE ENFORCEMENT		
Conventional LOT	85% effective 32 tons/trip	75% effective 70 tons/trip
Improved LOT	90% effective 21 tons/trip	85% effective 42 tons/trip

2.5.4 LOT (or ROB) discharges

According to the above considerations, a vessel purporting to use LOT or ROB procedures may be discharging anything between 1% and 100% of the oil contained in dirty ballast and washwaters depending on the length of haul, the destination of the slops, the availability of adequate shore reception facilities, the weather and sludge conditions, the vessel's equipment, the vessel's company and charter contract, the rules and enforcement policies to which the vessel is submitted, and finally the ability of the crew.

On medium to long-haul trades, barring deliberate slop discharges, it is reasonable to assume that the conventional LOT or ROB system is 85 to 99% effective depending on weather and sludge conditions while the improved LOT or ROB system should be 95 to 99% effective.[30] An effective enforcement policy should preclude deliberate discharges. In the absence of enforcement, however, roughly 50 per cent of the vessels sailing for dry-dock dump their slops at sea and vessels on routine voyages are something like 75 to 90 per cent effective on the average.

TABLE 6 shows reasonable effectiveness estimates and the corresponding oil pollution inputs for a 100,000 DWT crude oil tanker. According to this table, an effective enforcement policy and the use of improved LOT procedures and equipments would reduce LOT discharges by 80 to 90 perccent. In the absence of an effective enforcement policy, however, the use of improved LOT reduces LOT discharges by only 30 to 40 per cent.

2.6 ALTERNATIVES TO CURRENT PRACTICES

2.6.1 The 1973 Convention

The international Convention for the Prevention of Pollution from ships, 1973, which will replace the 1954 Convention and amendments when coming into effect, has adopted the LOT system as its primary means for pollution prevention. However, it differs substantially from the 1969 amendments in the following respects.[31]

a) Discharges from non persistent oil tankers are subject to the same limitations as for other tankers.

b) The 1973 Convention requires that all tankers will be able to use improved LOT (or ROB) procedures, that is, they will be provided with approved discharge monitoring and control equipment and with special pumping system and slop tank arrangements. In addition all tankers must maintain a detailed oil record book.

c) New tankers over 70,000 DWT tons must be provided with sufficient segregated ballast capacity so that they do not have to carry dirty ballast except in very severe conditions. New tankers are those ordered after December 31, 1975 or delivered after December 31, 1979. This requirement is therefore not dependent upon entry into force of the convention (provided the convention will be ratified ultimately).

d) Within special areas (Mediterranean, Baltic, Black and Red Seas and Persian Gulf) no discharge at all will be permitted subject to the provision of adequate reception facilities for dirty ballast and washwater in special areas. Governments are required to ensure the provision of these facilities. In the absence of adequate facilities, the use of LOT or ROB procedures is required subject to the discharge standards applying outside of special areas.

e) The discharge standards outside of special areas are almost the same as under the 1969 amendments (except that they will also apply to all tankers carrying refined oils). Under these standards discharges are prohibited unless: (1) the tanker is proceeding en route; (2) it is more than 50 miles from land; (3) the rate of discharge does not exceed 60 litres per nautical mile; (4) the total quantity of oil discharged does not exceed 1/15,000 of the cargo tonnage for existing vessels and 1/30,000 for new tankers.

f) Ballast and washwater reception facilities are required at product loading terminals, repair port areas, as well as at crude oil loading terminals where tankers will have arrived without sufficient time to have completed the LOT operations. This is specified as a ballast voyage of less than 1000 miles or 72 hours. Governments are required to ensure the provision of these facilities.

g) Contracting states would be permitted to deny port entry to foreign vessels which are not in conformance with the convention regardless of whether they are registered in contracting states.

h) Finally, the implementation and amendment process is considerably simplified compared to previous agreements.

In spite of the simplified implementation process, there still seems to be little chance that the 1973 convention will be ratified in the near future. The main obstacle is the requirement for the port reception facilities. Such facilities are difficult to site due to safety, environmental and space availability problems. They are also very expensive. As international cooperation is required to locate and finance these facilities, political issues come to interfere, especially in such regions as the Mediterranean or Persian Gulf areas. As a result, the problem is likely to remain for many years.

The provisions of the 1973 Convention define a possible alternative to current practices. This alternative, which will be referred to as the IMCO alternative basically reflects the views of the international community. To summarize, it may be described as follows:

- additional Segregated Ballast Capacity on new tankers (ordered after December 31, 1975 or delivered after December 31, 1979) aver 70,000 DWT Tons.
- Shore Reception Facilities in special areas, on short haul trades and in drydocking ports.
- Improved LOT on medium to long-haul trades

2.6.2 The "industry alternative"

Members of the industry generally view the 1973 convention as a major step forward in the prevention of pollution from ships. However, since limited port reception facilities are likely to hinder ratification for many more years, they argue that it is preferable to rely on alternate methods and to build only a minimum number of small facilities to handle whatever residues cannot be handled otherwise. Alternate methods basically involve the use of improved LOT procedures together with one or more of the following techniques.

a) As a short-term solution, given currently depressed market conditions, ships may slow down or divert to allow sufficient settling time.

b) This unprofitable practice becomes very difficult to enforce as the market recovers. In the long-run, however, the dirty ballast problem will be reduced as new tankers will be provided with additional segregated ballast capacity. In addition, even on short haul routes, tank washings may be properly dealt with, provided their volume is kept small enough. In this regard the use of crude washing or recirculatory water washing should considerably simplify the ROB procedure. In particular, the combined use of crude washing and sufficient segregated ballast capacity would even eliminate the need for ROB operations except in very severe weather.

It must be noted, however, that crude washing and recirculatory washing techniques require an inert gas system to prevent possible explosions. It is often argued in the industry that most explosions have been caused by the high pressure washing pumps used on larger vessels so that it is not necessary to inert smaller tankers. According to various industry sources, most of the ships over 150,000 DWT ordered after a series of explosions had destroyed three VLCC's in late 1969 are equipped with an inert gas system.[32]

To summarize, the "industry alternative," which essentially reflects current industry trends, may be described as follows:

- additional segregated ballast for new vessels (ordered after December 31, 1975 or delivered after December 31, 1979 over 70,000 DWT Tons (same as IMCO).
- inert gas, crude washing and washwater recirculation on tankers delivered after 1970 and exceeding 150,000 DWT tons.
- On short-haul routes, other vessels are diverted when necessary to allow sufficient time for LOT to be operated.
- Improved LOT for all vessels

2.6.3 The "Environmentalists" alternative"

The 1973 Convention has been primarily criticized by environmentalists on the ground that it does not go far enough toward achieving the goal set up by the United Nations Conference on the Human Encironment, 1972, that is, complete elimination of operational pollution by oil and other harmful substances and the minimization of accidental discharges of such substances by the end of the present decate. According to this view, the best tanker pollution control policy is the one that minimizes pollution. As a result, they criticize the 1973 Convention on the following points:

a) Adequacy of the 1973 Convention standards--The environmentalists contend that one should not relay on ROB procedure or on port reception facilities to control tanker operational pollution. They consider that the creation of shore reception facilities basically transfer the pollution problem from the vessel to the shore, not to mention the fact that their construction poses difficult practical problems. Regarding LOT or ROB practices, they question in the first place whether the theoretical effectiveness of this system is sufficient to protect the environment. Going a step further, they argue that reliance on such practices should be kept to an absolute minimum as theoretical effectiveness will not be achieved due to the difficulty of enforcement and lack of adequate control and monitoring systems. The environmentalists view the segregated ballast technique as the most effective way to prevent operational pollution because this eliminate the ballast problem. They further argue that in the absence of dirty ballast, the effectiveness of ROB practices would be enhanced since the volume of tank washings may be kept small enough to permit an easy control of slop tank discharges (while the control of huge dirty ballast tank discharges is much more difficult).

b) Segregated Ballast and the Problem of "Grandfather rights"--The environmentalists are not satisfied with the 1973 Convention "Grandfather clause" according to which only new vessels have to meet the segregated ballast requirements. They argue that, given the present tanker surplus capacity, no new tanker will be built until some time in the 1980's so that the segregated ballast requirements will not have any significant impact on tanker pollution for many more years. They further argue that this grandfatehr clause will create an artificial incentive for tanker owners to prolong the use of their older and less environmentally desirable vessels.

Accordingly, they propose to convert existing vessels to segregated ballast vessels by converting some cargo tanks to segregated ballast tanks, arguing that the present massive surplus capacity provides an opportunity to realize the conversion at minimum cost.

c) Double bottoms=-Having advocated the generalization of segregated ballast requirements, the environmentalists further contend that on new vessels part of the additional segregated ballast capacity should be provided by means of a double-bottom. In their view, double-bottoms reduce the risk of accidental outflow in case of stranding and they should contribute a further reduction to operational pollution for the following reasons:

- the presence of double bottoms yields a smoothetank bottom so that the sludge build up is effectively mitigated and the need to wash the tank periodically is much reduced.
- double bottom makes it possible to strip the oil residues at the unloading port from below the tank. This feature makes the stripping system more efficient so that the clingage is further reduced.

d) Inert gas system--Finally, the environmentalists claim that the 1973 convention should have required all tankers to provided with an inert gas system to prevent explosions.[33]

While this claim is primarily made for safety reasons, it may be further justified by arguing that crude washing may only be used on inert tankers.

On the other hand, the provision of a crude washing system on double bottom tankers reduces the advantages of double bottoms as regards operational pollution, since the sludge buildup may be easily removed anyway. Accordingly, the double-bottom requirement may be viewed essentially as a safety feature, and disregarded from now on.

To summarize, the "environmentalists' alternative" which reflects the lobbying efforts of environmentalist groups may be described as follows:

- additional segregated ballast for all vessels.
- inert gas and crude washing for all vessels.
- improved LOT and recirculation of washwater for occasional ballasting and cleaning requirements.

2.6.4 Industry views of Environmentalists' Proposals

The views of the environmentalists as regards IMCO and industry proposals have been described in the previous section. It is now interesting to describe the views of the industry on the environmentalist's proposals.

a) Segregated Ballast Tankers--Segregated ballast tankers are expensive but their cost may be offset by the following advantages:

- segregated ballast tankers are much easier to operate: first, due to the segregated piping system, ballasting and deballasting operations can be done concurrently with loading or unloading cargo and their is no risk of polluting port waters with cargo or residues left in the piping system. Thus, time is saved and an important cause of headaches eliminated. In addition, the operation of LOT is much simplified on segregated ballast tankers and good LOT performances are easier to achieve, especially if crude washing is also used.

- Segregated ballast tanks provide some protection in case of collision or grounding. In addition segregated ballast tankers are less subject to structural failures because the presence of segregated ballast tanks will reduce structural stresses. (It is also known that the mixing of oil and water in dirty ballast tanks creates corrosive chemicals which are one of the causes of structural failures.)
- As long as the segregated ballast requirement applies in a uniform way to all tanker fleets, its net cost will be passed upon to oil consumers.

For these reasons, the segregated ballast provision of the 1973 Convention is generally viewed in the industry as an acceptable price that had to be paid to reach a necessary concensus. Extensions of this provision to new vessels under 70,000 DWT tons and to existing vessels are rejected however on the following grounds:

- smaller tankers (less than 70,000 DWT Tons) are generally used for products so that the provision of additional segregated ballast capacity would not reduce cleaning requirements.
- In view of the very slow process of implementation of international decisions, the worldwide conversion of existing tankers to segregated ballast tankers before the surplus capacity situation has disappeared is not practicable. As a result, those countries or companies implementing the proposal would be put at an unacceptable disadvantage. In addition, the implementation of the proposal would involve large capital outlays which would be very hard to finance after a lengthy

period of poor market conditions; clearly, the conversion would speed up market recovery,[34] but the industry generally argues that the benefits from increased freight rates are unlikely to occur rapidly enough to offset the high initial costs of conversion.

Understandable the proposal receives some support from the shipbuilding industry and from a number of independent shipowners (which own most of the currently idle tanker capacity.)

b) Inert gas, crude washing and recirculation--Because crude washing reduces the clingage (and therefore increases the payload) and dramatically simplifies the cleaning task, it is increasingly considered in the industry that its implementation on inerted tankers pays for itself. The use of crude washing is particularly valuable when the ship has to be cleaned completely prior to drydock. In the absence of crude washing, the voyage to drydock does not generally allow sufficient time for cleaning all the tanks while using LOT properly. Thus, LOT is not used, or used improperly, which means considerable pollution; or, several days are lost in port to clean the tanks that could not be cleaned while at sea, which involves a high cost in terms of time, port charges and whatever manpower and facilities are required to handle hundreds of tons of residues. On the contrary, the use of crude washing prior to drydock requires at most one additional day at the unloading port with virtually no additional manpower. Then a simple LOT procedure while at sea permits the vessel to be completely clean when entering drydock. As an additional benefit to integrated oil companies, the residues end up at the company's refinery rather than at sea or at the drydock reception facility.

The introduction of a recirculatory washing system further simplifies the LOT and cleaning tasks and it is similarly considered as beneficial on inerted tankers.

Yet the decision to inert a ship is primarily taken on the basis of cost and safety considerations. In this regard, shipowners generally do not consider the provision of an inert gas system on smaller ships as economically warranted because explosions primarily occur on larger ships. The provision of an inert gas system on older ships is also considered to be uneconomic given the limited time available to recover the investment, and the increased cost of retrofitting compared to the cost of installing the same system on a new ship (taking into account the time lost in shipyard).

As a final point regarding alternatives to current practices it should be noted that the above controversies leave room for compromises. One possibility would be to implement the environmentalist's alternative on short=haul routes and within special areas while the industry alternative would apply to other routes and areas. This would place restrictions, however, on the transfers of tankers between trades.

2.7 Summary

This chapter has described alternate policies now available to control tanker operational pollution. Three basic alternatives are identified. These are (1) the IMCO alternative (2) the Industry alternative (3) the environmentalists' alternative.

Depending on the alternative, a given vessel may use one or more of the following techniques:

- LOT system
- Additional segregated ballast tanks
- Inert gas + Crude washing + recirculation
- Shore facilities

In the next chapter, each of these techniques is described in some detail to provide the background data to be used in the economic evaluation of the alternatives.

FOOTNOTES

CHAPTER 2

[1]Cargo evaporation losses primarily occur during cargo loading and ballasting operations at the crude loading terminal. See U.S. Department of Commerce, Maritime Administration, Survey of Ship Discharges, Report by EXXON Research and Engineering Company, Washington D.C., July 1974, pp. 6-15.

[2]Ibid., Compare Table 6 and Table 17.

[3]IMCO, Report on Study 4, p.4.

[4]This is actually a pollution prevention procedure.

[5]Victory, 6, The Load-on-Top System, Present and Future, Proceedings of the Symposium on Marine Pollution-Royal Institution of Naval Architects, London, 1973. See also; U.S. Department of Commerce, Maritime Administration, Tanker Tank Cleaning Research Program, p. 3-21 and 3-22.

Van Cleave H.D. and others, Techniques for Controlling Oil Discharge from Product oil Tankers, Proceedings of the IMCO Symposium on Prevention of Pollution from Ships, Acapulco, March 1976.

[6]VLCC = Very Large Crude Carrier

[7]See in particular IMCO, Report on Study 4, Clean Ballasting Before Sailing from Discharging Port, Schedule 18.

[8]In other words, the ballasted displacement is roughly comprised between 30% and 70% of the full load displacement.

[9]U.S. Coast-Guard, Regulations for U.S. Tank Vessels Carrying Oil in Foreign Trade and Foreign Trade Vessels that enter the Navigable waters of the United States, Appendix A.

[10]Van Cleave and others

[11]Captain Davies Patrick-(Shell Company) Personal Interview, London, April 1976.

[12]IMCO, Report on Study 4 (by P. Theobald), Section 5.3.4

[13]U.S. Department of Commerce, Maritime Administration, Tanker Tank Cleaning Research Program, Section 3.2.2.2

[illegible] N.O., Segregated Ballast and Related Aspe[illegible] Sym[illegible] Acapulco, 1976.

[14]See Gray, W.O., Segregated Ballast and Related Aspects of Tanker Design, IMCO Symposium, Acapulco, 1976.

[15]See IMCO, Introduction of Segregated Ballast in Existing Tankers.

[16]See Maybourn, R. Crude Oil Washing, IMCO Symposium, 1976.

[17]Eductors create a high velocity flow of seawater that draws the tank strippings to the slop tank.

[18]Port of Marseille, France (According to the World Tanker Fleet Review, December 1975). p. 11.

[19]Heaver, T.D. and Water, W.G.,An Economic Analysis of Controls on the Discharges of Oil at Sea.

[20]This section relies heavily on: Gray, W.O., The 1973 Convention: A Tanker Operator's viewpoint, Proceedings of the 1975 Conference on Prevention and Control of Oil Pollution, San Francisco, March 1975 and Victory, G. The Load on Top System Present and Future, and Zacher, The Politics of International Environmental Regulation: The Case of Oil Pollution Control.

[21]According to G. Victory, the LOT system is coping with more than 80 per cent of all crude oil traffic (Personal interview, London, March 1976.

[22]Sources: G. Victory, Personal Interview, London, March 1976 and C.L. Crane (EXXON Corporation) Personal Interview, New York, November, 1975.

[23]G. Victory, Personal Interview, London, March 1976.

[24]IMCO, Report on Study 4 (by P. Thsobald), Section 9.3.

[25]Holdsworth, M.P. Loading Port Inspection of Cargo Residue Retention by Tankers in Ballast, Proceedings of the IMCO Symposium on Prevention of Pollution from Ships, Acapulco, March 1976.

[26]This is an empirical formula given in the OCIMF/ICS Guide Monitoring Load-on-Top (London, 1973). OCIMF = Oil companies International Marine Forum.

[27]See Table 1 in this study and Table III

[28]In particular the U.S. and French Government

[29]See the Pollution Prevention Cole (oil Tankers) prepared by ICS, London, April 1976.

[30]It is estimated in the next chapter (TABLE 8) that improved LOT is at least 98 per cent effective when used properly.

[31] See Gray, W.O., The 1973 IMCO Convention: A Tanker Operator's Viewpoint, for a detailed discussion of the Convention.

[32] Walder, C.A. (OCIMF) and Cawley (British Petroleum), Personal Interviews, London, March 1976.

[33] In 1974 IMCO required new tankers above 100,000 DWT to be provided with an inert gas system. (1974 IMCO Convention for Safety of life at sea).

[34] The balance of supply and deamdn would be achieved about two years earlier (See IMCO, Introduction of Segregated Ballast in Existing Tankers.) Also Personal Interview with M. Holdworth, London, April 1976.

CHAPTER 3

TECHNIQUES TO CONTROL TANKER OPERATIONAL POLLUTION

The objective of this chapter is to describe the various techniques to control tanker operational pollution and to provide a data base for the economic evaluation of alternative control policies. The first sections provide estimates of costs and oil pollution inputs for each technique (or combination of techniques), assuming that these techniques are used properly (so that intentionall discharges are kept to a minimum). The actual costs and oil pollution inputs depend upon the enforcement policy. This is developed in the last section.

3.1 IMPROVED LOT

3.1.1 Routine oil discharges with improved Lot

The effectiveness of the LOT system may be improved significantly by installing on the ship reliable control and monitoring equipment, such as interface detectors, oil content monitors, oily water separators and automatic shutdown systems. Heavy oils (crude oils and fuel oils) and light oils (or nonpersistent oils) have different physical and chemical properties so that it has not been possible yet to design universal equipment that could be used with any sort of oil. The 1973 Convention requires a monitoring instrument for all tankers. In this regard, Gray noted (in 1975):

> Though seemingly a simple problem it has proven very difficult to reliably obtain accurate real time measurements of small quantities of oil in water. The problem is compounded by differences in oil make up, weathering, and the difference between dissolved and free oil in emulsion. Despite these drawbacks we feel that with the additional importance given to monitoring by the new convention, these problems should be capable of solution within a few years at least for heavy or persistent oils. In the case of non persistent (or light) oils, the monitoring problem is further compounded: so much so in fact that the 1973 convention contains a waiver if no monitoring instrument is available.[1]

The operation and control of the LOT (or ROB) system can be further simplified by installing a fixed piping system to allow transfer of dirty ballast residues and tank washings from the cargo tanks to the slop tank. Pipeline terminations may also be arranged to permit visual observation of discharges. Finally the slop tank capacity may be increased to allow a longer settling time.

Provided that (1) the discharge is monitored properly (2) the pumping rate is reduced when the rate of oil discharge approaches 60 litres per nautical mile (IMCO standards) and (3) the discharge is stopped to allow additional settling time before the 60 litres limit is exceeded, the oil content of the slop tank discharge is about 150 ppm while the oil content of the dirty ballast discharge is about 30 ppm.[2]

The total oil pollution input clearly depends upon the amount of contaminated water to be handled. The tank washings can be stripped from cargo tanks to the slop tanks using either stripping pumps or eductors. Eductors require large amounts of drive water and, therefore, generate three to four times as much contaminated water as stripping pumps. TABLE 8 shows average oil pollution inputs on routine trips for a conventional 100,000 DWT crude oil tanker. The calculations are made in annex A. TABLE 8 shows that when the improved LOT procedure is used properly, it is, on the average, more

TABLE 8

THE EFFECTIVENESS OF PROPERLY USED IMPROVED LOT PROCEDURES

	GOOD WEATHER	BAD WEATHER
Improved LOT without Eductors		
- Amount of oil discharged	1.5 tons/trip[b]	2.4 tons/trip[b]
- Effectiveness relative to no pollution control	99.3%[a]	99.2%[a]
Improved LOT with Eductors		
- Amount of oil discharged	3.2 tons/trip[b]	4.4 tons/trip[b]
- Effectiveness relative to no pollution control	98.5%[a]	98.4%[a]

[a] Using Table 5; The effectiveness is the percentage of oil retained relative to no pollution control.

[b] See Annex A

than 98 per cent effective, even when eductors are used. To compare, provided that intentional discharges are kept to a minimum, the conventional LOT procedure (visual checking of discharges, no automatic control of pumping rate) is 85 to 99 per cent effective, on the average, depending on weather, clingage conditions, and crew ability.

3.1.2 <u>The cost of Improved LOT</u>

a) Equipment costs--The U.S. Coast Guard recently estimated the cost of piping changes and monitoring and control equipment at $200,000 per ship (for all tankers).

b) Operating costs--The following definitions will be used in this study to estimate the impact of pollution control techniques on tanker operating costs.

- deadweight: a measure of the total carrying capacity of a tanker in metric tons. The deadweight tonnage includes the weight of all cargo oil plus the weight of fuel, stores water and crew.
- cargo carrying capacity: A measure of the maximum amount of oil that can be carried in a tanker (in metric tons). The cargo carrying capacity is approximately equal to 95 per cent of the ship's deadweight.
- throughput (per trip or per year): A measure of the amount of oil actually delivered (per trip or per year) by a tanker (in metric tons).
- Bill-of-lading weight: a measure of the amount of oil loaded on a tanker at the loading port (in metric tons) This is the measure used to calculate freight payments to tanker owners and payments to oil producers.

Pollution control does not affect the ship's deadweight or cargo carrying capacity but it reduces the ship's throughput and bill-of-lading weight.

When the LOT system is used, the slops remaining in the slop tank after final reduction contain approximately one-third of water. This water, which will be referred to as deadfreight water, and the clingage left in the ship after discharge reduce the ship's throughput. In addition, the slops and the clingage left in the ship after the ballast voyage reduce the bill-of-lading weight. The impact of improved LOT procedures on the throughput and bill-of-lading weight of a 100,000 DWT crude oil tanker is calculated in TABLE 9.

TABLE 9 shows that, when improved LOT is used properly, the ship's throughput is reduced by 105 to 139 tons per trip, on the average, relative to the case of no pollution control. This is entirely due to the deadfreight water in the slop tank. The bill-of-lading weight is reduced by 315 to 418 tons per trip, on the average, due to the slops in the slop tank.

At current freight rates (at most \$5 to \$6 per ton of crude[3]), the 315-318 tons reduction in the bill-of-lading weight means at most a \$1,500 to \$2,500 loss per trip to the shipowner and say two to five times as much during better market conditions.

The difference between the bill-of-lading weight and the ship's throughput is the amount of oil discharged to the sea each trip. This is also the amount lost by the refinery company each trip. For a 100,000 DWT crude oil tanker this amount is 213 to 283 tons per trip, on the average, in the absence of pollution control, and 2 to 4 tons per trip when improved LOT is used properly. Accordingly, the refinery company saves 209 to 281 tons of oil per trip when improved LOT is used properly. At current CIF prices of crude oil (about $80 per ton) the proper use of LOT on a 100,000 DWT crude oil tanker means a $16,500 to $22,500 gain to the refinery company, neglecting additional processing costs.

When the refinery pays the freight on the slops or when the ship and the refinery are owned by the same company, the gain to the refinery company is the sum of the above gains and losses, that is, at least $14,000 per trip at current freight rates and, at least, $4,000 per trip when market conditions improve (for a 100,000 DWT crude oil tanker), neglecting additional refinery processing cost and the costs of operating improved LOT properly.

To conclude, the proper use of LOT procedures is not only environmentally suitable but also financially desirable to refinery companies and integrated oil companies, provided that the additional refinery processing costs and the costs of operating LOT properly are negligible (or sufficiently small). The proper use of LOT is financially undesirable, however, to independent shipping companies, unless the freight is paid on the slops, and the costs of operating LOT properly are negligible, (in which case it is financially indifferent).

3.2 SEGREGATED BALLAST TANKERS

3.2.1 Routine oil discharges by segregated ballast tankers

3.2.1.1 Ballasting practices

Historically, the amount of ballast has been 35 to 40 per cent of the deadweight under good weather conditions and 50 to 60 per cent when heavy weather was expected.

TABLE 9

IMPACT OF IMPROVED LOT ON THE THROUGHPUT AND BILL-OF-LADING

WEIGHT OF A 100,000 DWT CRUDE OIL TANKER

Tons/Trip

	GOOD WEATHER	BAD WEATHER
NO POLLUTION CONTROL		
Throughput per trip		
- cargo carrying capacity	95,000	95,000
- lesssclingage left after cargo discharge	400	400
- total	94,600	94,600
Bill of Lading		
- cargo carrying capacity	95,000	95,000
- less clingage left after the ballast voyage	187[a]	117[a]
- total	94,813	94,883
IMPROVED LOT--PROPERLY USED		
Throughput per trip		
- cargo carrying capacity	95,000	95,000
- less clingage lefter after cargo discharge	400	400
- less deadfreight water	105[b]	139[b]
- total	94,495	94,461
Bill of Lading		
- cargo carrying capacity	95,000	95,000
- lesssclingage lefter after the ballast voyage	187	117
- less slops	315[c]	418[c]
- total	94,498	94,465

[a] Initial clingage less potential oil pollution--Table 5

[b] One-third of the slops--See footnote c

[c] 1.5 .985 of the oil pollution input shown in Table 5 (assuming one-third of deadfreight water and Improved LOT 98.5% effective).

The 1973 IMCO Convention provides that new tankers above 70,000 DWT be constructed with sufficient segregated ballast capacity to enable operation in normally severe weather. The Convention contains formulas which are intended to provide technical criteria and guidance for satisfactory segregated tanker designs. Tankers built in accordance with these formulas will have their segregated ballast capacity comprised between 30 and 40 per cent of the deadweight.[4] Under current ballasting practice IMCO segregated ballast tankers still have to take dirty ballast on board (about 15-20% of DWT) except in good weather (only 30% of the voyages from Europe to the Persian Gulf[5]). If new tankers are to avoid dirty ballast except in abnormally severe conditions (say 5% of all voyages from Europe to the Persian Gulf), lighter ballasting practices become desirable. Recent experiment showed that it is possible to operated at IMCO segregated ballast levels, without taking on dirty ballast, on more than 90 per cent of all ballast voyages.[6]

Lighter ballasting practices had not been tried earlier because there was no cost penalty associated with unlimited amounts of ballast (except for the adverse effect on speed, which was negligible until the recent large increases in fuel prices). Heavy ballasting practices now involve larger segregated ballast capacities and therefore significantly higher construction costs.

3.2.1.2 Deballasting operations

TABLE 10 summarizes the previous figures and shows the average oil discharges from deballasting for a 100,000 DWT crude oil segregated ballast tanker using improved LOT. No oil is discharged in good weather. In bad weather, the discharge depends on the ballasting practice and the effectiveness of improved LOT. Two cases are considered: (1) All ships used improved LOT properly and it is 98.5 per cent effective in the average; and (2) some ships do not operate improved LOT properly and it is 85 to 90 per cent effective, on the average, depending on weather conditions. These two cases correspond to the cases of effective enforcement and uneffective enforcement considered in Chapter. TABLE 10 shows that a 100,000 DWT crude oil tanker discharges .6 to 8.6 tons of oil during deballasting in bad weather conditions, depending on the effectiveness of improved LOT.

3.2.1.3 Cleaning operations

Segregated Ballast tankers will have to clean their tanks for routine maintenance, residue control, drydocking or change of cargo. On crude oil segregated ballast tankers, all tanks have to be washed every five to six voyages. In addition, some additional tank capacity must be cleaned to take on clean ballast in heavy weather. TABLE 11 shows the average oil discharges during tank cleaning for a 100,000 DWT crude oil segregated ballast tanker using improved LOT. Between 1.6 tons and 2.6 tons of oil are discharged each trip, when improved LOT is 98.5% effective; 10.3 to 26.2 tons of oil are discharged when improved LOT is only 85 to 90 per cent effective.

3.2.1.4 Summary

TABLE 12 summarizes previous results and shows the average oil discharges for a 100,000 DWT crude oil segregated ballast tanker using improved LOT. A total of 1.6 to 3.5 tons of oil are discharged each trip, when improved LOT is 98.5 per cent effective. But the oil discharge is comprised between 10.3 tons and 34.8 tons per trip when improved LOT is only

TABLE 10

AVERAGE OIL DISCHARGE FROM DEBALLASTING OPERATIONS FOR A 100,000 DWT CRUDE OIL SEGREGATED BALLAST TANKER USING IMPROVED LOT

	Good Weather	Bad Weather	Very Heavy Weather
Seg. ballast capacity (IMCO standards)	35% dwt	35% dwt	35% dwt
TRADITIONAL BALLASTING PRACTICE			
Dirty ballast	0	20% dwt	20% dwt
Oil in dirty ballast[a]	0	72 tons	72 tons
Potential oil pollution[b]	0	58 tons	58 tons
Oil Pollution during Deballasting			
- imp. LOT is 98.5% effective	0	.9 tons	.9 tons
- imp. LOT is 85 to 90% effective	0	8.6 tons	8.6 tons
LIGHTER BALLASTING PRACTICE			
Dirty ballast	0	0	15% dwt
Oil in dirty ballast	0	0	54 tons
Potential oil pollution	0	0	43 tons
Oil Pollution during Deballasting			
- imp. LOT 98.5% effective	0	0	.6 tons
- imp. LOT 85 to 90% effective	0	0	6.5 tons

[a]the total tank clingage is 360 tons (Chapter 2)

[b]This is the amount of pollution when LOT is not used at all (LOT zero per cent effective). 80% of the oil in dirty ballast is discharged to the sea.

TABLE 11

AVERAGE OIL DISCHARGES FROM TANK CLEANING FOR A 100,000 DWT CRUDE OIL SEGREGATED BALLAST TANKER USING IMPROVED LOT

Traditional Ballasting Practice

	Good Weather	Heavy Weather	Very Heavy Weather
% of dwt to be available for clean ballast	0	20% dwt	20% dwt
Total tank capacity to be cleaned (clean ballast plus residue control)	15-20% dwt	35-40% dwt	35-40% dwt
Clingage in tanks to be cleaned[a]	63 tons	135 tons	135 tons
Clingage in piping system[a]	40 tons	40 tons	40 tons
Potential pollution[b]	103 tons	175 tons	175 tons
Pollution with improved LOT 98.% effective	1.6 tons	2.6 tons	2.6 tons
Pollution with improved LOT 85% effective (heavy weather) 90% effective (good weather)	10.3 tons	26.2 tons	26.2 tons

TABLE 11
(Continued)

AVERAGE OIL DISCHARGES FROM TANK CLEANING FOR A 100,000 DWT

CRUDE OIL SEGREGATED BALLAST TANKER USING IMPROVED LOT

Lighter Ballasting Practice

	Good Weather	Heavy Weather	Very Heavy Weather
% of dwt to be available for clean ballast	0	0	15% dwt
Total tank capacity to be cleaned (clean ballast plus residual control)	15-20% dwt	15-20% dwt	30-35% dwt
Clingage in tanks to be cleaned[a]	63 tons	63 tons	117 tons
Clingage in piping system[a]	40 tons	40 tons	40 tons
Potential pollution[b]	103 tons	103 tons	157 tons
Pollution with improved LOT 93.98.5% effective	1.6 tons	1.6 tons	2.4 tons
Pollution with improved LOT 85% effective (heavy weather) 90% effective (good weather)	10.3 tons	15.4 tons	23.5 tons

[a]The total clingage in tank is 360 tons. The total clingage in piping system is 40 tons. Clingage from cleaned tanks is calculated on mean of per cent deadweight to be cleaned.

[b]Thus the amount of pollution when LOT is not used at all (100% of the oil in tanks to be cleaned and in piping system is discharged to the sea.

TABLE 12

AVERAGE OIL DISCHARGES FOR A 100,000 DWT CRUDE OIL SEGREGATED BALLAST TANKER USING IMPROVED LOT

(Tons/Routine Trip)

	Good Weather	Heavy Weather	Very Heavy Weather
TRADITIONAL BALLASTING PRACTICE			
Potential oil pollution[a]	103	233	233
ACTUAL OIL POLLUTION			
- LOT 98.5% effective	1.6	3.5	3.5
- LOT 85 to 90% effective	10.3	34.8	34.8
LIGHTER BALLASTING PRACTICE			
Potential oil pollution[a]	103	103	200
ACTUAL OIL POLLUTION			
- LOT 98.5% effective	1.6	1.6	3.0
- LOT 85 to 90% effective	10.3	15.4	30.0

[a]oil pollution when improved LOT is not used at all. The quantity of oil is the sum of oil in dirty ballast (Table 10) plus the oil from tank cleaning for clean ballast and for residue control (Table 11)

85-90 per cent effective. To compare, a 100,000 DWT conventional crude oil tanker discharges 213 to 283 tons of oil per trip, on the average, in the absence of pollution control.

3.2.2 The cost of segregated ballast tankers

3.2.2.1 New Ships

a) Construction costs--The construction costs of segregated ballast tankers were estimated in one of the major studies carried out for IMCO prior to the 1973 conference.[7] These estimates, as well as those obtained in the U.K. by Crighton and Telfer[8] are summarized in TABLE 13. The increase in construction costs to comply with IMCO segregated ballast requirements is less than 5 per cent for small ships (less than 100,000 DWT tons) and between 4 and 9 per cent for large ships.

In its background report on tankers,[9] the U.S. Congress provides actual increases in shipyard price for double-bottom tankers. These actual increases (2.5% to 4% for vessels in the 90,000 to 200,000 DWT tons range) suggest that the estimates in TABLE 13 are too high since, all other things being equal, double-bottom tankers are known to be generally more expensive than conventional segregated ballast tankers. This may not always be true since some shipyards may become specialized for double-bottom designs and require a higher price for conventional segregated ballast designs (segregated ballast in wing tanks or center tanks). In addition, these low actual increases in shipyard prices for double-bottom tankers may provide biased estimates of the additional cost brought about by double-bottom designs since as the double-bottom design is required by some individual countries, it will take a long time before new tankers are ordered). Finally it is not

TABLE 13

PERCENTAGE INCREASE IN CONSTRUCTION COST FOR SEGREGATED BALLAST TANKERS

Ship's Deadweight (M. tons)	Segregated Ballast Capacity (percentage of deadweight) 30	35	40	50	55
21[a]	2%	-	-	-	-
75[b]	-	-	-	-	4%
215[b]	-	8%	-	-	11%
250[a]	-	-	4%	-	10%
385[b]	-	-	-	-	13%
450[a]	-	9%	-	-	-
550[b]	-	-	-	-	12%

[a]IMCO, Report on Study I

[b]Crighton and Telfer, Segregated Ballast Tankers, Proceedings of the Symposium on Marine Pollution (Royal Institution of Naval Architects, London, 1973.

clear to the writer whether the segregated ballast capacity of the double-bottom tankers investigated is in compliance with IMCO requirements.

As a result, no definite conclusion can be drawn from the actual figures quoted above. In this study anuniform 5 per cent increase in construction cost has been assumed for new segregated ballast tankers complying with IMCO requirements.

b) Construction delays--The segregated ballast design does not generate any delays in shipyards unless the construction has already began when the decision to build additional segregated ballast capacity is made and last minute changes have to be made in work scheduling and material orders.

c) Operating costs--Due to the more complex piping system and the increased internal tankage area, maintenance and repair costs are higher for segregated ballast tankers. Based on IMCO study 1, a 6 per cent increase is assumed in this study.

On the other hand, since ballasting and deballasting operations may be performed while loading or unloading cargo without risking port pollution (due to the segregated ballast piping system) segregated ballast tankers tend to spend less time in port. To avoid the risk of port pollution, conventional tankers must spend an additional 3 to 6 hours in each port.[10] It is assumed in this study that segregated ballast tankers save 5 hours per round trip on the average.

Segregated ballast tankers generate less slops than conventional tankers. This has some impact on the ship's throughput. This impact is calculated in TABLE 14 for a 100,000 DWT crude oil segregated ballast tanker using improved LOT. The loss of throughput relative to the case of no pollution control is 52 to 115 tons per trip depending on weather and ballasting (that is, the amount of deadfreight water).

TABLE 14

IMPACT OF SEGREGATED BALLAST ON THE THROUGHPUT
OF A 100,000 DWT CRUDE OIL TANKER

Tons/Trip

	Good Weather	Bad Weather	Very Heavy Weather
TRADITIONAL BALLASTING PRACTICE			
Cargo carrying capacity	95,000	95,000	95,000
less clingage after cargo discharge	400	400	400
less deadfreight[a] water	52	115	115
Total throughput	94,548	94,485	94,485
loss of throughput relative to no pollution control	52	115	115
LIGHTER BALLASTING PRACTICES			
Cargo carrying capacity	95,000	95,000	95,000
less clingage after cargo discharge	400	400	400
less deadfreight water[a]	52	52	90
Total throughput	94,548	94,548	94,510
loss of throughput relative to no pollution control	52	52	90

[a]This is 50 per cent of (potential oil pollution less actual oil pollution, as calculated in TABLE 12) assuming that the slops contain one-third of deadfreight water. The calculations are made assuming that LOT is operated properly (98.5% effective). The amount of deadfreight water is 10-15% smaller if Lot is 85-90% effective.

d) Operating constraints--The segregated ballast design will result in increased ship's dimensions. For larger ships, this may preclude access to some ports. In such cases, it is necessary to lighten into smaller tankers or to offload part of the cargo at a previous call. This clearly puts extra contraints on the fleet operator. These constraints may only be met at some cost in terms of additional ships or voyages and in terms of port investments (dredging, berth extensions) and increased port charges.

e) Port charges--Even when the segregated ballast design does not put any restriction on port access, additional tugs and bigger loading/ discharge arms may be required at the ports because of increased ship's dimensions. On the other hand the previously mentioned time savings will reduce port congestion and therefore the need for new port facilities. According to one expert[11] the segregated ballast design should not affect port charges.

3.2.2.2 Existing ships

The cost of converting existing tanker to segregated ballast tankers is made up of the following elements:

- loss of carrying capacity
- shipyard conversion cost
- loss of time during conversion
- operating costs and benefits due to conversion

These costs have been investigated in depth in a recent study carried out for IMCO, the results are summarized below.

a) Effect on carrying capacity--There are two alternatives for converting an existing tanker to a segregated ballast tanker. The "existing arrangement solution" basically converts cargo tanks to segregated ballast tanks at a limited investment cost. This will reduce the ship's carrying capacity by 15 to 25 per cent.[12] The second solution consists of introducing additional structures and strengthening existing ones. This involves a larger investment cost but the capacity loss is reduced to 10-18 per cent of the initial capacity for smaller ships (less than 100,000 dwt tons) and 10-15 per cent for larger ships.[13] It must be noted that the total segregated ballast capacity will be higher under the first solution, although both are in compliance with IMCO regulations. The second solution is therefore referred to as the "minimum ballast solution".

b) Shipyard cost--The shipyard cost under the existing arrangement solution is comprised between $100,000 and $900,000 regardless of shipsize; $500,000 per ship is a typical figure.[14]

The cost is much higher for the minimum ballast solution. It varies between $1 million and $5.2 millions per ship and tends to increase with ship size. Typical figures would be 1.5 million per ship for those between 150,000 and 300,000 dwt tons and more for those above 300,000 dwt tons. Under both solutions, corrosion protection of the segregated ballast tanks could amount to an additional $250,000 or more; depending on the method applied.

c) Shipyard delays--Time at shipyard for conversion may vary between a few days and a month.[15] The cost of tanker's time during conversion (that is the benefits foregone during conversion) is small if the work is performed before the tanker freight market recovers.

d) Operating costs and benefits--The conversion of existing ships should bring about time savings in port, As in the case of new ships, a five-hour's saving per round trip is assumed in this study. Maintenance and repair costs should also be affected in much the same way for both new and existing ships (6 per cent increase).

It is estimated that, for a given draft, converted ships will have a larger cargo carrying capacity (10-20 per cent higher in most cases).[16] Accordingly, the conversion should not restrict port access but extend it. Port charges are likely to decrease for converted ships as the amount of cargo to be handled and the time spent in port are reduced. This impact is assumed to be negligible in this study.

3.3 CRUDE OIL WASHING

Research into crude oil washing goes back over three years. The technique has been developed to such an extent that it has been possible for at least one company, the British Petroleum (B.P.) to adopt it as the standard tank washing procedure in all owned VLCC's.[17]

3.3.1 Routine Oil Discharges with crude oil washing

3.3.1.1 Cleaning operations

Crude oil washing allows the residues on horizontal members of the tank structure to be removed with the cargo being discharged, which acts as a solvent, dissolving sludge and sediments. After crude washing, internal tank structures are coated with a light film of crude oil, representing say one-third of the initial clingage and no more water cleaning is needed for residue control. Maybourn reports that tank inspections can also be carried out without any need to water wash. This supposes that the tank atmosphere is virtually free of hydrocarbon gas. "Gas free" atmospheres may be achieved through ventilation. Since most of the clingage has been removed, the gas does not regenerate and entry is possible. B.P. however issued stringent safety regulations on this procedure.

Crude washing does not eliminate the need for cleaning the tanks intended for clean ballast, but due to the very low clingage, the cleaning and ROB operations are much easier. This particularly applies when the ship has to be entirely cleaned prior to drydock. Water cleaning is also needed to wash out the oil left in the piping system. This oil is sent to a dirty ballast tank or to the slop tank.

As crude oil washing creates an explosion hazard, the protection of an effective inert gas system is essential. With the inert gas system, washwater recirculation may be used, which further simplifies the cleaning and ROB operations, as it reduces the amount of contaminated water to be handled.

Typically, all tanks for clean ballast are washed plus at least half of the remainders[18] so that no water cleaning is needed for residue control and routine maintenance and clean ballast cleaning may be kept to a minimum. TABLE 15 shows the average oil discharges from cleaning operations for a 100,000 DWT crude oil tanker using crude oil washing. Conventional tankers using crude oil washing will not receive much benefit from lighter ballasting practices and these practices are not considered here. TABLE 15 shows that a 100,000 DWT crude oil tanker using crude washing will discharge 1 to 14.1 tons of oil during tank cleaning, depending on weather and effectiveness of improved LOT.

3.3.1.2 Deballasting operations

An entire crude washing cycle requires about one additional day in the port. The most common practice is to wash all tanks intended for clean ballast on every occasion plus as many other tanks as is possible without incurring delays. If cargo unloading is sufficiently slow all

TABLE 15

AVERAGE OIL DISCHARGES FROM CLEANING FOR A
CONVENTIONAL 100,000 DWT CRUDE OIL TANKER
USING CRUDE WASHING AND IMPROVED LOT

	Good Weather	Bad Weather
Tank capacity intended for clean ballast (% of dwt)	20-30%	40-50%
Tank capacity crude washed (% of dwt)	70%	70%
Oil left in tanks intended for clean ballast after crude washing[a]	30 tons	54 tons
Oil left in piping system[a]	40 tons	40 tons
Potential oil pollution[b]	70 tons	94 tons
<u>Oil pollution during cleaning</u>		
Improved LOT 98.5%%effective	1.0 tons	1.4 tons
Improved LOT 85 to 90% effective	7.0 tons	14.4 tons

[a] Before crude washing there is 360 tons of oil left in tanks and 40 tons in piping system. Crude washing removes 66 per cent of the clingage left in the tank.

[b] 100% of the oil left in piping system and in the tanks intended for clean ballast.

dirty ballast tanks may be washed but this is not always the case. Assuming (as in TABLE 15) that 70 per cent of the tanks are crude washed, it may be considered that all dirty ballast tanks are washed in good weather and only 50 per cent in bad weather. The resulting average oil discharges from deballasting are shown in TABLE 16 for a 100,000 dwt crude oil tanker using crude washing. The average discharge is comprised between 1.0 and 14.1 tons depending on weather and effectiveness of improved LOT.

3.3.1.3 Summary

TABLE 17 shows the average oil discharges for a conventional 100,000 dwt crude oil tanker on a routine trip. These discharges are comprised between 1.4 tons and 27.1 tons depending on weather and effectiveness of improved LOT.

It must be noted that crude oil washing generates hydro carbon gas which is expelled to the atmosphere during ballasting. This may create serious problems in port areas. This aspect is not dealt with in this study.

3.3.2 <u>The cost of crude oil washing</u>

3.3.2.1 Equipment requirements

Due to the high oil pressures required to carry out crude oil washing operations, portable cleaning machines with flexible hoses are inappropriate. Fixed washing machines must be used. If the ship is already equipped with fixed washing machines, as is the case for most VLCC's, the number of drive units required to drive these machines for water washing at sea must be increased for crude oil washing in order to avoid delays.[19]

TABLE 16

AVERAGE OIL DISCHARGES DURING DEBALLASTING FOR A 100,000 DWT CRUDE OIL TANKER USING CRUDE WASHING AND IMPROVED LOT

	Good Weather	Bad Weather
capacity of dirty ballast tanks (% of dwt)	20-30%	40-50%
Percentage of dirty ballast tanks crude washed	100%	100%
Oil left in dirty ballast tanks after crude washing[a]	30 tons	108 tons
Potential oil pollution[b]	24 tons	86 tons
<u>Oil pollution during Deballasting</u>		
- improved LOT 98.5% effective	[illegible].4 tons	1.3 tons
- improved LOT 85 to 90% effective	2.4 tons	13.0 tons

[a]See note a - TABLE 5

[b]80% of oil left in dirty ballast tanks.

TABLE 17

AVERAGE OIL DISCHARGES FOR A 100,000 DWT CRUDE OIL TANKER USING CRUDE WASHING AND IMPROVED LOT

(Tons/Routine Trip)

	Good Weather	Bad Weather
Potential oil pollution[a]	94	180
Actual Oil Pollution		
- Improved LOT 98.5% effective	1.4	2.7
- Improved LOT 85 to 90% effective	9.4	27.0

[a] Oil pollution when improved LOT is not used at all

In addition, crude oil washing requires an inert gas system. The cost of such a system is estimated at $300,000 to $500,000 depending on size. However, the decision to inert a ship is made for safety reasons and the possibility of using crude washing on inerted tankers is incidental. Accordingly, it is unappropriate to include inerting costs into crude washing equipment costs: the decision to use crude washing supposes that the ship is already inerted; a ship will not be inerted in order to use crude washing.

The cost of the additional fixed washing machines and drive units is not known to this writer. Information is needed in this regard.

3.3.2.2 Operating costs and benefits

The use of crude washing considerably reduces the overall time and effort applied to tank cleaning and LOT operations. However, it will increase the workload during discharge. Since the ship's crew is required for the normal vessel operations, it is necessary to have one to three additional men and one extra deck officer from the shore to assist the chief officer during cargo discharge.[20]

Provided that the crude washing operation is properly planned, it only causes small delays on routine voyages. When the entire ship has to be cleaned prior to drydock, an additional day is needed at the discharge port. This additional day makes it possible to save several days and the cost of handlifting hundreds of tons of residues at the drydocking port (or to avoid considerable pollution on the voyage to drydock).

Finally, the use of crude washing reduces the clingage and the amount of deadfreight water and, therefore, increases the ship's throughput. The impact of crude oil washing on the throughput of a 100,000 dwt crude oil tanker using crude oil washing is shown in TABLE 18. The use of crude

TABLE 18

IMPACT OF CRUDE OIL WASHING ON THE THROUGHPUT OF A 100,000 DWT CRUDE OIL TANKER USING IMPROVED LOT

(tons/trip)

	Good Weather	Bad Weather
Cargo carrying capacity	95,000	95,000
Less clingage after cargo discharge		
- clingage in crude washed tanks[a]	84	84
- clingage in other tanks[a]	108	108
- clingage in piping system	40	40
- total clingage	232	232
Less deadfreightwater[b]	47	90
Total throughput	94,721	94,678
Throughput increase relative to no pollution control	121	78

[a] It is assumed that 70% of the tanks are crude washed. The initial tank clingage is 360 tons. Crude washing removes two-thirds of the clingage.

[b] This is 50 per cent of (potential pollution less actual pollution, as calculated in TABLE 12).

washing increases the throughput of a 100,000 DWT crude oil tanker by 80 to 120 tons, on the average, depending on weather (assuming that improved LOT is 98.5 effective. The increase is slightly smaller if improved LOT is only 85-90% effective).

Increasingly, it is considered in the oil industry that crude washing "pays for itself". Equipment costs, manpower costs at the discharging port and small delays in ports are offset by time and manpower savings during drydocking, increased ship throughputs and above all, much easier cleaning and LOT operations. In addition, it reduces the amount of oil lost to the sea.

From the viewpoint of independent shipowners, crude washing increases the bill-of-lading weight (by reducing the amount of slops) and makes cleaning and LOT operations easier. There is no financial gain, however, from reduced oil discharges or increased ship throughputs.

3.3.3 Crude oil washing + Segregated Ballast

When crude oil washing is used on segregated ballast tankers, water cleaning is eliminated except when additional clean ballast is needed to cope with severe weather conditions.

In the latter case, however, water cleaning is kept to a minimum if the tanks intended for clean ballast are crude washed. It is possible, for instance, to use for clean ballast the tanks that have been washed for residue control and routine maintenance. TABLE 19 shows average oil discharges for a 100,000 dwt segregated ballast tanker using crude oil washing and improved LOT. These discharges are comprised between .6 tons and 18 tons per trip, depending on weather, ballasting practice and effectiveness of

TABLE 19

AVERAGE OIL DISCHARGES FOR A 100,000 DWT
CRUDE OIL SEGREGATED BALLAST TANKER
USING CRUDE WASHING AND IMPROVED LOT

	Good Weather	Heavy Weather	Very Heavy Weather
TRADITIONAL BALLASTING PRACTICE			
Segregated ballast	35% of dwt	35% dwt	35% dwt
Dirty ballast and clean ballast	0	20% dwt	20% dwt
Potential oil pollution[a]	40 tons	122 tons	122 tons
Actual oil pollution			
- improved LOT 98.5% effective	.6 ton	1.8 tons	1.8 tons
- improved LOT 85 to 90% effective	4.0 tons	18 tons	18 tons
LIGHTER BALLASTING PRACTICE			
Dirty ballast and clean ballast	0	0	15% dwt
Potential oil pollution	40 tons	40 tons	101 tons
Actual oil pollution			
- improved LOT 98.5% effective	.6 ton	.6 ton	1.5 tons
- improved LOT 85 to 90% effective	4.0 tons	4.0 tons	15 tons

[a] Oil in piping system + 80% of oil in dirty ballast tanks + 100% of oil left in clean ballast (after crude washing)

improved LOT. These figures assume that the tanks used for clean ballast are always crude washed.

TABLE 20 shows the impact of crude washing on the throughput of a 100,000 dwt segregated ballast tanker using improved LOT. The throughput is virtually the same as in the case of no pollution control.

3.4 SHORE RECEPTION AND TREATMENT FACILITIES

Most drydocking ports are equipped with small facilities to handle the slops of the tankers coming for repair. But research into the cost-effectiveness and technology of large facilities to handle the bulk of the dirty ballast and washwaters really started in 1971 when complete elimination of operational pollution by oil was established as a goal by IMCO.[21] Two of the nine IMCO studies carried out prior to the 1973 Conference[22] were focusing on the subject. In 1972, the U.S. government also sponsored a major study[23] to determine requirements for collection and separation facilities at U.S. ports (under a "no vessel discharge" assumption) and to show the economic cost and feasibility of such facilities. Large reception and treatment facilities are now being built in Valdez, Alaska and Marseille, France, but it has not been possible to obtain any cost information from the contractors.

3.4.1 Routine oil discharges with shore facilities

Tankers arriving at the loading port discharge dirty ballast and slops into storage tanks. This material is then treated by chemical and physical processes such as gravity separation, skimming, filtering, bioxidation, etc... The recovered oil may then be blended into the

TABLE 20

IMPACT OF CRUDE WASHING ON THE THROUGHPUT OF A 100,000 DWT SEGREGATED BALLAST TANKER USING IMPROVED LOT

(tons/routine trip)

	Good Weather	Heavy Weather	Very Heavy Weather
Cargo Carrying Capacity	95,000	95,000	95,000
TRADITIONAL BALLASTING PRACTICES			
Less clingage left after cargo discharge[a]	352	352	352
Less deadfreight water	20	60	60
Total throughput	94,628	94,588	94,588
Throughput increase relative to no pollution control	28	-12	-12
LIGHTER BALLASTING PRACTICES			
Less clingage left after cargo discharge	352	352	352
Less deadfreight water	20	20	50
Total throughput	94,628	94,628	94,698
Throughput increase relative to no pollution control	28	28	-2

[a] 20% of the tanks are crude washed for residue control and routine maintenance on every voyage.

terminal's crude storage tanks while the water with a low oil content is discharged back to the sea.

A multi-step treatment entailing progressively more sophisticated and costly methods may be applied to the water, depending on the effluent quality standards applying in the region. The treatment generally produces residual sludges that must be disposed of somewhere on shore at some additional cost. To illustrate, a very simple scheme only involving gravity separation in holding tanks would achieve the following performances.[24]

Quality of oil recovered: Poor

- Oil recovery: Low = 75% of the oil
- Oily sludge: High = 15-20% of the treated oil
- Oil content of the effluent: High - 50-100 ppm

The scheme to be implemented at Valdez for tankers engaged in the future Alaska trade is much more complex. It involves a four step treatment process: gravity separation, chemical coagulation and dissolved air flotation, PH adjustment and holding before discharge, as shown in exhibit (1). The performance is as follows:

Quality of oil recovered: Very good

- Oil recovery: very high: 98% of the oil
- Oily sludge: Low: 5% of the treated oil (includes water)
- Oil content of the effluent: Low 8-12 ppm

3.4.1.1 Deballasting operations

Tankers using a shore reception and treatment facility discharge all dirty ballast into the facility. The resulting discharge is calculated in TABLE 21 for a 100,000 dwt crude tanker depending on weather and ballasting practice. This oil is discharged in port waters.

Data Sheet

Ballast Treatment Facility 5/75

All oily ballast water from the holds of tankers arriving at the terminal of the trans Alaska pipeline at Valdez will be pumped ashore for treatment before being discharged into the Port of Valdez.

The water will be cleansed to 8 parts of oil per million on the average, meeting the requirements of both the E.P.A. and State of Alaska.

The ballast water will be treated in a four-step process involving primary separation, chemical coagulation and dissolved air flotation, pH (alkaline) adjustment, and holding before discharge.

In the primary separation stage, the ballast water will be pumped into storage tanks where it will be held in a quiet state, so that free oil can float to the surface. The floating oil will be removed by skimming devices.

Upon completion of that process, the ballast water will be discharged into an air-flotation basin. There, a coagulant (alum) and a polyelectrolyte will be mixed with the ballast water, forming particles of oil and chemical called "floc."

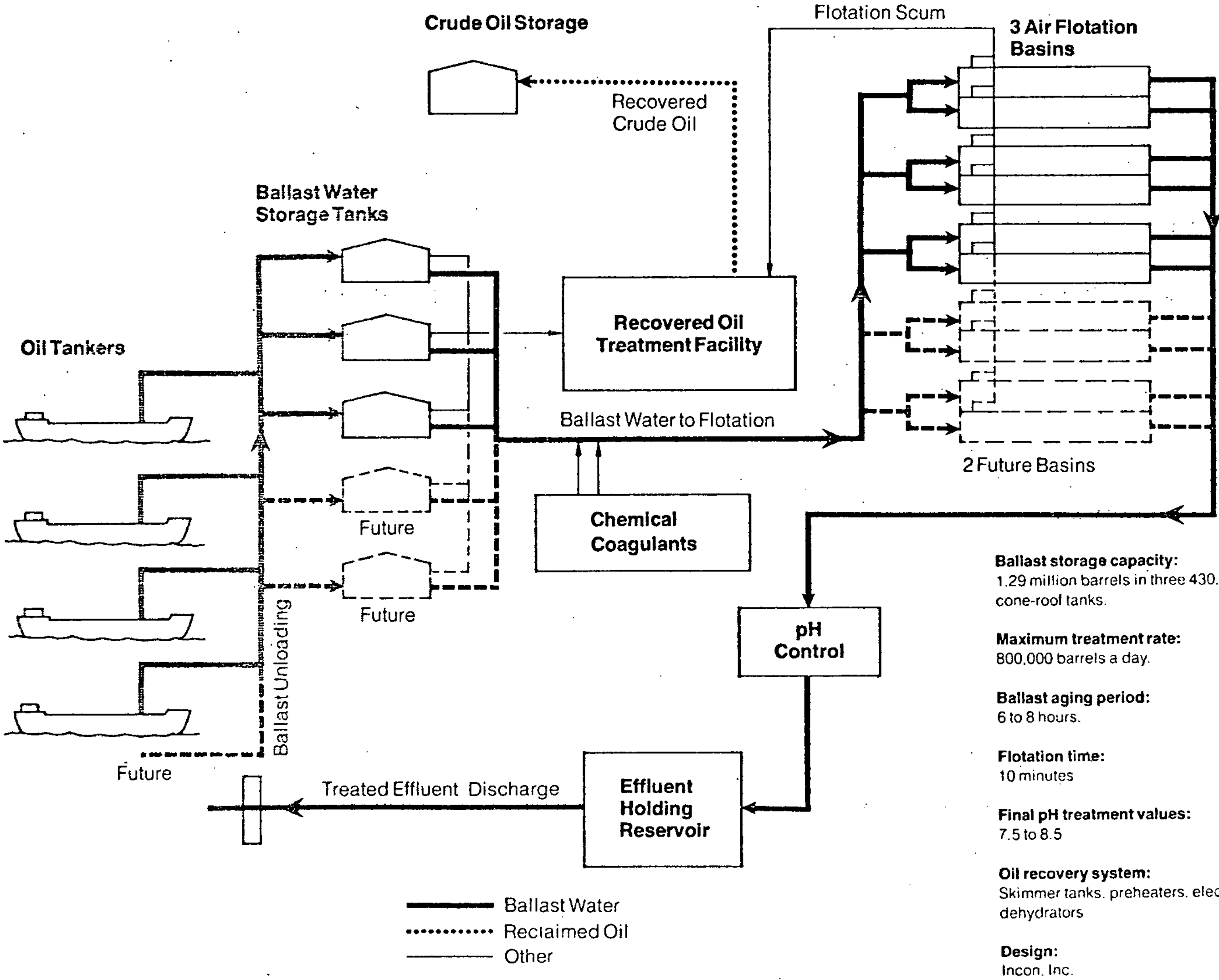
When the floc has formed, pressurized water containing dissolved air will be mixed with the floc-ballast mixture, causing the floc particles to rise to the surface where they will be skimmed. Solids, such as grit, settle to the bottom of the basin.

After the floated and settled solids have been eliminated, the ballast water will flow into the pH adjustment system where the side effects from the earlier addition of the coagulant (alum) will be controlled by the introduction of a dilute caustic (sodium hydroxide).

Two pH sensors, an automatic sampler device and an oil analyzer will be used to monitor water quality in this step before the ballast is transferred to an effluent holding reservoir where final quality control tests will be made.

If the final tests show that the ballast has not been treated sufficiently, it will be returned to the treatment facility for further processing. Otherwise, it will be discharged into the sea at a depth of between 200 and 375 feet, between 700 and 1,050 feet offshore, to secure maximum mixing with the sea water.

Oil recovered in the process will be cycled into the terminal's oil storage tanks. Sludge will be de-watered and disposed of in a manner acceptable to Alaska authorities.



Ballast storage capacity:
1.29 million barrels in three 430,000 barrel cone-roof tanks.

Maximum treatment rate:
800,000 barrels a day.

Ballast aging period:
6 to 8 hours.

Flotation time:
10 minutes

Final pH treatment values:
7.5 to 8.5

Oil recovery system:
Skimmer tanks, preheaters, electrostatic dehydrators

Design:
Incon, Inc.

Constructor:
FluorAlaska Inc.

Exhibit 1

TABLE 21

AVERAGE OIL DISCHARGES FROM DEBALLASTING FOR A 100,000 DWT CRUDE OIL TANKER USING A SHORE FACILITY

(Tons/Routine Trip)

	Good Weather	Heavy Weather	Very Heavy Weather
TRADITIONAL BALLASTING PRACTICE			
Amount of dirty ballast[a]	22,500	37,500	37,500
Potential oil pollution[b]	65	108	108
Oil pollution (in port)	.45	.75	.75
Oil recovered at the facility	64.5	107.2	107.2
LIGHTER BALLASTING PRACTICE			
Amount of dirty ballast	22,500	22,500	37,500
Potential oil pollution	65	65	108
Oil pollution	.45	.45	.75
Oil recovered at the facility	64.5	64.5	107.2

[a] See Annex A

[b] 80 per cent of the oil in dirty ballast

3.4.1.2 Cleaning Operations

The shore facility eliminates the clean ballast problem and, therefore, considerably reduces tank cleaning requirements. These may even be eliminated completely by use of crude washing during cargo discharge. Alternatively, the cleaning operations may be carried out using washwater recirculation. Due to the small volume involved, the washwater may be kept entirely in the slop tank for discharge into the shore facility. Both the crude washing and the recirculation procedure suppose that the ship is inerted.

Another way to avoid discharging contaminated washwater is to use a cargo tank of sufficient capacity as slop tank. It has become the practice to use specially designed tanks (that is, deep tanks with small cross section area provided with heating coils and carefully located inlets and outlets) since the separation and control of effluent quality is difficult when using a normal cargo tank.[25] Accordingly, some changes in the piping system are needed generally to use a cargo tank as slop tank. The problem of inadequate separation is irrelevant here since the contaminated water is discharged entirely into the shore facility.

If none of the above solutions is used some oil has to be discharged to the sea. On medium to long-haul trades, the oily mixture may beeallowed to settle before discharge but on short-haul trades, where most of the shore facilities will be found if the 1973 Convention is implemented, settling will generally not be possible and considerable pollution may result.

TABLE 22 shows the average oil discharges from cleaning operations in various cases for a 100,000 dwt crude oil tanker using a shore facility. When the washwater is discharged entirely into the shore facility, the resulting oil pollution in port is comprised between zero and .18 tons. When

TABLE 22

AVERAGE OIL DISCHARGES FROM CLEANING OPERATIONS FOR A 100,000 DWT CRUDE OIL TANKER USING A SHORE FACILITY

	Good Weather	Bad Weather
WITH CRUDE WASHING		
Oil pollution	0	0
WITH RECIRCULATION		
Tank capacity cleaned	15-20% dwt	15-20% dwt
Amount of washwater[a]	875 tons	875 tons
Oil pollution (in port)[b]	.02 tons	.02 ton
SLOP TANK OF SUFFICIENT CAPACITY		
Amount of washwater[a]		
- with eductors	8,820 tons	8,820 tons
- no eductors	2,520 tons	2,520 tons
Oil pollution (in port)		
- with eductors	.18 ton	.18 ton
- no eductors	.05 ton	.05 ton
TREATMENT-ON-BOARD		
Potential oil pollution	62 tons	62 tons
Oil pollution (at sea)	up to 62 tons	up to 62 tons
Oil pollution (in port)[c]	0-.02 ton	0-.02 ton

[a]See annex A

[b]Assuming that the oil content of the effluent is 20 ppm

[c]Due to remaining slops (2000 tons).

the washwater is treated aboard the ship, up to 62 tons of oil may be discharged (at sea) if the separation of the oil and water is inadequate.

3.4.1.3 Summary

TABLE 23 shows average oil discharge on a routine trip for a 100,000 dwt crude oil tanker using a shore facility. The average oil discharge in port is comprised between zero and .63 tons depending on ballasting practice and tank cleaning procedure. There is no discharge at sea except when the washwater is treated aboard the ship. In the latter case, the average oil discharge may be very high if the mixture is not allowed to settle (up to 62 tons).

3.4.2 The costs of Shore Facilities

The cost of treating oily mixtures in a shore facility is known to be highly variable. Important factors are:

- the availability of space and facilities (storage tanks, sludge incinerators, etc.) in the port area.
- the required effluent quality standard: complex and costly procedures must be used to produce high quality effluents.
- Sludge disposal method: sludge disposal cost may be as high as one-third of the total treatment cost. Sanitary landfill is hard to find and incinerators are costly, especially if air pollution is to be avoided.
- Deballasting procedure: deballasting of oily mixtures and loading of cargo are generally done concurrently in order to minimize ship delays and berth occupancy. This requires an additional piping anand pumping system at each berth to be used in parallel with the vessel's piping and pumping system. In this case, ship delay is

TABLE 23

AVERAGE OIL DISCHARGES FOR A 100,000 DWT
CRUDE OIL TANKER USING A SHORE FACILITY
(Tons/routine trip)

	Good Weather	Bad Weather
OILY MIXTURES ARE TREATED ENTIRELY ON THE SHORE		
Oil pollution (in port)		
- deballasting	.45	.45-.75[a]
- cleaning	0-.18[b]	0-.18[b]
- total	.45-.63	.45-.63
oil pollution at sea	0	0
oil recovered at the facility	127	127-170[a]
THE WASHWATER IS TREATED ON BOARD		
Oil pollution (in port)	.45-.63	.45-.63
Oil pollution (at sea)	up to 62 tons	up to 62 tons
Oil recovered at the facility	64-127[c]	64-170[c]

[a] depending on ballasting practice

[b] depending on cleaning procedure (crude washing, recirculation or use of a slop tank of sufficient capacity).

[c] depending on ballasting practice and the amount of oil pollution

limited to about four hours. The additional investment cost might be unwarranted, however, until the tanker market recovers.

- Facility size: Given the characteristics of tanker traffic, and the amounts of oily mixtures carried, there is an optimal facility size. At this optimal size, the cost of expanding the facility exceeds the benefits from reduced tanker delay and berth occupancy

1972 estimates of the cost of collecting and treating oily mixtures (and transporting the recovered oil to market) are given in TABLE 24 for complex facilities generating high quality effluent- (10-15 ppm).

The cost per recovered barrel of oil is comprised between $1.11 to $2.78 (or $8.4 to $21.0 per ton of oil recovered using a ton to barrel conversion factor of 7.58). Using a 10 per cent annual inflation rate, the cost in 1976 would be comprised between $12.3 and $30.7 per ton of oil recovered. These estimates do not include the value of the recovered oil. They represent the cost to the owner of the facility and do not take into account the cost of tanker delay to tanker owners. If these estimates are valid and if the price of the recovered oil is close from the price of normal crude (about $90 per ton) it may be concluded that the operation of a shore facility is a profitable business. This does not mean, however, that pollution control using shore facilities does not cost anything, relative to current practice (conventional LOT) as large quantities of oil can be recovered using LOT at a small cost. The following calculations will clarify this point.

In the absence of pollution control, the oil input to the world's oceans from tanker operational pollution would be 4.1 million tons per year.[26] Under current practice this oil input is about 1.4 million tons per year,[27] which means that 2.7 Million tons of oil are recovered annually. Now suppose

TABLE 24

ESTIMATED COST AND EFFECTIVENESS OF SHORE FACILITY

TREATMENT FOR VARIOUS U.S. PORTS

	Amount of oily water (M tons/year)	oil recovery (%)	oil content of effluent (ppm)	cost per[a] recovered barrel (1972 $/bbl)
New York[b]	5,498	98	10-15	1.67
San Juan[c]	429	98	10-15	2.41
Houston[d]	5,883	98	10-15	1.11
San Francisco[e]	2,041	98	10-15	1.33
Cleveland[f]	894	98	10-15	2.78

SOURCE: U.S. Department of Commerce, Maritime Administration, Port Collection and Separation Facilities for oily wastes.

[a]These costs do not include the value of the recoverd oil. They represent the cost to the owner of the facility and do not account for tanker delays.

[b]See Vol. 3, Tables 2-3, 2-12, 2-13

[c]See Vol. 3, Tables 4-3, 4-10, 4-12, 4-13

[d]See Vol. 3, Tables 5-8, 5-16, 5-18, 5-19

[e]See Vol. 3, Tables 7-3, 7-11, 7-13, 7-14

[f]See Vol. 3, Tables, 8-3, 8-11, 8-13, 8-14

that all tankers are required to use shore facilities for all dirty ballast and washwater. Suppose that 98 per cent of the oil is recovered (this is the percentage shown in TABLE 24). Then about 4 million tons of oil would be recovered each year, that is 1.3 million tons more than under current practice. Suppose that x is the average cost of recovering one ton of oil using a shore facility (this cost includes collection and treatment costs, transport to market costs and the cost of tanker delays).

Assuming that the value of the recovered oil is about \$80 per ton and that the cost of recovery oil using conventional LOT is negligible, the net cost (relative to current practice) of using shore facilities worldwide is (in \$million per year)

$$X \times 4 - 1.3 \times 80$$

This net cost becomes a net benefit for x smaller than 80 x 1.3 / 4 = \$26 per ton of oil recovered. To compare, it has been estimated previously, using TABLE 24, that the cost of recovering one ton of oil using shore facilities in U.S. ports was \$12.3 to \$30.7 plus the cost of tanker delays. The average cost worldwide might be less than \$26. In this case pollution control using shore facilities would cost less than under current practice.

3.5 POLLUTION CONTROL TECHNIQUES AND THE ENFORCEMENT PROBLEM

3.5.1 Routine voyages

A policy to control tanker operational pollution is not defined only by the pollution control techniques it requires. It should also include a set of standards that (1) consistent with the required pollution control techniques, and (2) enforceable.

In the case of effective enforcement, the required pollution control techniques are used properly and oil discharges are kept to a minimum. In the absence of effective enforcement, there is less incentive for operating properly pollution control procedures and willful or unintentional failures become more frequent.

If effective control and monitoring equipment is provided, unintentional failures in the operation of improved LOT should be eliminated. In the absence of effective enforcement, however, this equipment may not be provided or it may not be properly maintained.

Willful slop discharges are financially desirable on long-haul trades for crude oil tankers owned by independent shipping firms, unless the freight is paid on the slops. They are financially desirable for all crude oil tankers on short-haul trades when too much settling time or the use of a shore facility for unsettled slops is required.

Failures are not only made when using LOT procedures. Segregated ballast tankers may carry more dirty ballast than they are allowed to in order to avoid having to divert or reduce speed. Tankers using a shore facility may discharge dirty washwaters at sea. They may also discharge dirty ballast in order to reduce delays and port charges, if the weather improved and some ballast becomes unnecessary.

It is extremely difficult to predict the amount of oil pollution incurred in the absence of effective enforcement. TABLE 25 shows the hypothetical amounts of oil discharged by a 100,000 DWT crude oil tanker on a routine long-haul trip for a number of pollution control techniques, assuming that improved LOT is 98.5 per cent effective in the case of effective enforcement and 85 to 90 per cent effective (depending on the weather), on the average, in the absence of effective enforcement. It should be noted, however,

TABLE 25

IMPACT OF ENFORCEMENT ON THE AMOUNT OF OIL POLLUTION CAUSED BY A 100,000 DWT CRUDE OIL TANKER ON A LONG-HAUL TRIP[a]

(Tons of oil discharged per trip)

TECHNIQUES	EFFECTIVE ENFORCEMENT		NO EFFECTIVE ENFORCEMENT	
	Good Weather	Bad Weather	Good Weather	Bad Weather
Improved LOT	3.2	4.2	21.3	42.4
Improved LOT + crude washing	1.4	2.7	9.4	27.0
Improved LOT + seg. ballast	1.6	1.6-3.5[b]	10.3	34.8[c]
Improved LOT + crude washing + seg. ballast	.6	.6-1.8[b]	4	18[c]
Improved ROB + ballast facility	.6[d]	.6[d]	6.2[e]	9.3[e]

[a] assuming that improved LOT/ROB is 98.5% effective in the case of effective enforcement and 85-90% effective in the case of no effective enforcement.

[b] depending on ballasting practice.

[c] assuming that lighter ballasting practice will not be followed in the absence of effective enforcement.

[d] in port

[e] .6 tons are discharged in port, the rest at sea.

that the effectiveness of improved LOT should be higher on segregated ballasttankers, or on ships using crude washing than on conventional ships using improved LOT alone due to the smaller amount of contaminated water to be handled. Similarly, willful slop discharges are unlikely if the ship has to use a shore facility for dirty ballast since the slops may easily be discharged ashore. In other words, if improved LOT is say 90 per cent effective when used alone, it will be more than 90 per cent effective when it is supplemented with some other technique. According to TABLE 25, the average amount of oil discharged by a 100,000 dwt crude oil tanker on a routine trip comprised between .6 tons and 4.2 tons in the case of effective enforcement, and between 6 tons and 42 tons in the absence of effective enforcement. These figures are indicative of the importance of enforcement in tanker operational pollution control.

2.5.2 The drydocking problem

All the tanks must be clean when the ship enters drydock. The ships using crude washing will wash all their tanks after cargo unloading and carry out a rapid ROB operation while at sea. Other ships will clean all the tanks while at sea or at the drydocking port. Assuming that IMCO standards are effectively enforced, all the slops should be discharged into a slop reception facility at the drydocking port. If such facility is not available, the ship should go to another port. In the absence of effective enforcement, it may be expected that virtually all ships will dump their slops at sea if no slop reception facility is available at the drydock while roughly 50 per cent of the ships will use such facility if it is available.[28]

2.6 SUMMARY

This chapter has provided the background data required for the evaluation of the cost-effectiveness of alternate control policies. The information contained in this chapter will be used in Chapter 6 when illustrating the evaluation method (which is described in the next chapter).

FOOTNOTES

Chapter 3

[1] Gray, W.O., The 1973 Convention, a Tanker Operator's Viewpoint.

[2] Victory, G. The Load-on-top System, Present and future. See also U.S. Department of Commerce, Maritime Administration, Survey of Ship Discharges., pp. 31-36 and U.S. Coast Guard, Final Environmental Impact Statement, p. 53.

[3] World Tanker Fleet Review, December 1975, pp. 23-24 (freight rates on the Arabian Gulf to North Europe trade).

[4] See Gray, W.O. Segregated Ballast and Related Aspects of tanker design. See also IMCO, Report on Study IV, p. 32.

[5] According to Captain Davies-Patrick (Shell Co.), personal interview, London, April 1976.

[6] See Gray, W.O. Segregated Ballast and Related Aspects of Tanker Design.

[7] IMCO, Report on Study 1.

[8] Crighton and Telfer, Segregated Ballast Tankers, Proceeding of the Symposium on Marine pollution (Royal Institution of Naval Architects) London, 1973.

[9] U.S. Congress, Table iv-3.

[10] According to Arthur McKenzie (Tanker Advisory Center), personal interview, New York, November 1975.

[11] Captain Davies-Patrick (Shell Co.), Personal interview, London April, 1976.

[12] IMCO, Introduction of Segregated Ballast in Existing Tankers, Annex B Figure 5.

[13] Ibid, Annex B, Figure 4.

[14] Ibid, Annex A, Figure 2.

[15] Ibid, Section ii (d) (i)

[16] Ibid, Annex A, Section 7. Probably because for a given deadweight, converted ships have larger bottom dimensions than non converted ships (so that less draft is needed to displace the ship's weight of water).

[17] See Maybourn, 12, Crude Oil Washing.

[18]Ibid., 3 (d)

[19]According to Maybourn, 4 to 6 drive units are adequate for water washing at sea while 16 to 25 units are needed for crude washing.

[20]U.S. Department of Commerce, Maritime Administration, Crude Washing Guidelines, Report by EXXON corporation, April 1975.

[21]See IMCO Assembly Resolution A 237 (VII), 1971.

[22]See IMCO, Report on Study IV, 1973.

See IMCO, Report on Study V, 1973.

[23]U.S. Department of Commerce, Maritime Administration, Port Collection and Separation Facilities for oily wastes, 1973.

[24]Ibid., Vol. 4, p. 37.

[25]See Victory, G., The Load on Top System, Present and Future. Also Fiocco and Ridley, Slop Tank Design for Improved LOT, proceeding of the 1975 conference on Prevention and Control of Oil Pollution.

[26]Using the estimates shown in U.S. Congress, Oil Transportation by tankers: An Analysis of Marine Pollution and Safety Measures, Table III-I and Section III-A-I.

[27]Ibid.

[28]See Chapter 2--Section 2.5.2.2.

CHAPTER 4

ECONOMIC EVALUATION OF THE ALTERNATIVES OUTLINE OF THE METHOD

This chapter is in two parts. The first part describes the cost-effectiveness framework used to evaluate alternative policies to control tanker operational pollution. The second part describes the estimation procedure itself.

4.1 THE COST-EFFECTIVENESS FRAMEWORK

The purpose of the economic evaluation is to provide estimates of the costs and benefits that will be incurred by society if the contemplated pollution control policies are implemented. In other words, it should provide estimates of the pollution control costs and pollution costs relative to current practice.

Operational pollution costs are for all practical purposes impossible to predict in monetary terms, since they include such considerations as reductions in fish catches and hazards on the health of future generations. The cost effectiveness framework used in this study therefore does not estimate pollution costs in monetary terms. These costs however, depend upon the characteristics of the discharges, such as the quantity of oil discharged or the location of the discharges. The evaluation will be limited to the impact of alternate control policies on discharge characteristics.

Exhibit 2 summarizes the parameters which affect the costs of oil pollution. The basic parameters are (1) the type of discharge (2) the location

1) Type of discharges

   - type of oil

   - quantity of oil discharged

   - concentration of the discharge

2) Location of the discharges

   - currents, dominant winds

   - physical features of the region (open or closed water....)

   - previous exposure to oil pollution

   - exposure to other pollutants

   - fauna and flora of the area

   - availability of oxygen and biological nutrients

3) Depth of the discharge

4) Frequency of discharges

5) Weather conditions

   - temperature

   - winds and sea state

6) Season of year

EXHIBIT 2

PARAMETERS AFFECTING THE COSTS OF TANKER OPERATIONAL POLLUTION[a]

[a]Based on U.S., National Academy of Sciences, Petroleum in the Marine Enfironment, Washington, D.C., 1975

and depth of the discharge (3) the frequency of discharges, (4) the weather conditions and (5) the season of the year. It might be possible to contemplate weather or season dependent pollution control methods (e.g. "do not discharge in good weather or during the summer") but this is not relevant here. Accordingly, the effectiveness of a pollution control alternative will be characterized by only three parameters. These are (1) the type of discharge (2) the location and depth of the discharge and (3) the frequency of discharges.

This study estimates pollution control costs in monetary terms, and pollution characteristics in terms of the above three parameters. This cost effectiveness approach leaves a large scope for value judgments in the interpretation of the results. To illustrate, suppose the effectiveness of a given alternative can be expressed simply in terms of the quantity of oil discharged annually to the oceans. Suppose also that the economic evaluation provides the following estimates:

	Pollution prevention cost	Effectiveness (annual oil discharge)
Alternative A	$ 1 million	1000 tons/year
Alternative B	$ 2 million	800 tons/year
Alternative C	$ 3 million	1500 tons/year

In this case Alternative C is clearly inferior, in economic terms, to alternative A as it generates a larger pollution cost. However, there is no objective way to say whether alternative B should be preferred or not to alternative A. In this regard, the economic evaluation only permits the formulation of the following relevant questions:

- given that 1000 tons are discharged annually, what are the benefits of reducing these discharges by 20 per cent?
- Do these benefits justify the additional pollution prevention costs?

This study does not attempt to answer these questions but it attempts to find the facts and figures that will permit the formulation of the trade-offs. The selection of the best alternative is then a matter for judgment based on available evidence as regards the effects of oil pollution on man and the environment.

4.2 THE COSTS OF OPERATIONAL POLLUTION CONTROL.

From the extraction of crude oil to the final delivery of the processed oil, a certain quantity of economic resources are consumed: labor, capital, raw materials and time. The value of these resources to society represents the economic cost of supplying processed oil to the consumers.

Pollution control affects this economic cost. In the long run, cost variations result in price variations through market mechanisms. Increases in the market prices of processed oils in turn reduce the demand for such products. Suppose the quantity of processed oil sold initially is Q1 tons, and the cost of supplying these Q1 tons to the consumers is C1.

After implementation of the pollution control alternative, these figures become Q2 and C2 and the average value to society of one ton of processed oil changes from VL to V@, the total economic cost of pollution prevention is:

$$EC = (V1Q1 - V2Q2) + (C2 - C1)$$

Tanker operational pollution control essentially affects waterborne transportation costs. Increases in transportation costs are partially or fully passed on to the consumers through increased tanker freight rates. Tanker freight rates represent less than 5-10 per cent of the total cost of supplying the processed oil to the consumers. It is known that freight rates increase as a result of pollution prevention should not exceed 10-15 per cent. Thus, the maximum increase in the price of processed oil will be in the order of one per cent. Such increase will hardly affect the demand for processed oil, consideringgthat the recent changes in the price of crude oil demonstrated this demand to be considerably ineleastic. Therefore, it is assumed in this study that the demand for processed oil is not affected by tanker operational pollution control. As the quantity and quality of the processed oil consumed by society are unaffected, the average value to society of this processed oi l remains unchanges. Consequently, the economic cost of pollution control is simply:

$$E\ C = C2-C1$$

where C1 and C2 are the cost of supplying processed oil to the consumers respectively before and after the implementation of the pollution control alternative.

It has been assumed above that the demand for processed oil is unaffected by operational pollution control. Suppose that Q tons of crude oil are needed each year at the refineries to supply this demand. Soppose that q1 and q2 tons of oil are discharged to the sea each year respectively before and after the implementation of the pollution control alternative. Then the annual cost of supplying D tons of processed oil to the consumers depend (inter alia) on the variables shown in Exhibit 3.

Although the amount of crude oil to be processed at the refineries is unaffected, operational pollution control techniques may generate some additional refinery processing costs due to the mixing of oil and saltwater. However, this impact may be assumed to be negligible as most refineries are now equipped to handle saltwater contaminated crude oil, due to the natural presence of saltwater in some crude oils.[1]

Operational pollution control has some impact on land transportation costs as the amount of oil to be transported each year from the extraction site to the loading port is reduced by q1-q2. Land transportation mainly takes place through pipelines. The marginal cost of transporting oil by pipeline is very low. The amounts q1 and q2 are very small relative to the total amounts transported. It may be assumed, therefore, that the impact of pollution control on land transportation costs is negligible.

To summarize, the cost of operational pollution control is the difference between (1) the additional ocean transportation cost and (2) the value to society of the oil saved by pollution control. The following sections will describe the procedure followed to estimate these two elements.

4.3. THE ESTIMATION PROCEDURE

This section will describe the procedure used to estimate the comparative economic cost and effectiveness of alternate control policy on some trade route. This procedure may be used to evaluate alternate control policies defined at the worldwide or regional level, or on a trade by trade basis.

4.3.1 Outline of the procedure

Consider some pollution control policy (say the conversion of existing tankers to segregate ballast tankers) to be evaluated on some trade.

	Before pollution control	After pollution control
Amount of crude oil consumed annually	Q + q1	Q + q2
Amount of crude oil transported annually		
- on land to tankers	Q + q1	Q + q2
- by tankers	Q + q1	Q + q2
Amount of crude oil processed annually	Q	Q

EXHIBIT 3

IMPACT OF TANKER OPERATIONAL POLLUTION CONTROL

ON THE AMOUNTS OF CRUDE OIL TRANSPORTED, PROCESSED

AND CONSUMED ANNUALLY

If the contemplated policy is implemented, the throughput (per trip or per year) of existing ships will be reduced so that changes in the composition and allocation of the tanker fleet will be required to supply the demand for crude oil (which has been assumed in the previous section to be unaffected by operational pollution control). New vessels have to be ordered or some of the existing tanker surplus capacity has to be used. Shipyards have to build new vessels and to convert existing vessels. Ports may have to either buy new equipment to handle the converted vessels or build new berths due to increased congestion. Finally, the organizations (Cost Guards) responsible for administrating pollution control regulations have to develop the new design regulations, and possibly to extend some policing activities, such as vessel inspection.

On the benefit side, the contemplated pollution control policy will save, say, 10,000 tons of oil from waste and avoid pollution costs which are not evaluated here.

The procedure to be described now involves the following steps:

1) Estimate the composition of the fleet (number of vessels of each type used on the trade) and its allocation betwwen the various ports involved.
2) Estimate ocean transportation costs on the trade (including shipyard, port, vessel, and policing costs.
3) Estimate the characteristics of operational discharges on the route (annual amount of oil pollution, concentration, location etc....). This defines the effectiveness of the control policy.
4) Repeat the above steps for the reference alternative.
5) Estimate the additional transportation cost relative to the reference alternative.

6) Estimate the amount of oil saved relative to the reference alternative.

7) Estimate the total cost of pollution control, relative to the reference alternative.

Steps 4 to 8 are straightforward. The following subsections will develop steps 1 to 3.

4.3.2 Composition and Allocation of the tanker fleet

The composition and allocation of the tanker fleet is decided by individual fleet operators on commercial viability grounds. It is assumed that on a given period of time the cost incurred by tanker owners is minimized, subject to the supply and demand for oil on the trade and the characteristics of the route (distance, port size limitations, etc...)

The optimal composition of the fleet may change over time (as supply and demand conditions or the availability of existing tankers evolve over time). Basic periods are defined, during which the factors affecting the composition of the fleet are fixed. The optimal fleet is obtained for each basic period by minimizing the annual cost incurred by tanker owners. At the beginning of a new period some tankers may become suboptimal. It is assumed that tankers may be transferred to (or from) other trades when they are no longer optimal. This involves a frictional cost between each period, which is assumed to be negligible. (Would this cost be negligible, the appropriate procedure to obtain the optimal fleet over time is to minimize the discounted sum of future costs rather than the annual cost in each basic period).

The costs incurred by tanker owners are described in Exhibit 4. It is distinguished first between fixed and variable costs. The tankers used on

FIXED COSTS

Capital Costs

- Construction cost of new vessels
- Opportunity cost of existing vessels
- Pollution Control Investment on existing vessels.

Fixed Operating Costs

- Insurance cost
- Crew cost
- Provision/Stores
- Maintenance and repair
- Overhead
- Miscellaneous (crew transportation, etc.)

VARIABLES COSTS

Variable Operating Costs

- Fuel cost
- Port charges

EXHIBIT 4

COSTS INCURRED BY TANKER OWNERS

a trade are not necessarily used at full capacity all the time. They may operate at reduced speed or they may be kept idle from time to time (unless it is possible to transfer tankers between trades for very short periods of time at small cost; this is not assumed in this study). The full variable cost is incurred only if all tankers are used at full capacity. It is assumed in this study that the annual variable cost of a tanker (fuel cost plus port charges) is proportional to the number of trips carried out. (The impact of speed on fuel costs is not dealt with in this study.[2]) On the other hand, the full annual fixed cost is incurred by the tanker owner whether the tanker has been used at full capacity or not during the year.

Fixed costs include fixed operating costs and capital costs. Fixed operating costs are well defined but the concept of capital cost must be clarified.

The capital cost of a new vessel to the vessel's owner is simply the construction cost of this vessel, and the annual capital cost of a new vessel is equal to the standard annual amortization cost which is obtained by applying the appropriate capital recovery factor and tax rate to the vessel's construction cost. The annual capital cost of an existing vessel, however, is not necessarily equal to the standard annual amortization cost. The decision to use an existing vessel does not involve any construction cost since the vessel has already been built. But it involves an opportunity cost. The annual opportunity cost (to the vessel's owner) of an existing vessel can be viewed as the highest profit which the vessel's owner can earn by chartering the vessel for one year. Clearly, this profit varies considerably, depending on tanker market conditions. At the long-run equilibrium of tanker supply and demand, an existing tanker will earn a "normal" profit (just equal to the capital cost of an identical new vessel[3]) and the vessel's opportunity cost is equal to the vessel's standard amortization cost. When there is a shortage of tanker tonnage, higher-than-normal profits can be earned by existing vessels and the opportunity cost exceeds the vessel's amortization cost. On the other hand, the use of existing vessels does not involve any opportunity cost when there is a large surplus of existing tonnage, as is currently the case, since charter rates hardly cover vessel operating costs[4]).

On any given year there may be a surplus of tankers within specific sizes ranges (VLCC's, handy tankers, etc.) and a shortage within other ranges. It is known that there will be a surplus of medium sized tankers (45-160 MDWT) and VLCC's (above 160 MDWT), until 1984-1985 unless special measures are adopted (such as the conversion of existing tankers to segregated ballast)[5]. Projections beyond 1985 are very difficult, however, and they are not attempted in this study. Consequently future opportunity costs cannot be projected. But the following two theoretical cases are considered.

1) Under the first case, there is a permanent surplus of tonnage for all types of vessels. The opportunity cost of existing vessels is negligible. This situation may be viewed as an extrapolation of the current situation.

2) The second case corresponds to the long-run equilibrium of tanker supply and demand. The opportunity cost of an existing tanker is equal to the capital cost of an identical new vessel. This situation is sometimes referred to as "normal" or "average" situation.

The annual capital cost of an existing vessel is the sum of the vessel's annual opportunity cost plus the annual cost of pollution control equipment.

Thus, in the first case, the annual capital cost of an existing vessel is simply equal to the annual cost of pollution control equipment, amortized over the vessel's remaining life.

In the second case, two limit situations are considered:

1) Pollution control equipment is required on all trades worldwide. Thus the annual opportunity cost of an existing vessel decreases by an amount equal to the annual cost of pollution control equipment (since the profits that can be earned by existing vessels decrease by the amount on any trade). As a result, the annual capital cost of an existing vessel remains equal to the annual capital cost of an identical new vessel.

2) Pollution control equipment is only required on the contemplated trade. Existing ships can be used on other trades where they escape pollution control equipment costs. The annual capital cost of an existing ship is, therefore, the sum of the annual capital cost of an identical new vessel plus the annual cost of pollution control equipment. Existing vessels are no longer optimal on the trade. They are replaced by new vessels.

To summarize, the annual capital cost of an existing vessel is shown in Exhibit 5 under each of the above cases and situations. Only existing vessels are used on the trade when there is a permanent large surplus (provided the annual cost of pollution control equipment does not exceed the annual capital cost of new vessels). On the other hand, only new vessels are used on the trade at the long-run equilibrium, when pollution control equipment is not required on other trades. And both new and existing vessels are used at the equilibrium when pollution control equipment is required worldwide.

Case	Situation: Pollution control Equipment Required Worldwide (1)	Pollution control Equipment not Required on other Trades (2)
Permanent Large Surplus -1-	Annual cost of pollution control equipment (amortized over the ship's remaining life)	Annual cost of pollution control equipment (amortized over the ship's remaining life)
Long-Run Equilibrium -2-	Annual Capital cost of an Identical New Vessel	Annual Capital cost of an Identical New Vessel plus Annual cost of pollution Control Equipment

EXHIBIT 5

ANNUAL CAPITAL COST OF AN EXISTING VESSEL DESCRIPTION

The optimal composition and allocation of the fleet, and subsequently the economic cost and effectiveness of alternate control policies, are estimated under each of the following cases and situations. The results will provide probable ranges (i.e., the ranges where the actual cost and effectiveness of alternate control policies are likely to belong.).

The composition and allocation of the tanker fleet under each of the above cases and situations is estimated as follows:

1) Estimate the annual fixed and variable costs of new and existing tankers, assuming they are used at full capacity. This is done by using available estimates of basic vessel costs in the absence of pollution control (See Table 29) and the previously estimated costs of pollution control techniques (See chapter 3).

2) Estimate the annual cargo throughput of new and existing vessels, assuming they are used at full capacity. This is done by using the previously estimated impacts of pollution control techniques on tanker throughputs (See chapter 3).

3) Estimate the composition and allocation of the tanker fleet under each basic period (a basic period has been defined as a period during which the factors affecting the optimal composition and allocation of the tanker fleet, such as the supply and demand for oil on the trade, are fixed). This is done by means of the optimization model described in Annex B. This model minimizes the total annual cost incurred by vessel owners, subject to the demand and supply of crude oil on the trade and the characteristics of the route (port depth limitations, distances etc..). The model does not consider the

possibility of multiple calls by tankers for loading or discharging. Nor does it account for refinery storage capacity constraints. However, the model is a tool to estimate the cost and effectiveness of alternate control policies rather than the optimal tanker fleet on a given trade. It is an imperfect representation of the reality but it is thought to be sufficient for the purposes of this study.

4.3.3 Ocean Transportation Economic Costs.

Once the composition and allocation of the tanker fleet have been estimated, the annual fixed and variable costs incurred by tanker owners (annual insurance cost, annual fuel cost, etc.) can be estimated over the whole fleet, using simple arithmetic. The exact procedure is described in Annex C. The cost incurred by vessel owners is distinct from the economic cost of ocean transportation. This subsection will explain how the latter cost can be estimated.

The economic cost of ocean transportation includes port and shipyard costs, vessel costs and the cost of policing activities.

4.3.3.1 Port Costs

This study assumes that the port charges incurred by tanker owners reflect port costs. This may lead to underestimating the total ocean transportation cost as some port costs might be passed upon only partially to tanker owners (the rest being passed on to other vessel owners, or to the general public). This may be the case, for instance, if the tanker traffic generates increased port congestion for non-tankers (unless tanker port charges are increased to compensate non tankers for the additional delays).

4.3.3.2 Shipyard cost

This study assumes that the construction costs incurred by tanker owners reflect shipyard costs. This assumption may also lead to underestimating the total ocean transportation cost, if shipyard costs (e.g. extension of shipyard facilities to meet new tanker design regulations) are passed on only partially to tanker owners.

The annual construction costs incurred by tanker owners is the annual capital costs of new vessels, plus the annual capital cost of pollution control equipment on existing vessels. These capital costs may include some taxes. These taxes correspond to a trasnfer at no real resource cost. Therefore, they will be eliminated when estimating shipyard economic costs.

4.3.3.3 Vessel Costs

Excluding port charges, the capital costs of new vessels and the capital cost of pollution control equipment on existing vessels (since they are counted as port and shipyard costs), vessel costs are the vessel operating costs plus the economic opportunity cost of existing vessels.

The economic opportunity cost of existing vessels may differ, as a result of tanker pollution control, from the opportunity cost incurred by tanker owners. Suppose, for instance, that additional segregated ballast is required on new vessels. This requirement increases the capital cost of new vessels. As a result, tankers freight rates and, therefore, the opportunity cost of existing vessels tend to increase. At the long-run equilibrium the opportunity cost (to tanker owners) of existing vessels will include the cost of providing new tankers with additional segregated ballast capacity. However, no real resource cost is incurred. The increase in opportunity cost reflects a transfer from society to tanker owners.

(In welfare economics terms, tanker owners increase their share of the economic surplus produced by ocean transportation, while the consumer's surplus decreases. The value of ocean transportation to society, and therefore, the total economic surplus, do not change since it is assumed that the demand for ocean transportation is not affected by tanker pollution control, (See section 4.2)).

The increase in opportunity cost due to the cost of pollution control on new vessels must be included when estimating the composition and allocation of the tanker fleet, but eliminated when estimating the economic cost of ocean transportation.

4.3.3.4 Policing costs

The objective of policing activities is to prevent illegal discharges of oil. To achieve this objective, it is necessary to establish a set of standards which are (1) consistent with the proper use of required pollution prevention techniques and (2) enforceable.

It has been seen that current practice (the reference alternative in this study) is characterized by the absence of consistent and enforceable standards. Accordingly, there is no policing activity and no policing cost under the reference alternative.

It is assumed that proper standards have been established under the other alternatives and that policing activities will ensure the proper use of the required techniques. The following assumptions and data will be used to estimate the corresponding policing cost.

- All vessels using LOT are boarded for inspection of the slop tank and oil record book. According to one source, the cost of such inspection is estimated to be $250 per boarding.[6]

- The area is patrolled by aircrafts. The cost of aerial surveillance is $500 per aircraft hour.[7] (The Alaska trade zone is patrolled by two aircraft,[8] each flying 20 hours per week, at a cost of $1 Million per year).

The above figures and assumptions are very crude. They are expected, however, to provide the order of magnitude of policing costs. If these costs turn out to be potentially significant further work will be needed in this area as policing costs could vary depending on the pollution control alternative.

4.3.4 Characteristics of Operational Discharges and the value of the Oil saved.

Given the composition and allocation of the tanker fleet, the number of trips per year for each port and each type of tanker can be estimated. Using the information contained in Chapter 3 (average discharges per trip, concentration, etc.) the characteristics of operational discharges on the route can be estimated. The amount of oil saved may then be estimated relative to the reference alternative. The value to society of this oil is assumed to be adequately reflected by the market price of crude oil (approximately $90 per tons).

4.3.5 Summary

The section has described a procedure to assess the economic cost and effectiveness of alternate control policies. A number of theoretical cases are considered (e.g. long-run equilibrium of tanker supply and demand + Same Pollution Control equipment required worldwide). The procedure can be used to estimate the annual cost of pollution control and the characteristics of operational discharges under each case, in each basic period. When all cases

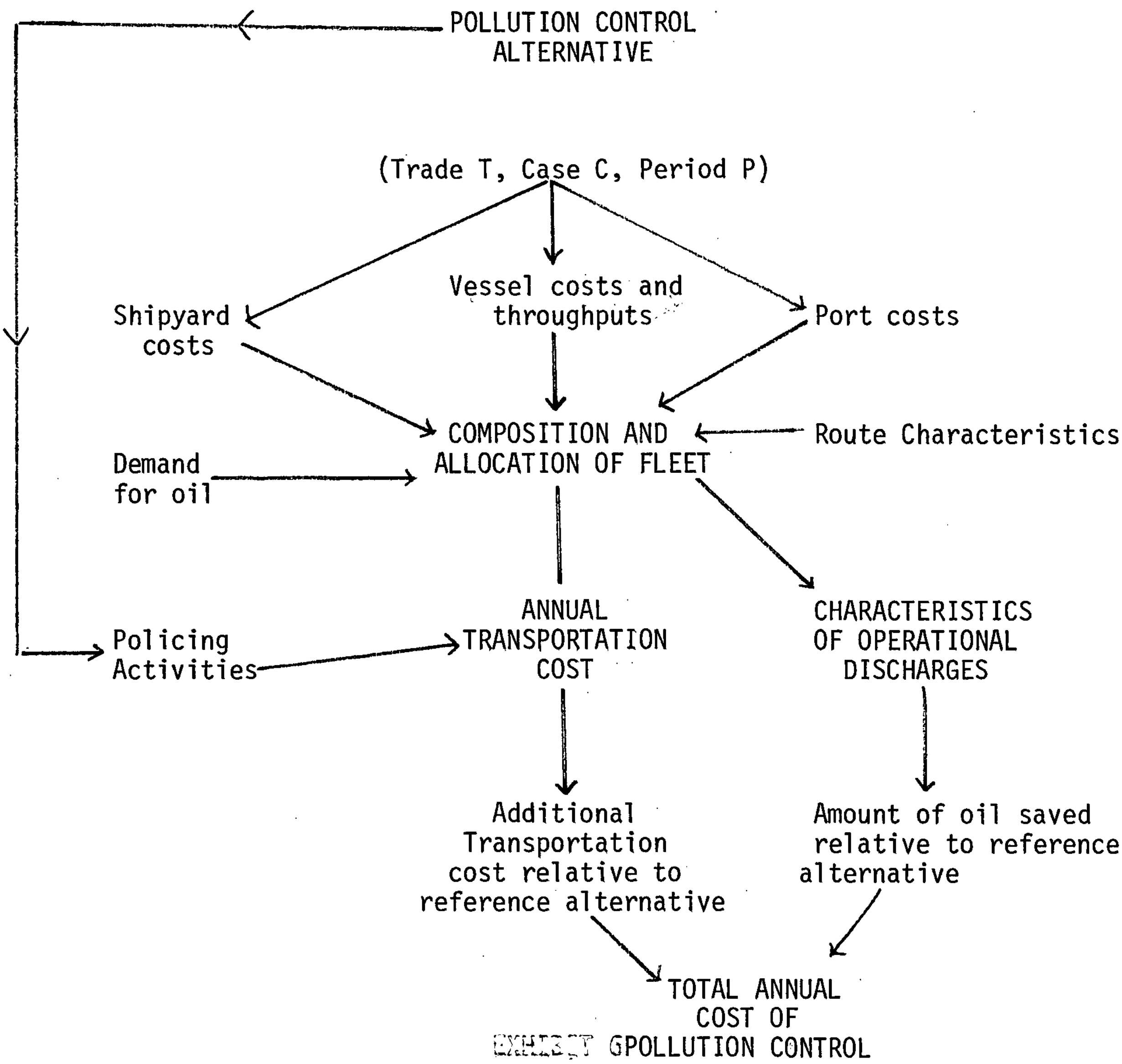


EXHIBIT 6

THE ESTIMATION PROCEDURE

have been considered, probable ranges for the cost and effectiveness (in each basic period) of alternate control policies can be proposed.

Exhibit ¢ is a concise and convenient way to summarize the estimation procedure.

FOOTNOTES

CHAPTER 4

[1]According to C.A. Walder, OCIMF, Personal Interview, London April 1976.

[2]In this regard, see U.S. Department of Commerce, Maritime Administration, Tanker Ballasting: How light can you go, Washington D.C. 1975

[3]That is, a vessel with same commercial profitability.

[4]According to Mr. Cawley (Economic Manager, British Petroleum) Personal Interview, London, April 1976.

[5]Mueller, W.H., The Worldwide Need for Tankers, From Sea Trade Conference: Money and ships, London, March 18, 1975.

[6]According to A. McKenzie, Tanker Advisory Center, an inspector was paid $150 per ship to inspect the slop tank and oil record book at the ARAMCO terminal in the Arabic Gulf. This was in 1971. The figure adopted in the study allows for an inflation (Personal interview, New York, 1975).

[7]U.S. Coast Guard, An Analysis of Mission Performance, Report, Washington, D.C., 1975, p. 111.

[8]According to the Canadian Federal Fisheries Minister Romeo LeBlanc, the new Canadian 200-mile coastal fishing zone can be patrolled by one aircraft. The Alaska trade zone will be roughly twice as large, Vancouver Sun, "Canada able to police 200-mile zone", June 14, 1976.

CHAPTER 5

THE ALASKA TRADE

The evaluation method described in Chapter 4 will be used in the next chapters to evaluate the cost-effectiveness of the IMCO pollution control alternative (See chapter 2) on the Alaska trade route. This chapter will describe the conditions prevailing on the Alaska trade. It provides the specific data that are needed, in addition to the background data provided in Chapter 3, to evaluate alternate control policies on the Alaska trade. The first section describes the supply and demand for oil on the Alaska trade. The second section describes the characteristics of the Alaska trade route. The last section provides the basic vessel costs on the Alaska trade.

5.1 SUPPLY AND DEMAND FOR THE ALASKAN CRUDE OIL

The trans-Alaska pipeline is scheduled to begin operations in the third quarter of 1977. From Valdez, Alaska the pipeline's throughput will be shipped by tanker to oil importing regions. According to a recent report for the U.S. Maritime Administration,[1] the pipeline will initially transport 600,000 barrels per day. By the beginning of 1978, this throughput is expected to rise to about 1.2 millions barrels per day and by the beginning of 1980, the piepline is expected to carry its full capacity of two millions barrels per day. After exhaustion of the Prudhoe Bay Field producible reserves, the pipeline will continue to be used for transportation oil from other fields on the Alaska North Slope and Arctic Ocean shelf.

The destination of the pipeline's throughput is still subject to considerable uncertainty. It is generally considered that the oil will be shipped to Puget Sound, San Francisco and Lons Angeles-Long Beach on the U.S. West Coast. It is believed that up to 1980 the throughput will be divided between Puget Sound, San Francisco and Long Beach on a 15-40-45 basis. When the pipeline reaches its maximum throughput of two million barrels a day in 1980, it is probable that a surplus will develop on the West Coast.[2]

It is also probable that this surplus will be moved from the West Coast to the U.S. Midwest by pipeline. In May 1975, Standard Oil of Ohio (SOHIO) announced its plans to move this anticipated surplus via a pipeline originating in Long Beach.[3] In the late fall of 1975, however, as a result of the phasing out of Canadian oil exports,[4] a consortium of companies, the Northern Tier Pipeline Company announced its project to build a pipeline from Puget Sound to Clearbrook, Minnesota, Montana, North Dakota, and Wisconsin which currently depend upon Canadian crude (SOHIO's line would serve refineries further south and east).[5]

A third proposal under study would be to ship Alaskan oil by tankers to Kitimat, British Columbia. The oil would then be transshipped to Edmonton through a new pipeline; and from Edmonton to the U.S. Midwest through existing pipelines. The plan is proposed by the Trans Mountain Oil Pipeline Corporation which presently supplies U.S. refineries with Canadian crude from Alberta. This plan is considered to be environmentally preferable to the Puget Sound scheme as a large tanker spill in the Puget Sound area would be a major disaster for both the United States and Canada.[6]

It is difficult to predict which of the above schemes will be implemented, as no construction permit has been delivered yet by the responsible governments. Decisions in this regard will clearly affect the allocation of Alaskan oil among the ports of the U.S. and Canadian West Coast. Another source of uncertainty is the magnitude of the surplus to be transported to the U.S. Midwest.

The most probable case (in June 1975) was that a 500,000 barrels per day surplus would develop on the U.S. West Coast. This surplus would be transported to the Midwest totally out of Long Beach. The rest of the oil would still be divided between Puget Sound, San Francisco and Long Beach on a 15-40-45 basis.[7] This might not be the most probable case anymore given the developments that have taken place since June 1975. But available information does not yield more probable figures.

Based on these figures, TABLE 26 shows the destination of the Alaska pipeline's throughput. It takes into account the oil production of Cook Inlet, Alaska, which will also be shipped by tankers from Valdez. This production is expected to yield 220,000 barrels a day by the beginning of 1978 and 241,000 by the beginning of 1980.[8]

5.2 THE CHARACTERISTICSSOF THE ALASKA TRADE ROUTE

5.2.1 Size constraints

The following size constraints will apply on the Alaska trade:

a) The port of Long Beach cannot accommodate tankers larger than 138,000 DWT unless part of the cargo has been offloaded at a previous call. With only minor dredging and expansion of onshore pipeline and storage tank facilities, this limit would be increased to 200,000 DWT for new tankers "of the wide beam configuration now being proposed".[9]

TABLE 26

DESTINATION OF THROUGHPUT OF ALASKAN OIL PIPELINE

(thousands of barrels per day)

	1978	1980
Puget Sound	213	261
San Francisco	568	696
Long Beach	639	1,284
Total = North Slope + Cook Inlet	1,420	2,241

SOURCE: U.S. Department of Commerce, Maritime Administration, Tanker Supply and Demand for the Alaskan Oil Trade, Washington, D.C. June 1976.

b) Puget Sound is currently able to accommodate tankers up to 210,000 DWT.[10] However, in May 1975, the Governor of the State of Washington signed into law a bill which places severe limits and controls on tanker traffic in Puget Sound. Among other things tankers greater than 125,000 DWT are not allowed in Puget Sound waters. This law faces a suit in court by Atlantic Richfield Company. ARCO contends that the law is pre-empted by U.S. federal laws, in particular those regulating interstate and foreign commerce.[11]

c) The port of San Francisco is not able to accommodate fully loaded tankers above 35,000 DWT. However, the practice of lightening into small tankers will permit to accommodate tankers up to 100,000 DWT.[12]

Due to these size constraints, tankers greater than 200,000 DWT tons are not suitable on the Alaska trade. This limit may be considerably increased if a deepwater port (or offshore terminal) is built on the Canadian or U.S. West Coast. The question has been much debated in recent years, but tanker operators do not seem to expect such developments. None of the vessels presently scheduled for use on the Alaska trade exceeds 190,000 DWT.[13] The size constraints that are most likely to apply are summarized in TABLE 27.

5.2.2 Vessel operating conditions

TABLE 28 describes the operating conditions for conventional tankers using conventional LOT on the Alaska trade route. A sustained sea speed of 15.5 knots is assumed for all vessels. No allowance is made for possible slow steaming practices during weak market conditions, due to the

TABLE 27

SIZE CONSTRAINTS FOR TANKERS IN DISCHARGING PORTS FOR THE ALASKAN OIL TRADE

PORT	SIZE LIMIT
Puget Sound	
- physical limit	200,000 DWT
- legal limit	125,000 DWT
San Francisco	
- with lightening	100,000 DWT
Long Beach[a]	
- new vessels	200,000 DWT
- existing vessels	150,000 DWT

[a] Plans are underway in Long Beach to increase the present ship size capacity (150,000 DWT).

TABLE 28

OPERATING CONDITIONS ON THE ALASKA ROUTE FOR
CONVENTIONAL TANKERS USING CONVENTIONAL
LOT

	UNLOADING PORT		
	Puget Sound	San Francisco	Long Beach
Round trip (miles	2,500	3,400	4,100
Sea Speed (knots)	15.5	15.5	15.5
Sea days	6.72	9.14	11.02
Port days	3	3	3
Voyage delay per trip	.5	.5	.5
Days/trip	10.22	12.64	14.52
Operational days per year	350	350	350
Trips per year	34.25	27.69	24.10

SOURCE: U.S. Department of Commerce, Maritime Administration, Tanker Supply and Demand for the Alaskan Oil trade, Washington, D.C., 1975 lack of data. All vessels are assumed to spend three days per trip in port. Twelve hours per trip are allowed for voyage delays and 15 days per year for voyage repair. No allowance is made for the possible impact of vessel size on the above operating bases, due to the lack of information in this regard.

5.3 BASIC VESSEL COSTS ON THE ALASKA TRADE

By U.S. law the vessels operating on the Alaska trade must be U.S. flag vessels. The capital and operating costs of U.S. flag tankers are generally higher than the costs of other tankers. Estimates of basic cost for conventional tankers on the Alaska trade are provided in TABLE 29, using the following assumptions:

- ship economic life = 20 years
- cost of capital = 10%
- Scrap value = 10%
- Tax rate = 0

5.4 SUMMARY

This chapter has described the basic conditions prevailing on the Alaska trade. The supply and demand for oil are unaffected by pollution control. Nor are the port depth limitations. Pollution control, however, has an impact on the basic vessel costs and operating condition described in this chapter. This impact must be estimated when assessing the economic cost and effectiveness of alternate pollution control policies. This is illustrated in the following chapter.

TABLE 29

BASIC VESSEL COSTS FOR CONVENTIONAL TANKERS

ON THE ALASKA TRADE

	(SHIP SIZE (MDWT)				
	65	85	115	140	175
Initial construction costs (MM$)	29	36	41	47	55
	FIXED ANNUAL COSTS (M$/ship/year				
Amortization	3000	3700	4250	4875	5700
Insurance + uninsured loss	925	1050	1240	1390	1610
Crew Cost	1000	1000	1000	1000	1000
Prov/stores	115	125	125	135	135
Maintenance and repairs	370	450	480	500	530
Overhead	90	90	100	110	110
Miscellaneous	60	60	70	80	80
	VARIABLE ANNUAL COSTS				
Fuel (M$/ship/year	2000	2420	2570	2695	2870
Port charges (M$/ship/year	15	18	25	30	38

SOURCES: Interpreted from: American Petroleum Institute (API: estimates for 1976). and U.S. Department of Commerce, Maritime Administration. Tanker Ballasting: How light can you go, Appendix C. Washington D.C. May 1975

(Using linear interpolations between sizes)

FOOTNOTES

CHAPTER 5

[1]U.S. Department of Commerce, Maritime Administration, Tanker Supply and demand for the Alaskan Oil Trade, Washington D.C. June 1975

[2]Ibid., p. 2.

[3]Ibid., p. 2.

[4]The Canadian Government announced in November 1975 that the delivery of Canadian Crude oil to the U.S. would stop in 1981.

[5]"Oil update 76", Pacific Northwest Sea, (Vol. 8, No. 4, 1975 and Vol. 9, No. 1, 1976), pp. 16-21

[6]Vancouver Sun, June 1976

[7]U.S. Department of Commerce, Maritime Administration, Tanker Supply and Demand for the Alaskan Oil Trade, p. 2.

[8]Ibid., p. 2

[9]Ibid., p. 9.

[10]U.S. Corps of Engineers, U.S. West Coast Deep Water Port Facilities Study, Appendix C, 1973.

[11]U.S. Department of Commerce, Maritime Administration, Tanker Supply and demand for the Alaskan Oil Trade, p. 9
Pacific Northwest Sea, p. 18
U.S. Congress, Oil Transportation by Tankers: An Analysis of Marine Pollution and safety Measures, pp. 81-82.

[12]U.S. Congress p. 24 and U.S. Corps of Engineers, Appendix D.

[13]U.S. Department of Commerce, Maritime Administration, Tanker Supply and demand for the Alaskan Oil Trade, Table 3.

[14]These assumptions are based on the sources shown under TABLE 28.

CHAPTER 6

ILLUSTRATION OF THE EVALUATION METHOD: THE COST-EFFECTIVENESS OF THE IMCO ALTERNATIVE ON THE ALASKA TRADE

6.1 INTRODUCTION

The objective of this chapter is to estimate the economic cost and effectiveness of implementing the IMCO alternative on the Alaska trade. The IMCO alternative has been described as follows in Chapter 2.

- Additional segregated ballast capacity on tankers over 70,000 deadweight tons ordered after December 31, 1975 or delivered after December 31, 1979.
- Improved LOT is used by all tankers on medium to long-haul trades.
- Shore reception facilities are used on short-haul trades, in special areas and in drydocking ports. Short-haul trades means a trade involving ballast voyages of less than 1000 miles or three days.

According to Chapter 5 (TABLE 28), there is no ballast voyage less than 1000 miles or three days on the Alaska trade (unless some oil is shipped from Valdez to Canada). The Alaska trade area is not defined as a special area by IMCO. Accordingly, no shore facility is required on the Alaska trade under the IMCO alternative.

The pollution control standards under the IMCO alternative are those contained in the 1973 Convention. It is assumed that the U.S. Coast Guard inspects all vessels loading at Valdez and patrols the Alaska trade zone with aircraft to enforce these standards. It is further assumed that the penalties are sufficiently high to prevent failures in the use of improved LOT. The significance of this assumption will be tested at the end of the chapter.

The cost-effectiveness of pollution control under the IMCO alternative is obtained by comparison with the reference alternative using the procedure described in Chapter 4 and the data provided in Chapter 3 and 5.

The reference alternative, which has been referred to as current practice in Chapter 2, simply involves the voluntary use of conventional LOT by shipmasters. According to Chapter 5 (Table 28), ballast voyages require 80 to 140 hours on the Alaska trade route. This leaves enough time for the LOT operations to be carried out. The task may be difficult, however, when severe weather is encountered.

The pollution control standards under the reference alternative are those contained in the 1954 Convention, as amended in 1962. These standards are not consistent with the proper use of LOT and they are extremely difficult to enforce. As a result, governmental enforcement has no significant impact on operational pollution. It is assumed that there is no governmental enforcement on the Alaska trade under the enforcement alternative. It is further assumed that the oil companies have set up a voluntary inspection scheme at Valdez (because it is consistent with oil companies' current policy and practice). As a result, conventional LOT is assumed to be, on the average, 90 per cent effective in good weather, and 80 per cent effective in bad weather.

Due to variations in supply and demand for Alaskan oil two basic periods (as defined in section 4.3) are defined: (1) the period 1978-1980 during which the trans-Alaska pipeline operates at about half capacity and (2) the period 1980-and-after during which the pipeline operates at full capacity. The calculations are the same for both periods. They are made in this study for the second period only.

According to the previous chapter, it is assumed that the tankers used on the Alaska trade have their size comprised between 60,000 dwt and 200,000 dwt.[1] Given the pollution control standards to be investigated and the port depth limitations described in Chapter 5, the following size classes are used.

CLASS SIZE MDWT	REPRESENTATION SIZE MDWT
60-69	65
70-99	85
100-125	115
126-150	140
151-200	175

The next two sections estimate the annual economic cost of ocean trnasportation and the characteristics of operational discharges of oil under the reference alternative and under the IMCO alternative. The last section of this chapter estimates the economic cost of pollution control under the IMCO alternative.

6.2 THE REFERENCE ALTERNATIVE

The following steps are carried out in this section:

Estimate 1 Annual vessel throughputs

2 Annual vessel fixed and variable costs

3 Composition and allocation of the tanker fleet

4 Characteristics of tanker operational discharge

5 Annual cost of ocean Transportation

6.2.1 Annual Vessel throughputs under the reference alternative

According to Chapter 3, the throughput per trip of a 100,000 dwt crude oil tanker is 95,000 tons in the absence of pollution control. Assuming that conventional LOT is 80 to 90 per cent effective, depending on weather, the amount of oil retained in the slop tank is 192 to 226 tons (using Table 5) and the amount of dead weight water (one-third of the slops) is 96 to 113 tons. The loss of throughput relative to the case of no pollution control is 96 to 113 tons per trip depending on the weather.

Heavy weather is frequent in the gulf of Alaska. In the absence of any specific data, it is assumed that heavy weather is encountered on 50 per cent of the ballast voyages. Therefore, the average loss of throughput for a 100,000-dwt crude oil tanker on the Alaska trade is 104 tons per trip under the reference alternative. The resulting throughput per trip is 94,496 tons on the average allowing for 400 tons of clingage. Using this figure and the operating bases shown in TABLE 28, it is now possible to calculate annual throughputs for each vessel size. These annual throughputs are shown in TABLE 30.

6.2.2 Annual vessel costs under the Reference Alternative

According to Chapter 4, the following cases are considered to estimate vessel fixed costs.

TABLE 30

VESSEL THROUGHPUTS UNDER THE REFERENCE ALTERNATIVE[a]

	Vessel Size (MDWT)				
	65	85	115	140	175
Throughput/trip[b] (M Tons)	61.41	80.30	108.80	132.27	165.34
	VALDEZ TO PUGET SOUND				
Trips/year[c]	34.25				
Annual throughput (M Tons/year)	2103	2750	3726	4530	5663
	VALDEZ TO SAN FRANCISCO				
Trips/year[c]	27.69				
Annual throughput (M tons/year)	1700	2223	3013	3663	4578
	VALDEZ TO LONG BEACH				
Trips/year[c]	24.10				
Annual throughput (M tons/year)	1480	1935	2622	3188	3985

[a] Assuming vessels are used at full capacity

[b] It is proportional to size (94.496 tons for a 100,000 dwt tanker according to the text).

[c] Using TABLE 28

Case 1: Large permanent surplus. The opportunity cost of existing vessels is zero.

Case 2: Long-run Equilibrium of Tanker supply and Demand. The annual opportunity cost of an existing vessel is equal to the vessel's amortization cost.

The annual fixed and variable costs are calculated in TABLE 31. The resulting costs per ton transported are shown in TABLE 32. Only the relevant sizes are included (See Section 5.2.1) TABLE 32 shows that it is always uneconomic to order new vessels where there is a large surplus (even though there are less size constraints applying on new vessels). The costs per ton transported are the same for new and existing ships at the long run equilibrium.

6.2.3 Composition and Allocation of the Tanker Fleet under the Reference Alternative.

Based on the previously calculated vessel costs, the composition and allocation of the tanker fleet under the reference alternative is estimated for each period, using the optimization model described in Chapter 4 (and Annex B). The number of vessels used on the trade and the allocation of the fleet is shown in Table 33. According to Chapter 4, vessels are attached to the trade over the year, since they cannot be transferred to other trades for small periods of time. However, they are not attached to a given port. TABLE 33 shows, for instance, that four vessels in the 100,000 to 125,000 dwt range are used on the trade when there is a large surplus. 3.373 of these four vessels are used on the Valdez to Puget Sound route (that is, each vessel is used 52 x 3.373/4 = 43.8 weeks per year on the average, on the Puget Sound route)

TABLE 31

ANNUAL VESSEL FIXED AND VARIABLE COSTS UNDER THE REFERENCE ALTERNATIVE[a]

	Vessel Size (MDWT)				
	65	85	115	140	175
ANNUAL FIXED COSTS--LARGE SURPLUS					
New Ships[b]	5560	6475	7265	8090	9165
Existing ships[c]	2560	2775	3015	3215	3465
ANNUAL VARIABLE COSTS--LARGE SURPLUS					
Puget Sound[d]	2513	3036	3426	3722	4171
San Francisco[d]	2415	2918	3262	3522	3922
Long Beach[d]	2360	2854	3172	3418	3786

[a]The annual costs of existing vessels are estimated in the case of a large surplus only since the costs of new and existing vessels are about the same at the long-run equilibrium

[b]This is the sum of the fixed costs shown in TABLE 29.

[c]No opportunity cost

[d]Using the basic variable costs shown in TABLE 29 and the number of trips per year shown in TABLE 28.

TABLE 32

UNIT TRANSPORTATION COST OF ALASKAN OIL

UNDER THE REFERENCE ALTERNATIVE

($ per ton of crude transported)

Vessel Size	65	85	115	140	175
			Surplus		
Puget Sound					
- Existing Ships	2.41	2.11	1.73		
- New Ships	3.84	3.46	2.87		
San Francisco					
- Existing Ships	2.93	2.56			
- New Ships	4.69	4.22			
Long Beach					
- Existing ships	3.32	2.90	2.36	2.08	
- New Ships	5.35	4.82	3.98	3.61	3.25
			Long-Run Equilibrium		
Puget Sound					
- New and Existing ships	3.84	3.46	2.87		
San Francisco					
- New and Existing ships	4.69	4.22			
Long Beach					
- New and Existing ships	5.35	4.82	3.98	3.61	3.25 (only new)

TABLE 33

NUMBER AND ALLOCATION OF THE ALASKA TANKER FLEET
UNDER THE REFERENCE ALTERNATIVE
(after 1980)

Vessel Size	65	85	115	140	175
	Large Surplus (No new vessel)				
Puget Sound	0	0	3.373	0	0
San Francisco	0	15[a]	0	0	0
Long Beach	0	0	.479	19	0
Total	0	15	4	19	0
	Long-run equilibrium (new and existing vessels)				
Puget Sound	0	.924	2.69	0	0
San Francisco	0	15	0	0	0
Long Beach	.84	0	.31	0	15
Total	1	16	3	0	15

each .479 of these vessels are used on the Long Beach route (each vessel is used 6.2 weeks per year, on the average, on the Long Beach route). Each of these four vessels is idle for two weeks per year, on the average.

6.2.4 Characteristics of Tanker Operational Discharges under the Reference Alternative

The number of trips per year is now estimated for each port, using TABLE 33 (allocation of the fleet) and TABLE 28 (number of trips per year for an individual vessel used at full capacity). TABLE 33, for instance, shows that .479 vessels in the 100,000 to 125,000 dwt range are used on the Valdez to Long Beach route where there is a large surplus. According to TABLE 28, a vessel used at full capacity on the Valdez to Long Beach route completes 24.10 trips per year. Accordingly, vessels in the 100,000 to 125,000 dwt range complete .479 x 24.10 = 11.54 trips per year on the Valdez to Long Beach route. Similar calculations are made for each vessel type and each port. The results are shown in TABLE 34. TABLE 34 also shows the average discharge of oil per trip for each vessel type. The average discharge of oil is calculated for a 100,000 dwt tanker using Chapter 2 (TABLE 5) and assuming that LOT is 80 to 90 per cent effective, depending on weather. Then the average discharge of oil is calculated for the relevant vessel sizes, assuming it is proportional to size. The characteristics of oil discharges under the reference alternative are given finally in TABLE 35. It is shown that the total discharge of oil on the Alaska trade is 36,360 tons per year under the reference alternative (this amount does not depend upon the fleet since all vessels use the same pollution control technique so that oil discharges are proportional to the amount of oil carried only). The average discharge is 36 to 39 tons, depending on the fleet.

TABLE 34

NUMBER OF TRIPS AND AMOUNTS OF OIL DISCHARGED
UNDER THE REFERENCE ALTERNATIVE

	Vessel size (MDWT)				
	65	85	115	140	175
Average discharge of oil per trip (tons)	20.7	27.1	36.7	44.7	55.8
Trips per year--Large surplus					
Puget Sound	0	0	115	0	0
San Francisco	0	415	0	0	0
Long Beach	0	0	11.5	458	0
Trips per year--Long run Equilibrium					
Puget Sound	0	31.64	92	0	0
San Francisco	0	415	0	0	0
Long Beach	20	0	7.5	0	361

TABLE 35

CHARACTERISTICS OF OIL DISCHARGES

UNDER THE REFERENCE ALTERNATIVE

Unloading port	Puget Sound	San Francisco	Long Beach	Total
		LARGE SURPLUS		
Annual amount of oil discharged (tons/year)	4,220	11,246	20,894	36,360
Frequency of discharge (# trips/year	115	415	469	999
Average amount of oil discharged (tons per trip)	37	27	45	36
Concentration[a] and location		50 to 700,000 ppm anywhere at sea		
		LONG-RUN EQUILIBRIUM		
Annual amount of oil discharged (tons/year)	4,220	11,246	20,894	36,360
Frequency of discharge (# trips/year)	124	415	388.5	927.5
Average amount of oil discharged (tons/trip)	34	27	54	39

Concentration and location: 50 to 700,000 ppm anywhere at sea.

[a] 700,000 ppm when dumping pure slops

6.2.5 Annual Cost of Ocean Transportation under the Reference Alternative

The annual cost incurred by tanker owners is $ Million 236,557 when there is a large surplus and $ Million 384.198 at the long-run equilibrium (these figures are produced by the optimization model). There is no tax (see Section 5.3) and no increase in the opportunity cost of existing tankers due to pollution control on new vessels (See Section 4.3.3.3). The cost incurred by tanker owners therefore reflects exactly vessel, port and shipyard costs. There is no governmental enforcement activity under the reference alternative, but the oil company inspection scheme at Valdez costs $250,000 per year (since the cost of inspection is $250 per boarding. There are approximately 1000 trips per year). The annual cost of ocean transportation under the reference alternative is therefore:

236.557 + .250 + $million 236.807 when there is a large surplus

and 384.198 + .250 ≑ $million 384.448 at the long run equilibrium.

6.2.6 Summary

The following estimates have been obtained in this section:

- 36,360 tons of oil are discharged annually by tankers engaged in the Alaskan oil trade when conventional LOT is the pollution control technique for all tankers.
- The annual cost of ocean transportation for the Alaska trade is $ Million 236.807 when there is a large surplus and $ million 384,448 at the Long-run equilibrium when conventional LOT is the pollution control technique for all tankers.

6.3 THE ANNUAL COST OF OCEAN TRANSPORTATION AND THE CHARACTERISTICS OF OPERATIONAL DISCHARGES UNDER THE IMCO ALTERNATIVE.

The calculations in the previous section have been detailed extensively. The calculations in this section are quite similar and the explanations already given are not repeated.

6.3.1 Annual Throughputs under the IMCO Alternative

Vessel operating conditions under the IMCO alternative differ from those prevailing under the reference alternative in the following respects.

- segregated ballast tankers save 5 hours in port per trip (See 3.2.2.1 (c)).
- Improved LOT and the additional segregated ballast capacity affect the throughput per trip. The loss of throughput including 400 tons of clingage for a conventional 100,000 dwt tanker is 504 tons per trip under the reference alternative (See 6.2.1). Based on TABLE 14, the loss of throughput for a 100,000 DWT segregated ballast tanker using improved LOT properly (and lighter ballasting practices) is 470 tons per trip. The loss of throughput for a conventional tanker using improved LOT is properly is 522 tons.

Based on these figures, the annual throughputs are calculated in TABLE 36.

6.3.2 Annual Vessel Costs under the IMCO Alternative

Vessel costs differ from those prevailing under the reference alternative in the following respects:

TABLE 36

VESSEL THROUGHPUTS UNDER THE IMCO ALTERNATIVE

SIZE	65	85	115	140	175
Cargo throughput per trip (M tons)					
- existing ships	61.40	80.28	108.78	132.24	165.30
- new ships	61.40	80.37	108.89	132.37	165.46
PUGET SOUND					
Number of trips[a] per year					
- existing ships	34.25	34.25	34.25	34.25	34.25
- new ships	34.25	34.96	34.96	34.96	34.96
Annual throughput (M tons)					
- existing ships	2103	2750	3726	4530	5663
- new ships	2103	2810	3807	4628	5784
SAN FRANCISCO					
Number of trips/year[a]					
- existing ships	27.69	27.69	27.69	27.69	27.69
- new ships	27.69	28.16	28.16	28.16	28.16
Annual throughput (M tons)					
- existing ships	1700	2223	3013	3663	4578
- new ships	1700	2263	3066	3728	4659
LONG BEACH					
Number of trips[a] per year					
- existing ships	24.10	24.10	24.10	24.10	24.10
- new ships	24.46	24.46	24.46	24.46	24.46
Annual throughputs (M tons)					
- existing ships	1480	1935	2622	3188	3985
- new ships	1480	1966	2663	3238	4047

[a]Taking into account the 5 hours saved in port by segregated ballast tankers.

- Segregated ballast tankers save time in port and, therefore, complete more voyages per year. The variable cost is affected.
- Segregated ballast increases construction cost by 5 per cent and repair and maintenance costs by 6 per cent (See section 3.2.2).
- Improved LOT requires a $200,000 investment for all ships. This is amortized over 20 years for new ships, and over 10 years for existing ships, using a 10 per cent cost of capital (See Section 5.3).

The resulting fixed and variable costs are shown in TABLE 37. The fixed cost of existing tankers is calculated in the case of a large surplus only since the costs of new and existing vessels are about the same at the long-run equilibrium. The costs per ton of oil transported are finally shown in TABLE 38. It is uneconomic to use new vessels when there is a large surplus.

6.3.3 Composition and Allocation of the Tanker Fleet under the IMCO Alternative.

The composition and allocation of the tanker fleet is given in TABLE 39. Only existing vessels are used when there is a large surplus. Both new and existing vessels can be used at the long-run equilibrium. TABLE 39 assumes that no existing vessel is used at the long-run equilibrium. When as many existing vessels as is economic are kept on the trade, the fleet is as shown in TABLE 33, at the long-run equilibrium.

TABLE 37

ANNUAL VESSEL COSTS UNDER THE REFERENCE ALTERNATIVE

(M $ / year)

	Vessel Size (MDWT)				
	65	85	115	140	175
	FIXED COSTS				
New vessels					
Basic fixed cost[a]	5560	6470	7265	8090	9165
+ Capital cost of segregated ballast	0	185	212	244	285
+ Capital cost of Improved LOT	21	21	21	21	21
+ Increase in maintenance and repair cost	22	27	29	30	32
TOTAL FIXED COST	5603	6708	7527	8485	9503
Existing vessels--Long-run Equilibrium					
Basic fixed cost	2560	2775	3015	3215	3465
Capital cost of im. LOT	28	28	28	28	28
Total fixed cost	3682	2817	3057	3257	3507
	VARIABLE COSTS				
Puget Sound					
- New[b]	2513	3048	3440	3742	4195
- Existing[c]	2513	3036	3426	3722	4171
San Francisco					
- New[b]	2415	2928	3275	3537	3942
- Existing[c]	2415	2918	3262	3522	3922
Long Beach					
- New[b]	2360	2860	3102	3428	3798
- Existing[c]	2360	2854	3172	3418	3786

[a] Fixed cost under the reference alternative (TABLE 31)

[b] Allowing for the increased number of trips completed by new ships (due to the time savings in port).

[c] Same as in TABLE 31.

TABLE 38

UNIT TRANSPORTATION COST OF ALASKAN

OIL UNDER THE IMCO ALTERNATIVE

($ per ton)

Shipsize MDWT	65	85	115	140	175
	LARGE SURPLUS				
Puget Sound					
- Existing	2.43	2.13	1.74		
- New	3.85	3.47	2.88		
San Francisco					
- Existing	2.95	2.58			
- New	4.70	4.26			
Long Beach					
- Existing	3.35	2.93	2.38	2.09	1.83
- New	5.36	4.86	4.02	3.65	3.29
	LONG-RUN EQUILIBRIUM				
Puget Sound					
New and Existing	3.85	3.47	2.88		
San Francisco					
New and Existing	4.70	4.26			
Long Beach					
New and Existing	5.36	4.86	4.02	3.65	3.29

TABLE 39

NUMBER AND ALLOCATION OF THE ALASKA TANKER

FLEET UNDER THE IMCO ALTERNATIVE

Vessel size (MDWT)	65	85	115	140	175
			LARGE SURPLUS		
Puget Sound	0	0	3,372	0	0
San Francisco	0	15	0	0	0
Long Beach	0	0	.479	19	0
TOTAL	0	15	4	19	0
			LONG-RUN EQUILIBRIUM[a]		
Puget Sound	0	0.36	3,275	0	0
San Francisco	0	14,810	0	0	0
Long Beach	0	0	.725	1	14
TOTAL	0	15	4	1	14

6.3.4 Characteristics of tanker Operational Discharges under the IMCO Alternative

The number of trips per year and the average amount of oil discharged per trip is estimated for each vessel type and each port, as explained in the previous section (using chapter 3 to estimate the average amount discharged by conventional or segregated ballast tankers using improved LOT.) The characteristics of operational discharges of oil on the Alaska trade under the IMCO alternative are shown in TABLE 40. The total discharge of oil is about 4000 tons in the large surplus case (only existing vessels are used). It is 2900 to 3500 tons at the long-run equilibrium depending on the number of existing vessels used. The average amount is 3 to 5 tons under both cases. All discharges take place outside of the 50 miles zone.

6.3.5 Annual cost of Ocean Transportation under the IMCO Alternative

The annual transportation cost under the IMCO alternative is computed in TABLE 41. Policing costs are estimated using the following figures:

- each vessel is boarded each trip for inspection of the slop tank and oil record book. The cost is $250 per boarding (See Chapter 4).
- The Alaska trade zone is patrolled by two aircrafts (20 hours per week each). The cost of aerial surveillance is $500 per tour (See Chapter 4).

According to TABLE 41, the annual cost of ocean transportation under the IMCO alternative is $Million 240.97 under the large surplus case and $Million 386.81 at the long-run equilibrium (when only new vessels are used. It is less when existing vessels are used too since the opportunity cost to

TABLE 40

CHARACTERISTICS OF OPERATIONAL

DISCHARGES UNDER THE IMCO ALTERNATIVE

Route	Puget Sound	San Francisco	Long Beach	All routes
		LARGE SURPLUS		
Annual amount of oil discharged (tons/year)	502	1340	2166	4008
Frequency of discharges (trips/year)	115	415	470	1000
Average amount of oil discharged (tons/trip)	4.37	3.23	4.61	4.00
Concentration and location	30=10,000 ppm outside of the 50 miles zone			
		LONG-RUN EQUILIBRIUM		
Annual amount of oil discharged (tons/year)	336-504	896-1340	1662-1692	2894-3536
Average amount of oil discharged (tons/trip)	2,93-4.07	2.16-3.23	4,34-4.36	3.17-3.61
Concentration and location	30-10,000 ppm outside of the 50 miles zone			

TABLE 41

ANNUAL COST OF OCEAN TRANSPORTATION

UNDER THE IMCO ALTERNATIVE

($ million/year)

	Large Surplus	Long-run equilibrium (new vessel only)
Vessel shipyard and port costs		
- Cost incurred by shipowners[a]	237.62	385.52
- less tax	0	0
- Total	237.62	385.52
Policing costs		
- Boarding	.25	.25
- aerial surveillance	1.04	1.04
- Total	1.29	1.29
Annual cost of ocean Transportation	238.91	386.81

[a] Given by the optimization model

the shipowner overestimates the economic opportunity cost of existing vessels. See Chapter 4, Section 4.3.3.3).

6.3.6 Summary

The following estimates have been obtained in this section:

- 2,900 tons of oil are discharged annually by tankers engaged on the Alaska trade under the IMCO alternative when all tankers above 70,000 dwt are segregated ballast tankers using improved LOT, and 4000 tons of oil are discharged annually when all tankers are conventional tankers using improved LOT only.
- The annual cost of ocean transportation is $ million 238.91 under the large surplus case and at most $ Million 386.81 at the long-run equilibrium.

6.4 THE COST EFFECTIVENESS OF THE IMCO ALTERNATIVE ON THE ALASKA TRADE

The economic cost of implementing the IMCO alternative on the Alaska trade is calculated in TABLE 42. TABLE 42 shows that pollution control under the IMCO alternative generates a net benefit per ton of oil saved, assuming that enforcement is effective and the value of the oil saved (generally found in the slops) is close from the market price of crude oil. The net benefit per ton of oil pollution saved is $20 to $25 depending on the tanker supply and demand conditions.

TABLE 42 also shows that the additional ocean transportation cost, including policing cost, under the IMCO alternative is about $2 million, that is less than one per cent of the total ocean transportation cost.

By comparing the results obtained at the long-run equilibrium under the reference alternative and under the IMCO alternative, it is possible

TABLE 42

THE ECONOMIC COST OF THE IMCO ALTERNATIVE

ON THE ALASKA TRADE

	Large Surplus	Long-Run Equilibrium (new vessels only)
Additional transportation cost ($ million/year	2.103	2.330
Amount of oil saved (tons)	32,360	33,460
Value of the oil saved ($ Million)	2.912	3.011
Annual cost of pollution control	.808	.670
Net benefit per ton of oil saved	$25	$20

to estimate the incremental cost-effectiveness of requiring segregated ballast on new tankers in addition to improved LOT. When all tankers are new and all use only improved LOT, the fleet is as shown in TABLE 33 (long-run equilibrium case). The additional ocean transportation cost is simply the cost of providing the ships shown in TABLE 33 with the improved LOT equipment ($21,000 per year and per ship) and the cost of enforcing the proper use of improved LOT.

The incremental pollution control cost of requiring segregated ballast on new ships is calculated in TABLE 43. Two cases are considered. The case of effective enforcement where improved LOT is 98.5 per cent effective, and the case of no effective enforcement where improved LOT is only 90 per cent effective on the average. No policing cost is assumed in the case of no effective enforcement. TABLE 43 shows that the incremental cost of segregated ballast is $182 per ton when improved LOT is properly enforced. But the segregated ballast requirement generates a net benefit of $37 per additional ton saved when improved LOT is not properly enforced. These results show the importance of enforcement when evaluating the cost-effectiveness of a pollution control policy.

6.4 SUMMARY

This chapter has described the calculations required to estimate the cost of tanker pollution control. The calculations showed that pollution control under the IMCO alternative generates a net benefit. This benefit is estimated to be $20 to $25 per ton of oil pollution prevented. The use of additional segregated ballast capacity on new ships (in addition to improved LOT) involves a net cost (about $180 per additional ton of oil saved) when LOT is used properly. It generates a benefit and prevents large pollution when LOT is poorly operated.

TABLE 43

THE INCREMENTAL COST OF REQUIRING SEGREGATED BALLAST

ON NEW TANKERS ON THE ALASKA TRADE

	Effective Enforcement	No Effective Enforcement
IMPROVED LOT ONLY		
Amount of oil discharged	4000 tons	26,600 tons
Amount of oil saved relatively to reference alternative	32360 tons	9,760
Value of the oil saved	$2,912,000	$874,000
Cost of improved LOT		
- equipment cost	$ 735,000	$735,000
- policing cost	$1,290,000	0
- Total	$2,025,000	$735,000

--continued--

TABLE 43 (Continued)

	Effective Enforcement	No Effective Enforcement
IMPROVED LOT + SEGREGATED BALLAST		
Amount of oil discharged	2900 tons	19,314 tons
Amount of oil saved relatively to reference alternative	33,460 tons	17,046 tons
Cost of Improved LOT + segregated ballast		
- vessel, port and shipyard cost	$1,040,000	$1,040,000
- policing cost	$1,290,000	0
- total	$2,330,000	$1,040,000
Value of the oil saved	$3,011,000	$1,534,000
INCREMENTAL COST-EFFECTIVENESS OF SEGREGATED BALLAST		
Incremental ocean transportation cost	$ 300,000	$ 305,000
Incremental value of the oil saved	$ 99,000	$ 660,000
Net incremental cost	$ 201,000	$ 355,000
Incremental amount of oil saved	1100 tons	9,554 tons
Incremental cost per ton of oil saved	$183	- $37.

FOOTNOTES

CHAPTER 6

[1] Crude oil tankers are generally above 60,000 dwt.

CHAPTER 7

SUMMARY AND CONCLUSIONS

Operational discharges of oil by tankers are a major source of marine pollution. There are a number of policies available to control these discharges. This study has provided a method and a data base to evaluate the cost-effectiveness of these policies. This method and data base have been used to evaluate the cost-effectiveness of implementing the provisions of the 1973 IMCO Convention on the future Alaskan oil trade.

Most tankers currently use retention-on-board (ROB) or load-on-top (LOT) procedures to prevent the discharge of oil during deballasting and cleaning operations. The effectiveness of these procedures may vary considerably depending on such factors as length of haul, weather and clingage conditions, and crew ability. There is a financial incentive, however, for integrated oil companies to use retention-on-board or load-on-top effectively since the value of the oil saved is likely to exceed the cost of carrying deadfreight water in the slops and processing salt contaminated oil at the refinery. But good LOT or ROB performance are financially undesirable to the independent shipowner, unless he receives the freight on the slops (and a compensation for any incurred delays).

The 1954 Convention, as amended in 1962, is the existing law on the subject of tanker operational pollution. But this convention is virtually impossible to enforce and has practically no impact on tanker operational discharges of oil.

A number of policies have been proposed in recent years to reduce tanker operational discharges of oil from their current level. Three basic policies are identified in Chapter 2. First, the industry alternative, which reflects current industry trends, relies on improved LOT or ROB, crude washing techniques, and segregated ballast for new vessels. Second, the environmentalists' alternative (which reflects the views of the environmental groups) relies primarily on segregated ballast for both new and existing vessels. The use of LOT or ROB procedures is kept to a minimum. Third, the IMCO alternative, which reproduces the 1973 Convention, is similar to the industry alternative except that it requires the use of shore facilities to handle cleaning and ballast water in special areas and on short-haul trades.

Chapter 3 provides a data base to be used when evaluating the cost-effectiveness of alternate policies. Chapter 3 gives estimates of the impact of pollution control techniques on (1) the capital and operating costs of tanker transportation and (2) the amounts and concentrations of operational oil discharges.

The method described in Chapter 4 permits the assessment of alternate policies in cost-effectiveness terms. The effectiveness of a given control policy is evaluated by studying the characteristics of operational discharges under this policy. These characteristics are (1) amounts of oil (2) concentration of oil discharges (3) location and depth of oil discharges and (4) frequency of oil discharges. The economic cost of a given control policy relative to the reference alternative is the additional tanker transportation cost, including policing costs, less the value of the additional oil saved. A distinction is made between the costs incurred by tanker owners and the economic cost of tanker transportation.

It is assumed that the allocation of the tanker fleet is such that the total cost incurred by tanker owners is minimized. Taxes and transfers are excluded to estimate the economic cost of tanker transportation. Various cases are considered to estimate the opportunity cost of existing vessels.

The proposed method is used to estimate the cost-effectiveness of implementing the IMCO alternative on the Alaskan oil trade routes. Chapter 5 describes the relevant characteristics of the Alaskan oil trade. In Chapter 6 it is estimated that the value of the oil saved under the IMCO alternative (relative to current practice) exceeds the additional transportation and policing costs. Thus, the cost of tanker operational pollution control has become small (or negative) as a result of the recent increase in the price of oil. In this regard the estimates obtained prior to the 1973 IMCO Convention are no longer valid.

Chapter 6 also shows that the cost of pollution control depends upon the enforcement policy. In the case of effective enforcement, the cost of requiring segregated ballast for new tankers engaged in the Alaskan oil trade is approximately $200 per additional ton of oil pollution prevented. But this cost is negative in the absence of effective enforcement (that is, the additional cost due to segregated ballast on new tankers is more than offset by the value of the oil saved, relative to current practice). The less effective the enforcement policy, the more desirable it is to require segregated ballast.

This study has only provided cost-effectiveness estimates for one pollution control policy on a single trade. The method and data provided in this study should permit further investigations. In particular, it would be interesting to compare alternate pollution control policies on various trades and to identify the most important factors by means of a sensitivity analysis

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ANNEX A

AVERAGE DISCHARGES FOR A CONVENTIONAL 100,000 DWT CRUDE OIL TANKER USING IMPROVED ROB

		Good Weather	Bad Weather
1.	Capacity of dirty ballast tanks	20-25% of DWT	35-40% of DWT
2.	Amount of dirty ballast	22,500 tons	37,500 tons
3.	Settled part of dirty ballast (90% of (2))	20,000 tons	33,750 tons
4.	Oil discharge from dirty ballast tanks ((3) x 30 ppm)	.60 ton	1.00 ton
5.	Washwater for a complete washing cycle (stripping pumps only)	14,400 tons	14,400 tons
6.	Tank capacity cleaned	25-35% of dwt	35-40% of dwt
7.	Washwater on a routine voyage (stripping pumps only)	4,300 tons	5,400 tons
8.	Dirty part of dirty ballast (10% of (2))	2,000 tons	3,750 tons
9.	Total amount of slops (stripping pumps only) = (8) + (7)	6,300 tons	9,150 tons
10.	Oil discharge from slop tank (stripping pumps only) = (9) X 150 ppm	.94 ton	1.37 tons
11.	Total oil discharge (stripping pumps only) = (10 + (4))	1.54 tons	2.38 tons
12.	Washwater on a routine voyage (with eductors) = 3.5 x (7)	15,000 tons	18,900 tons
13.	Total amount of slops (with eductors) to be handled. (12) + (8)	17,000 tons	22,650 tons
14.	Oil discharge from sloptank (with eductors) = (13) x 150 ppm	2.55 tons	3.40 tons
15.	Total oil discharge (with eductors) (14) = (4)	3.15 tons	4.40 tons

ANNEX B

AN OPTIMIZATION MODEL TO ESTIMATE THE COMPOSITION AND ALLOCATION OF THE TANKER FLEET ON THE ALASKA TRADE

1) GENERAL

The model minimizes the annual cost incurred by shipowners on the Alaska trade, subject to supply and demand (for oil) constraints, and to integer constraints. Integer constraints arise from the fact that the entire fixed cost must be paid, even if the vessel is not used at full capacity. Such constraints are necessary unless it is assumed that tankers can be transferred to another trade at a small cost and for a small period of time. This assumption is not made in the study.

2) MODEL DESCRIPTION

All the costs mentioned here are annual costs

The cost to be minimized can be expressed as follows:

$$\text{Minimize} \quad \sum_{i=1}^{3} \sum_{j=1}^{5} Aijn$$

where

$$Aijn = Vijeijn + fjEjn + Vijmijn + FjMjn$$

Vij = Variable cost of existing vessels (Port i, size j)

Vij = Variable cost of new vessels (port i, size j)

Fj = fixed cost of existing vessels (Size j)

Fj = fixed cost of new vessles (Size j)

Ejn = # existing vessels (size j) in year n

Mjn = # New vessels (size j) in year n

eijn = # existing vessels (size j, port i) in year n

mijn = # New vessels (size j, port i) in year n

3) <u>Constraints</u>

The following constraints have to be met

a) <u>Crude Oil Requirement</u>

$$\sum_{j=1}^{5} (eijn + mijn)\ Tij \geq Rin$$

where Rin = Annual Crude Requirement

Tij = (Port i - Year n)

Tij = Annual Throughput

(Port i - size j)

b) <u>Capacity Constraints</u>

$$Ejn \geq \sum_{i=1}^{3} eijn$$

$$Mjn \geq \sum_{i=1}^{3} mijn$$

These two constraints express the fact that vessels cannot be used beyond full capacity

c) <u>Fixed cost constraints</u>

Ejn = Integer

Mjn = Integer

These constraints express the fact that vessels cannot be transferred to another trade during the year.

3) Implementation

The expression $\sum_{i=1}^{3} \sum_{j=1}^{5} Aijn$ is minimized using a conventional linear program package, and the "branch and bound" algorithm to account for the integer constraints.

To avoid having large cost increases caused by small changes in vessel throughputs, figures within 1 per cent of an integer are accepted as integers. This recognizes that in reality vessel size are not limited to the five representative sizes used in the study. For instance Mjn = 15.15 and size j = 100,000 dwt means that 15 vessels in the 100,000 dwt class are used on the trade, with the average size being equal to 101,000 dwt.

ANNEX C

FIXED AND VARIABLE COSTS

FIXED COSTS

1) Capital Costs are obtained, using the assumptions and procedures described in Chapter 4 and the amortization costs provided in TABLE 29, for each vessel. They are then summed up over the whole fleet.

2) Fixed Operating Costs: Vessel fixed operating costs are obtained, using the costs described in TABLE 28, and making proper allowance for any impact of pollution control on these costs.

VARIABLE COSTS

1) The number of trips for each port, and ship size is calculated.

2) Fuel costs and port charges are calculated assuming that these costs are proportional to the number of trips completed.