III-C. PREVENTION OF OIL SPILLS

The ideal solution to the oil-on-water problem is to prevent oil discharges from occurring, but the efforts expended in this area are subject to local, State, Federal, and international regulations. This section examines four areas of prevention; namely: tankers, traffic control systems, oil detection, and oil handling facilities. Each is discussed with respect to regulations and state-of-the-art techniques.
1. OIL TRANSPORTATION ON WATER

One of the primary sources of oil spills is waterborne traffic; in particular that associated with large vessels. Efforts undertaken to prevent spills from this source occur on three fronts with regard to tankers: policy, design, and operations. Because of the nature of waterborne commerce, policy for such commerce must begin in the international arena. The implications of such policy on Puget Sound, filtered through the federal, state, and local authorities is presented in this section.

These implications take their form in regulations governing the design and operation of tankers. Both revolutionary techniques and modification of current procedures are discussed, along with their inherent benefits and disadvantages. Finally, a list of long run and short run proposals is recommended for Puget Sound.

a. Policy

The problem of oil pollution of the seas has been recognized for some time. As early as 1922 the U. S. Congress proposed an international conference on oil pollution. Studies that were carried out led to a National Oil Pollution Act in 1924. Later, the U.S. convened an Inter-governmental Conference of Maritime Nations in 1926. About the only result from this conference was an agreement among several ship owners to refrain from discharging oil within 50 miles of a coastline. After this nothing was effectively accomplished until the 1954 Convention for Prevention of Pollution of the Sea by Oil. Interim attempts included the 1936 League of Nations proposal to consider the problem (this conference never took place). The United Nations in 1949 accumulated views on the problem from various governments, and in 1953, the Economic and Social Council of the U. N. attempted to establish a council of experts to evaluate the problem. This was postponed until the 1954 conference.

The thrust of the 1954 conference was to establish zones where the discharge of oil or mixtures of oil and water was prohibited. They also initiated a procedure whereby an oil handling log book was to be maintained onboard the ship. The convention adopted a requirement that
by 1957 all signature governments should establish adequate oil disposal facilities in their ports. They also stipulated that one year after coming into effect, all ships of signature nations be fitted such that all bilge discharges be eased through oil water separators. The major weakness of the convention is that it did not specify uniform penalties or means of enforcement. The U. S. did not ratify the convention until 1961 in time to join the 1962 Conference.

The 1962 Conference aimed to amend the 1954 Conference resolutions in the following ways: 2

1. Extend the prohibited zones further to sea.
2. More clearly define the oil handling log.
3. Allow direct pumping of bilge waste overboard so long as the oil mixtures set by the 1954 Convention were not exceeded.
4. Remove the signature governments obligation to establish oily water reception facilities and instead require them to promote such facilities.

These amendments effectively reduced the restrictions previously imposed and brought the convention resolutions more in line with economic reality. Since 1962 the policy making pace has quickened. The growth of tankers during this period coupled with the greater demand for petroleum products and a new awareness of our ecological system has made the problem more severe than ever. In 1969, the 1962 Convention resolutions were once again modified in the following manner: 3

1. Elimination of free dumping zones where the discharge of oil is not regulated with the exception that a vessel passing through such an area may have an instantaneous rate of discharge of oil content not to exceed 60 liters per mile.
2. Extend the prohibition of oil discharge close to coastlines to all ships besides tankers.
3. Limit the total discharge from a tanker to 1/15,000 its total cargo carrying capacity and require any discharge be more than 50 miles off shore.
4. Remove the exemption set in 1954 of discharge of oily residue sledge.

The 1970's opened with increased pressure to prevent the spilling of oil. In November of 1970, Secretary of Transportation John Volpe proposed before the NATO Conference on Challenges of Modern Society a complete...
halt to all discharge of oil into the seas by tankers and other vessels before the end of the decade. The convention adopted his resolution and agreements among the NATO nations to achieve this goal include:

1. Early ratification of the 1969 amendments to the Convention for Preventing Pollution of the Sea by Oil.
2. Support and acceleration of the work being done by international organizations toward the development of increased prevention measures, particularly IMO.
3. Improvement of all oil waste reception facilities.

These resolutions, then, are the sum of the efforts with regard to state-of-the-art in oil pollution prevention. Legal interpretation of international controls for oil pollution is presented in Appendix 4.

Efforts are being directed on many varied levels toward the achievement of the overall goal. The problem is of such a nature that the major efforts will continue to be expended on the international level. The significant domestic advances in oil pollution prevention maritime activities will be based on the resolutions derived from international agreement. In the United States, the Coast Guard is vested with the authority for control and regulation of the technical aspects of the maritime industry. On the international level, the Intergovernmental Marine Consultative Organization (IMO) appears to be the most productive forum in dealing with the technical aspects of the pollution problem. To clarify the functions of both IMO and the Coast Guard with regard to the preventative aspects of pollution a brief discussion follows.

1. Coast Guard

The Coast Guard is responsible for minimizing the loss of life, property damage and personal injury that may result from marine transportation activities. Their focus on the accomplishment of this goal is through two primary preventative programs.

a. Development and enforcement of vessel design and construction standards, and

b. Licensing of personnel for maintenance of technical operating competence.
Both of these programs are managed under the Merchant Marine Safety Division of which there are five departments. Merchant Vessel Personnel (MVP) exercises control over licensing function. Merchant Marine Technical (MMT), Merchant Vessel Inspection (MVI), Merchant Vessel Documentation (MVD), and Hazardous Materials (MIM) exercise control over the maintenance and development of the technical standards function. The operational aspects of the preventative program are carried out at a local port level through the officer in charge of Marine Inspection Offices (OCMI). Branches of (MMT) have been established in four cities to provide staff support in the form of technical guidance to the OCMI's in their geographical area.

All standards with regard to vessel design, operation, documentation, or personnel competence are published in Chapter I of Title 46 of the Code of Federal Regulations (CFR). These regulations are a part of the U. S. Code (USC), the authority of which have been granted by Congress. These regulations for the most part provide the minimum standards for safe design and operation of vessels.

A listing of vessel standards that fall under the authority of the Coast Guard are cited below:

Seven subchapters prescribe the vessel design and construction standards.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Subchapter</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>46CFR 24-26</td>
<td>C</td>
<td>Uninspected Vessels</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Tank Vessels</td>
</tr>
<tr>
<td>70-78</td>
<td>U</td>
<td>Passenger Vessels</td>
</tr>
<tr>
<td>90-98</td>
<td>I</td>
<td>Cargo &amp; Miscellaneous Vessels</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>Nautical Schools</td>
</tr>
<tr>
<td>175-187</td>
<td>T</td>
<td>Small Passenger Vessels</td>
</tr>
<tr>
<td>188-196</td>
<td>U</td>
<td>Oceanographic Vessels</td>
</tr>
</tbody>
</table>

Three subchapters prescribe rules for system and specific equipment utilized on vessels.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Subchapter</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>46CFR 50-63</td>
<td>F</td>
<td>Marine Engineering</td>
</tr>
<tr>
<td>110-113</td>
<td>J</td>
<td>Electrical Engineering</td>
</tr>
<tr>
<td></td>
<td>Q</td>
<td>Equipment Specifications</td>
</tr>
</tbody>
</table>

Four subchapters prescribe operating limitations or conditions for various types of vessels.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Subchapter</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>46CFR 42-46</td>
<td>E</td>
<td>Load Lines</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>Bulk Grain Cargos</td>
</tr>
<tr>
<td>146-149</td>
<td>N</td>
<td>Dangerous Cargos</td>
</tr>
<tr>
<td>157</td>
<td>P</td>
<td>Manning</td>
</tr>
</tbody>
</table>
Five subchapters prescribe various administrative, personnel and investigative procedures.

<table>
<thead>
<tr>
<th>Subchapter</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Procedures applicable to the Public</td>
</tr>
<tr>
<td>B</td>
<td>Merchant Marine Officers</td>
</tr>
<tr>
<td>K</td>
<td>Casualty Investigation, Suspension and Revocation Proceedings</td>
</tr>
<tr>
<td>L</td>
<td>Overtime Services</td>
</tr>
<tr>
<td>S</td>
<td>Numbering, Undocumented Vessels, Boating Accident Reports and Statistics</td>
</tr>
</tbody>
</table>

As stated previously, the objective of these standards is to minimize loss of life and property at sea. Pollution reduction results primarily as a byproduct of the minimization of property loss objective. Although most of the problematical aspects of oil pollution from vessels in adequately covered by this arrangement of objectives, there still remain serious flaws. It appears necessary to achieve the goals set by the NATO conference that minimization of pollution potential must become a major objective in the Coast Guard Marine Safety program.

2. Intergovernmental Marine Consultative Organization (IMCO)

IMCO was formed in 1959 as a specialized agency of the United Nations for maritime matters. Its creation provided a forum for continuing exchange among the world's maritime safety administrators. The organization soon became the sponsor of international conventions regarding the sea. One of its first activities was the 1962 amending Convention for Prevention of Pollution of the Sea by Oil. Because of the importance of international body in eliminating oil pollution of the sea by vessels it is appropriate to gain some insight as to the mandate, structure, and procedures of the body.

The Assembly is the central body of the Organization and is composed of 72 member nations. The Council is the administrative arm and generally meets twice a year. Beneath the Council are the three working committees. They are Legal, Facilitation, and Marine Safety (MSC). MSC is the primary action group and of basic interest for purposes of this study. The committee is made up of 16 member nations and at present there are 11 working subcommittees handling technical matters as related to the specific disciplines. A complete organization chart is shown in Figure III-C1.
FIGURE III-C1
INTERGOVERNMENTAL MARITIME CONSULTATION ORGANIZATION (IMCO)
The representatives of the member nations working primarily at the subcommittee level conduct the bulk of the effort. Each member nation is responsible to undertake basic research which is used in support of proposals placed before the various subcommittees.

A proposal by a member nation becomes an IMCO resolution after it has been carefully considered for its technical viability at the subcommittee level and approved by a vote of the Assembly. All member nations have an equal representation in the Assembly.

It should be noted that all IMCO resolutions are not automatically binding on the member nations. The resolution actually takes the form of a recommendation upon which the various member governments may or may not adopt. In the United States an IMCO resolution relating to an International Convention or an amendment to an International Convention would not become binding on private industry until the following steps were completed.

a. IMCO resolution ratified by U. S.
b. Implementing any required legislation by Congress.
c. Writing of regulations as required (as promulgated in the normal manner this requires a public hearing before the regulation becomes binding).

Where an IMCO recommendation does not relate to an International Convention, ratification is not necessary and the matter is generally referred by the State Department directly to the appropriate agency. In cases of recommendations originating out of MSC that agency would be the Coast Guard.

The present efforts of IMCO, expended basically through MSC, are specifically directed at reduction and eventually complete elimination of oil pollution of the sea. Following the Torrey Canyon incident the pace was quickened considerably with measures, to be discussed, broken into three areas:

a. Preventative
   i. Sealanes
   ii. Shore Guidance
   iii. Speed Restrictions
   iv. Navigational Equipment
   v. Officers and Crew Training
   vi. Automatic Pilots
   vii. Construction and Design of Tankers
   viii. Identification and Charting of Hazards
b. Remedial
   i. Procedures in the Event of Accidents
   ii. Research in Oil Clearance

c. Legal
   i. Legal Rights of a Coastal State
   ii. Official Inquiries
   iii. Liability in Event of Accidents
   iv. Compulsory Insurance for Tankers
   v. Movement of Salvage Equipment

Official action with regard to these measures came in the form of resolutions presented by the Assembly in 1968 and 1969. By far the most significant action, resolution 175, is directed at promoting the load on top procedure in tankers. Although the LOT procedure has its shortcomings it was recognized that it offered a means of significantly reducing the amount of oil discharged to the sea.

The majority of these proposals do not directly affect Puget Sound. Their primary impact will be quite subtle, only to be seen over time as a better safety record and lower incident of pollution resulting casualties. The only resolution that would have immediate effect on the Puget Sound area is #161, calling for the establishment of traffic separation schemes. At the international level, this would be adoption of a traffic separation scheme in the Strait of Juan de Fuca. At present this particular measure has not been considered by IMO.

b. Ship Design Standards

1. Hull Damage and Oil Spill Statistics

Oil has been moved in large quantities for years on the sea. Almost every vessel, whether a tanker or not, carries enough oil either as cargo or fuel to be a potentially large polluter. Oil has been, and will continue for some time to be, the major energy source for man. Until an adequate substitute is fully developed it will continue to be moved in these large quantities over the water.

Prior to the oil spill at West Falmouth, Massachusetts, 7 it was commonly thought that release of oil into the sea had, at the worst, only short term effects on the environment, and that these were confined
primarily to the aesthetic values of that environment. However, a thorough scientific analysis of the effects of the West Falmouth spill by Dr. Max Blumer and his team at Woods Hole not only demonstrated the long term effects of oil spills, but more dramatically the interruption and destruction of marine life and the ecological environment which is the basis of the food chain. As a result of Dr. Blumer's work the potentially harmful effects of oil were better understood and it was realized that potential future spills were more significant ecologically than previously thought.

Much effort began to be directed toward the evaluation of existing methods of transporting oil; the design of vessels began to receive close scrutiny with a perspective of reducing possible pollution sources as well as designing for the safety of personnel and preventing the loss of equipment. Other efforts were directed at learning how collisions or groundings occur, and what were the potential causes of spills.

The Dillingham Report, completed in 1970 for API, on oil spill cleanup procedures attempted to analyze some of the reasons for oil spills and how and where they are most likely to occur. Its analysis is based primarily on historical frequency data of groundings and collisions and is presented in graphical form.

Their findings regarding the patterns of past spills is summarized as follows:

<table>
<thead>
<tr>
<th>Source</th>
<th>75 percent were associated with vessels, principally tankers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>90 percent involved crude or residual oils.</td>
</tr>
<tr>
<td>Volume</td>
<td>10 percent of the spills were greater than 5000 bbls.</td>
</tr>
<tr>
<td>Distance Offshore</td>
<td>80 percent occurred within 10 miles of the shoreline.</td>
</tr>
<tr>
<td>Duration</td>
<td>75 percent of the spills incidents lasted more than five days.</td>
</tr>
<tr>
<td>Extent</td>
<td>80 percent contaminated less than 20 miles of coastline.</td>
</tr>
<tr>
<td>Distance from Port</td>
<td>75 percent were within 25 miles of the nearest port.</td>
</tr>
</tbody>
</table>
On the basis of these findings, the typical situation that might be expected in an offshore spill is that (a) the source is likely to be a tanker, (b) crude or residual fuel oils are likely to be involved, and (c) the size of the spill most likely will be greater than 5,000 bbls. The spill will probably occur a few miles offshore and the duration of the spill incident will be more than five days. Most likely, contamination of the beach will take place. Further it is likely that the spill will occur within 25 miles of a port and most likely not more than 50 miles from such a port.

2. Design Factors

The two principal factors of interest to ship designers are (1) the most likely volume of spill, and (2) the type of vessel most likely to be involved in a spill situation. Dillingham's findings bear out that definite problems exist as to tanker size (the median volume was 25,000 bbls.) and structural integrity of tankers.

In 1967, the Maritime Safety Committee (MSC) of IMCO established a subcommittee on Ship Design and Equipment. Their initial efforts were directed toward the hazards of bulk shipping of chemical cargos, on the strength of a proposal from the United States. However, shortly thereafter the Torrey Canyon incident brought into focus the full potential for pollution from a common cargo - that being the transport of oil. The need for a complete study and re-evaluation of existing vessel design was fully realized. It was agreed in the fourth session of the Subcommittee to collect the necessary data base of grounding casualties of major ocean going ships with respect to the frequency of casualties and the position and extent of bottom damage and rupture in order to assess the effectiveness of present double bottoms in large tankers. At their meeting in October, 1970, an interim agreement was made to indicate to tanker interests that no further increase in tank size should be considered, and a limitation was applied to present volumes of 30,000 m$^3$ for wing spaces and 50,000 m$^3$ for center spaces. Further, the Subcommittee has declared its intention to lower such values subsequent to evaluation on the impact of additional subdivision on the cost of ship construction and operations.
Data has been collected and analyzed to determine the effectiveness of double bottoms. The consensus of the committee was that the effectiveness of double bottoms would, under present requirements (the current height average 6% of the breadth of the vessel), be limited to low energy groundings and that further study was required to make further advances.

The proposed improvements in ship design standards are looked at from two points of view:

a. those proposals aimed at preventing or avoiding a loss of cargo containment due to a collision or stranding, and
b. those proposals put forth to limit the loss of cargo from a damaged tank due to collision or stranding.

It should be noted that these proposals are not to be considered as independent alternatives. To be effective in improving the existing design standards the proposals from each point of view must be considered as complementing each other (i.e., one of either set is not as effective an improvement as some combination of the two).

a. Improvements to Prevent Loss of Cargo

The suggested improvements for preventing the initial loss of cargo from a tank are as follows:

i. Maneuverability - general.
ii. Stopping and backing power.
iii. Prime movers.
iv. Controllable pitch propellers.
v. Contrarotating propellers.
vi. Vertical axis propellers.
vii. Multiple screws.
viii. Stern anchors.
ix. Remote release for anchors.
x. Rudders.
xii. Twin rudders.
xii. Side thrusters.
xiii. Speed reduction equipment.
xiv. Protection of hull.

Each of the following proposals is discussed further with brief comment as to their present feasibility and effectiveness.

(1) If maneuverability in low energy impact situations is determined to be a major factor in these impacts then the establishment of criteria for
maneuverability should be developed. For example, this criteria could include the ability to stop within a given distance when operating at a given speed and under a standard set of conditions; the ability to change a vessel’s heading at a specified rate under a standard set of conditions. Some indication of the differences that exist tactical diameters can be viewed in Table III-C1. It is not known at this time what efforts are being directed toward the establishment of such standards, although it does appear some work is needed in this area. An expanded list of other proposals that meet the general maneuverability proposal is discussed below.

(ii) As an interim measure the operators of each vessel could be provided with information for operational limits of stopping and backing capabilities of the vessel they control. The basic constraint on stopping ability is the limitation of the propeller or propellers to absorb energy over time. Thus, it is feasible, knowing the characteristics of the propeller along with empirical data, to determine this stopping and backing capability. 11

(iii) With regard to prime movers, most of the various types are capable of being designed to provide the necessary power to shorten stopping distances and thus improve stopping time. Each type presents some difference with respect to response time for maneuvering demands and the choice is generally based strictly on economic considerations.

(iv) Stopping ability can be enhanced through the use of controllable pitch propellers. A greater range of effectiveness is obtainable at the expense of increased cost, more complexity and less reliability (most cargo and tank vessels operate on one screw). Recent technology continues to make this idea more feasible as more of the engineering problems involved are solved.

(v) Contrarotating propellers offer some of the same advantages as the controllable pitch screws but introduce the same problems. These types of screws appear less practical than the adjustable pitch propellers.

(vi) Vertical axis propellers provide for improved maneuverability and backing characteristics, however, the complexity of these devices reduces their reliability. Other disadvantages include a limitation as to practical size, and their susceptibility to damage.
<table>
<thead>
<tr>
<th>Vessel Parameter</th>
<th>Cedros</th>
<th>N. News</th>
<th>N. News</th>
<th>Oriental Giant</th>
<th>Esso Suez</th>
<th>Nissho Maru</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBP</td>
<td>940'</td>
<td>685'</td>
<td>535'</td>
<td>804'</td>
<td>600'</td>
<td>906'</td>
</tr>
<tr>
<td>Breadth</td>
<td>142'</td>
<td>93'</td>
<td>75'</td>
<td>108'</td>
<td>82' 6&quot;</td>
<td>141'</td>
</tr>
<tr>
<td>Depth</td>
<td>81' 48' 7&quot;</td>
<td>40' 5&quot;</td>
<td>-</td>
<td>-</td>
<td>42' 6&quot;</td>
<td>-</td>
</tr>
<tr>
<td>H</td>
<td>54' 36' 8&quot;</td>
<td>31' 9&quot;</td>
<td>-</td>
<td>-</td>
<td>31' 10&quot;</td>
<td>-</td>
</tr>
<tr>
<td>dwt</td>
<td>175,940</td>
<td>50,200</td>
<td>25,500</td>
<td>92,980</td>
<td>34,840</td>
<td>162,300</td>
</tr>
<tr>
<td>shp</td>
<td>27,500</td>
<td>26,500</td>
<td>15,000</td>
<td>-</td>
<td>12,500</td>
<td>28,000</td>
</tr>
<tr>
<td>Wk</td>
<td>18.3</td>
<td>19.5</td>
<td>18.8</td>
<td>17.6</td>
<td>16</td>
<td>16.5</td>
</tr>
<tr>
<td>Technical Diameter, ft.</td>
<td>3,105</td>
<td>2,380</td>
<td>3,200</td>
<td>2,500</td>
<td>2,280</td>
<td>-</td>
</tr>
<tr>
<td>Technical Diameter, ft/LBP</td>
<td>3.31</td>
<td>3.47</td>
<td>5.97</td>
<td>3.22</td>
<td>3.8</td>
<td>-</td>
</tr>
<tr>
<td>Turning Circle, miles</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.34</td>
<td>-</td>
<td>2.06</td>
</tr>
</tbody>
</table>
(vii) Multiple screw arrangements increase the reliability of the propulsion system. If one screw is damaged, fifty percent power remains in the other screw. Twin screws result in improved turning ability particularly at low speed, but may somewhat affect backing ability because of their smaller diameter. Multiple screw arrangements are also more vulnerable to damage than a single screw on the centerline.

(viii) The proposal for stern anchors would allow a vessel, if stopped in a narrow channel, to maintain its heading when used in conjunction with the normal bow anchor. Similarly, if a vessel is broken in half, the stern anchor would allow for securing the aft section of the vessel. The main disadvantage of using stern anchors is the possible damage that may be inflicted to the propeller and rudder, rendering the ship uncontrollable.

(ix) The primary advantage in a remote release capability of the anchors is a reduction of the response time in initiating the action. This advantage does not appear significant, however, when the hazard of accidental release is considered along with the incapability of an anchor effectively reducing the speed of a vessel with any appreciable way on.

(x) Rudders work most effectively when employed in conjunction with a propeller. For multiple screw arrangements, multiple rudders should be used. Improvement of the existing rudder designs could result in improved maneuverability but most likely at a cost such that the marginal benefits would be uneconomical.

(xi) Currently, bow thrusters are used as aids in vessel control at very low speeds. Their effectiveness decreases appreciably at speeds above four knots. At higher speeds the effective employment of bow and/or stern thrusters is limited by their practical size and the sheer mass of large vessels.

(xii) The most significant aspect of speed reducing equipment is the reduction of the number of high energy impact situations to low energy impact situations. The equipment currently takes the form of bow flaps, split rudders, drogues, and reverse thrust devices. Their effectiveness decreases as velocity of the vessel increases and much research and development remains to make many of these proposals suitable for practical application.

(xiii) To reduce the chance of grounding it is proposed to equip vessels with a detection capability of submerged obstructions that lie in its path.
Systems of this type are presently employed in low speed situations such as docking, or in close quarter conditions. At higher speeds such a system would be useful provided it gave warning in sufficient time for the vessel to take corrective action.

b. Improvements to Limit Loss of Cargo

Proposals to avoid or limit the outflow of oil from a container in the event of a collision or a stranding include the following:

i. Limiting the size of cargo tanks.

ii. Move longitudinal oil tight bulkheads near sides of vessel.

iii. Interrupt wing tank spaces with ballast spaces.

iv. Requirement for more longitudinal bulkheads.

v. Place small tanks forward (where there is more possibility of hull damage) in conjunction with larger tanks aft.

vi. Isolate tanks from ship’s side and bottom.

vii. Isolate internal cargo piping from side or bottom damage.

viii. Increase strength of hull through thicker hull plating, use of high strength plates, etc.

ix. Rubber linings for tanks.

x. Provision for the rapid discharge or transfer of cargo in the event of an emergency.

xi. Reduction in the overall size of tankers.

A discussion of the relative merits, feasibility, and limitations of each of the above proposals follows.

(i) The resultant effect from limiting of cargo tank size is that less oil will be spilled in the breaching of a tank. However, as bulkhead spacing is reduced, the probability that a given length of damage will rupture more than one tank increases. This increase in probability is somewhat negated when it is considered the additional bulkheads provide extra energy absorbing structure, which could reduce the extent of damage. With a high energy impact, tank size differences would have little significance on the amount of oil spilled. The explosion hazard resulting from tank cleaning may be changed. While the time each tank is in the explosive range during cleaning is decreased, the total time of cleaning would be increased. For the same deadweight (cargo) carried the smaller tanks mean additional bulkheads and weight. This results in increased construction and operational costs. Because loading rates are based more on overall vessel size than on individual tank size, there is more
of a chance of overflow using present day loading procedures and piping arrangements. Maintenance expenses would increase as there are more internal surfaces on which tank cleaning residues could collect. Likewise the time required for vessel inspection would increase.

(ii) The strategy of moving the longitudinal bulkheads nearer the vessel sides decreases the size of the side tanks, while increasing the size of the center tanks. A low energy impact on the side or bilge would result in less oil being spilled. However, in a high energy impact more oil would be spilled as the chance of the inner bulkhead being pierced is increased. There would also be increased weight to the vessel resulting from the increased size of structural transverse members between the longitudinal bulkheads. More oil would most likely be discharged as a result of bottom damage due to the increased size of the center tanks. Certain operational restrictions most likely would result because of the requirement to keep the center tanks pressed full to reduce the free surface athwartship effects on ship stability.

(iii) Interruption of the wing tanks spaces with ballast tanks would reduce the probability of multiple cargo tank damage resulting from side collisions. The piping arrangements would become more complex and tend to increase the weight of the vessel.

(iv) The requirement for additional longitudinal bulkheads would result in a more complex structure, with more piping and fittings required. Tank sizes would be reduced, the structural integrity of the vessel would be increased but at the expense of increased vessel weight and the corresponding construction, operating and maintenance costs.

(v) The reduction of tank size forward on the vessel appears to have little merit. Present design standards allow tankers to absorb a considerable amount of damage resulting from head on collisions. However, in the high energy impact situation, such an arrangement may have additional value. The idea also has practical limitations as the probability distribution of collisions over the length of the vessel decreases only for the aft two-thirds of the vessel.

(vi) Isolating cargo tanks from the sides and bottom of the vessel would most likely result in less oil discharge in low energy impact situations.
There are other advantages in such an arrangement. Tank cleaning would be simplified as the internal surfaces of the tanks for the most part would be smooth. The innerbottom and additional longitudinal bulkheads would contribute to the hull glider strength, with the possibility of using thinner less notch sensitive plating. Additionally, the isolation spaces could serve as clean ballast tanks. The disadvantages include an increase in the explosion hazard as gas vapors could accumulate in the void spaces through leaks or vents. These spaces would require an additional system to maintain them in a gas-free state. To carry the same volume of cargo the ship would have to be larger, thus it would weigh more, adding to operational and construction costs. The increased structural complexity and hull size would result in larger maintenance and inspection costs. In a high energy impact situation the cargo tank isolation would make little if any difference.

(vii) In a low energy impact the isolation of pipes from the sides and bottom would most likely prevent their disturbance. There are practical limitations as to piping placement to avoid damage from high energy impacts. Cargo volatility and pumping limitations under low cargo levels in tanks place constraints on the height piping may be placed above the compartment bottom. Cargo stripping from tanks would become more difficult resulting in more involved gas freeing problems. One means to combat these problems is by employing individual deepwell pumps with all piping run vertically to the deck.

(viii) A stronger hull under low energy impact conditions would result in less probability of hull penetration. Under abnormal conditions there would be less chance of overstressing the structure. It is doubtful under high energy impacts that additional structural strength would be at all effective. The thicker plating would result in a heavier vessel with the corresponding increases in construction and operating costs.

(ix) In an emergency situation the rapid transfer of oil from a damaged tank could limit the total outflow. To make this idea effective standardized hull fittings must be provided on all cargo tanks. The cargo could possibly be pumped into a reserve tank aboard the vessel or to portable reserve tanks deployed from the vessel or by some other means.
(x) The use of rubber linings in tanks is not yet at a practical application stage of development to prevent the outflow of oil in low energy impact situations. Liners would not be effective in high energy impacts. This idea, however, has much potential and requires much more research and development.

(xi) By reducing tanker size there would theoretically be less chance of bottom damage due to the reduced operating draft. Practically speaking, however, there would remain the same operational judgement errors in attempting to traverse channels thought to be a foot or two over the vessel draft. Any one total casualty would result in less oil discharge, larger tankers are less likely to visit congested traffic areas because of their larger drafts, thus reducing their collision potential. For a given amount of cargo to be transferred, fewer vessels (of supertanker size) would be required. This means less drain on the available manpower pool with the result that more experienced crews are likely to be serving on the larger vessels. Because the probability of a collision increases in part as the square of the number of vessels in a given channel, the overall probability of a collision may be reduced through the use of larger tankers. However, this does not take into consideration that these larger vessels are more difficult to control thus raising the probability of their grounding.

c. Operational Procedures

A second area closely related to improvements in vessel design is the improvement of operational procedures and expertise of personnel. The MARAD Report on a pollution abatement plan for oil and the testimony of Dr. Max Blumer state another major source of oil pollution is the result of inadequate operating procedures and human error. Factual data as to the extent of spillage resulting from operations and personnel is nonexistent. However, estimates have been made that show approximately .0002% of the oil handled in any one port can be expected to be lost. This figure was arrived at on the basis of the experience in Milford Haven, a large British oil port. This particular port had taken extensive measures to prevent the spillage of oil because of its close proximity to a national park. This experience strongly suggests that much effort needs to be directed to procedures and personnel, and unloading equipment.
Proposals to deal with the problem of vessel-caused oil pollution are primarily being directed at two facets. The first are sources of pollution resulting from deliberate or accidental discharges of oil in the loading, unloading and transporting operations of oil. The second aspect are sources resulting from unintentional release of oil into the water as a result of collision or grounding. It is the general consensus of opinion that the most significant source of oil pollution is not from collision or groundings, but from the less dramatic continual everyday operational aspects of oil handling. This is not to say that sources of pollution from collisions and groundings can be disregarded as being insignificant. The Liverpool Underwriters Association statistics on ship collisions and groundings do show that losses result all too often to be neglected, however, the loss of oil at .0002% of the total volume handled bears mute testimony to the size of the problem at hand.

Many of the present discharges of oil into the water can be eliminated through improved operational procedures. Presently, both MARAD and INCO have proposals in this area. For the most part the following suggested improvements are general in nature; however, they can be considered in varying degrees as potential solutions to the specific problems of Puget Sound. These proposals include:

1. Load on top procedure of tank cleaning and ballasting.
2. Clean ballast operation.
3. Navigating equipment standards.
5. Training of personnel.
7. Reliable instrumentation.
8. Fail-safe engineering design criterion.
9. Uniform tank and piping construction and arrangement standards.

(1) The development of the Load on Top (LOT) procedure is the direct result of the requirement that cargo be replaced with ballast after a cargo has been discharged to insure stability of the vessel as it proceeds to another port. As a result, there is some mixing of cargo oil residue and sea water. The usual practice has been to wash these tanks down at sea and dispose the oily
ballast and wash water to the sea. Free dumping of this waste ballast is now prohibited except under specified conditions. In order to meet these requirements the LOT procedure was developed. Figure III-C2 depicts the mechanics. The residue that remains after tank washing is pumped into one of the ship's normal cargo tanks designated as a slop tank and allowed to separate into oil and water. The separated water is decanted until only oil remains. This is then combined with the next cargo, hence the LOT designation.

In theory, the LOT idea appears simple and an adequate solution to the problem. However, there are many problems existing that prevent it from being a totally effective solution. It is not a requirement but only an operational procedure practiced by 25 percent of the tankers in service today. It requires special piping arrangements thus imposing an economic penalty on the owners of those vessels not equipped for it. There are certain technical problems to be overcome. Detection of the oil water interface is necessary to prevent pumping some oil overboard from the slop tank. Time constraints do not always allow for complete separators need to be employed. Product tankers present problems in that they carry various products and must present "clean" tanks at loading. They cannot load on top of tank cleaning slop. This requires completely separate tanks for the slop or extensive facilities at each port.
As the ship eases out to sea, tanks 2, 4, 6 are filled with sea water ballast to maintain stability. These tanks then contain a mixture of clean water with residual oil.

Tanks 1, 3, 5, and 7 are cleaned with high pressure hoses. The oil water mixture in 2, 4, 6 begins to separate with the oil floating to the top of the tanks. A mixture of wash down water and oil residue exist in tanks 1, 3, 5, and 7.

The wash down mixture is pumped to tank 8. Also the separated oil water mixture in 2, 4, 6, is pumped down to the oil level. This oil is then pumped into tank 8 with the other slop and allowed to separate once again. Tanks 1, 3, 5, and 7 are filled with clean ballast to maintain stability.

The oil water mixture in tank 8 becomes separated and the water can be pumped to sea leaving only the oil in tank 8.

As the vessel enters a port to receive a new load all tanks are clean and ready to receive a new cargo.
(2) Most vessels do carry some clean ballast because of their excess volume relative to the allowable deadweight for the cargo carried. Clean ballast is not a problem unique only to tankers. Ships of all types encounter the problem of oily ballast water disposal, primarily because of the insufficient importance given to the problem during the design phases. Thus, to sufficiently solve the problem a departure from the current design practices is necessary. The primary argument against changes in design are economic in nature; however, it has been shown that the percentage increases in costs may be small when compared to the potential environmental threat posed by existing ballast operations. 22

A second argument put forth is that the elimination of ballast water from compensating spent fuel will require a larger beam to maintain intact stability. This results in a ship that is overly stiff and more difficult to control.

The second frequently proposed solution to the problem of oily ballast is the increased availability of shoreside facilities for the processing of oily ballast. IMCO has recommended that all ships be fitted with standard international shore connections to allow for the discharge of oily ballast to the shore. This is most likely to be the interim solution. Most tanker ports are already equipped with some type of oily ballast water disposal capability, however, the situation with respect to other types of vessels is not clear. Presently, the operators find themselves in an economic squeeze in properly disposing of their oily ballast and all too often it finds it is way over the side.

(3) Clearly the present system of navigation equipment standards is far from universal. True, most vessels are equipped with the standard aids to navigation such as radar, LORAN, RDF among others; yet, there are no standards on an international basis that control the degree of effectiveness of these instruments. Many vessels operate today with radar that does not function properly and with LORAN receivers that are not calibrated properly. To this end some system of control over a universal installation of navigating equipment aboard ships, as well as on the shore, would in all probability reduce the number of collisions and groundings. Some efforts now are being made in this direction. For Puget Sound, Honeywell recently proposed a
traffic control system that would encompass all the major shipping lanes. IMCO has adopted such measures as constraints on the use of the automatic pilot, carriage of radar, gyrocompass, and echo sounding equipment (SONAR). They have also recommended more efficient navigation light. The Coast Guard, on the national scene, is currently developing a precision location system for harbors and narrow channels. It is anticipated this system will be implemented in two steps by December 1972. Regardless of these effects and others not mentioned, much more can be done to develop an international plane the practical standards necessary for a new updated system of vessel navigation.

(4) A more long run solution lies in the proposal to modify the various Maritime Academy curricula to stress pollution abatement in the operation of ships. MARAD is presently working in the forefront of the effort at both the national academy and various state academies.

(5) In addition to the pollution abatement oriented training proposed for the future generation of ship operators, effort needs to be directed at the retraining of existing operating personnel along these same lines. Presently, many operators have been brought up in the "old school" and because of various pressures do not fully appreciate the importance of a complete pollution abatement program. Their retraining can best be done through the unions, the companies that employ them and through the control the Coast Guard exercises in their licensing function. However, regardless of these efforts, no significant gains can be made until the economic advantages to polluting are completely removed.

(6) Presently, a disparity exists between cargo loading and discharge procedures at various ports. The operational procedures followed will vary depending on many factors, most notably the owners of the receiving dock. The recent Anacortes oil spill in Puget Sound points out the necessity of more standardized operations as well as a clearer delineation of the responsibility for the overall loading or discharge operation. Currently, the responsibility is divided between those on the vessel and onshore personnel. Perhaps a model loading and discharge procedure can be developed for all those receiving and discharge points in Puget Sound through the joint efforts of all those concerned.
(7) The proposals for more reliable instrumentation fall into two areas. Those for improving the navigational aspects of vessels, which include the ideas discussed part (b), as well as the idea of requiring more sophisticated instruments aboard vessels. Some of these include inertial guidance systems, satellite guidance, and collision avoidance devices. The technology exists today to make these types of devices feasible; what is needed is some effective measure to require their use on vessels. The second area has to do with better control of the loading and discharge of cargos as well as the detection of possible spilled oil during these operations. Again the spill at Anacortes pointed out the need for more reliable instrumentation. 24

(8) Fail-safe engineering design criteria can be incorporated into the overall design of a system that handles oil. Fail-safe simply means that through proper incorporation of design standards into a system any fault that develops in the system and results in a failure, that failure will not jeopardize the system or the environment in which it operates any further. Clearly, this idea can be employed to prevent those accidents that result from human error of one sort or another.

(9) The idea of uniform oil handling systems in the form of tank and piping arrangements is aimed at reducing the confusion of personnel in operating and controlling the system. Although many problems exist as to large scale application of this idea, certainly it could prove beneficial within smaller locales. For example, within a company which owns a fleet of vessels, a standardized piping system on all those vessels will reduce the probability of company personnel controlling the flow of oil through the piping system making an error which results in an oil spill.

d. Applicability to Puget Sound

In evaluating which of the above proposals is most applicable to the particular conditions in the Puget Sound region, consideration of the implementation time is necessary. For many of the proposals, the time from inception of the idea to its actual implementation is often many years. The oil-on-water problem exists today, and the initiation of any action will not be felt for some time to come. Thus, it is imperative to consider interim or short range measures that can be applied with only a short time lag.
Both long range and short range proposals are briefly discussed below.

Long Run Proposals

Proposals which are currently under development but, because of their nature, will not become effective in reducing oil pollution for several years are listed below. The primary reason for the delay is that all of the proposals involve changes in the basic design of the vessel. Considering that the economic life of a ship is approximately 20 years, it will take that many years before the present fleet is replaced.

1. Clean Ballast

Present overboard discharge of tank cleaning residues and oily ballast water is one of the most significant sources of oil pollution from vessels, primarily because of the lack of attention to pollution reduction objectives during basic design stages. Design changes are necessary to solve the problems created by the existing overboard discharge systems on present vessels. A study of what the economic consequences are as a result of designing for clean ballast was done by E. Scott Dillon of MARAD. Three types of vessels are considered:

   a. a conventional cargo ship,
   b. a container ship, and
   c. a tank ship.

   For the cargo ship two clean ballast alternatives were proposed and the incremental increase in the required freight rate (RFR) was determined over the RFR of the original vessel, to achieve the same economic return. The increase in RFR required for alternative (a) was 7.9%, for alternative (b) 3.4%. Thus, the penalties imposed by a clean ballast operation are not that severe.

   Because of the configuration of container ships, clean ballast can be obtained without encroaching on the vessels earning capacity. Considering this flexibility there appears to be no excuse for overboard discharge of oily water from new ships of this class.
Until recently clean ballast operation in tankers was not considered a practical possibility. There is simply not sufficient space for tankage exclusively devoted to clean ballast if the vessel is to take full advantage of minimum freeboard decrees under the 1966 International Load Line Convention. Generally, clean ballast in a tanker is achieved by adding wing tanks or double bottoms. Four schemes are shown of possible alternatives in Figure III-C3 through III-C6, with Figure III-C7 showing the percent increase in RFR vs. percent clean ballast operation.

2. Double Bottoms

Extra protection is afforded oil tanks by double bottoms on tankers. At the same time clean ballast can be achieved. The Subcommittee on Ship Design and Equipment undertook a study to determine the effectiveness of double bottoms as a result of grounding or stranding in preventing an oil outflow.\textsuperscript{30} The basic findings indicate that for an average double bottom height of .06 B, the probabilities indicate oil tanks would not be damaged in 73% of the groundings. In approximately one fifth of this 73% the outer shell was not penetrated. A study of this type has yet to be considered regarding collisions.

3. Limitation of Tank Size

This proposal is currently the most feasible. IMCO has generated a resolution to the effect of limiting tank size. The economic penalties associated with a limitation in tank size are shown in Figures III-C8. The fixed limit of oil outflow decided upon by IMCO is 30,000. Thus, the percent increase in RFR for a 200,000 ton tanker at this outflow is approximately 1/2 of 1%.

4. Maneuverability

The ability of existing large tankers to avoid dangerous situations in a minimal amount of time is quite limited. Presently, much work is being focused on this aspect in an effort to determine practical means to increase ship maneuverability. This aspect of preventative proposals is perhaps more in the developmental stage and as such will involve a longer delay to implementation.
CONVENTIONAL 250,000 TON DWT TANKER, 13.7 % FULL LOAD DISPLACEMENT IN CLEAN BALLAST.

**FIGURE III-C3**
PRINCIPAL DIMENSIONS OF CONVENTIONAL 250,000 DWT TANKER, PLAN & MIDSHIP SECTION VIEWS
250,000 TON DWT TANKER WITH DOUBLE BOTTOM 13.7% FULL LOAD DISPLACEMENT IN CLEAN BALLAST.

FIGURE III-C4
PRINCIPAL DIMENSIONS OF BASIC 250,000 DWT TANKER FITTED WITH DOUBLE BOTTOM TANKS, PLAN & MIDSHIP SECTION VIEWS
250,000 TON DWT TANKER WITH COMPLETE DOUBLE SKIN
22.5 % FULL LOAD DISPLACEMENT IN CLEAN
BALLAST. 40.1 % FULL LOAD DISPLACEMENT "IN BALLAST"
CONDITION.

FIGURE III - C5
PRINCIPAL DIMENSIONS OF DOUBLE BOTTOMED TANKER
WITH SIDE BALLAST TANKAGE PLAN & MIDSHIP
SECTION VIEWS
250,000 TON DWT TANKER WITH COMPLETE DOUBLE SKIN (ALL CLEAN BALLAST) 41.1% FULL LOAD DISPLACEMENT IN CLEAN BALLAST. 60.1% FULL LOAD DISPLACEMENT "IN BALLAST" CONDITION.

FIGURE III-C6
PRINCIPAL DIMENSIONS OF DOUBLE BOTTOMED TANKER WITH LARGE SIDE BALLAST TANKAGE PLAN & MIDSHIP SECTION VIEWS 28
FIGURE III-C7
ECONOMIC EFFECT OF CLEAN BALLAST CAPACITY

"IN BALLAST" DISPLACEMENT AS % OF FULL LOAD DISPLACEMENT
FIGURE III-C8
PERCENTAGE INCREASE IN REQUIRED FREIGHT RATE TO LIMIT OIL OUTFLOW
(REFERENCE HAS 4 WING TANKS ON A SIDE)

NOTE: OUTFLOW EQUALS COMBINED CAPACITY OF TWO ADJACENT WING TANKS
5. Education

This proposal is accomplished through the various state and the U. S. Marine Academies. Emphasis on principles of pollution abatement in vessel operation. A proposal such as this can be achieved at virtually no incremental costs and the benefits derived therefrom could be enormous.

Short run proposals are of more interest as they involve measures over which more control can be exercised from the local level. Of necessity the measures involve the operational aspects of prevention and are as follows:

1. Load on Top Procedures

Although the LOT procedure does not result in 100 percent reduction in oil pollution, it does provide some immediate relief to the problem. Much of the existing local traffic can institute LOT operations through minimum changes in existing vessel makeup. Although it is not known if any specific costs studies regarding the RPR penalty imposed by LOT procedures have been done, it is the opinion of this study that they are not that severe; and thus, all efforts should be undertaken to see that LOT is implemented for all concerned vessels on Puget Sound.

2. Port Facilities

Generally, it is the economic penalty of increased operating time associated with most preventative measures that lead to their perceived ineffectiveness. Provision of oily waste reception facilities at strategic ports in Puget Sound would help alleviate this penalty motive. Presently, a survey is underway of all available reception facilities in U. S. ports. The most recent, taken in 1960, indicated that Puget Sound had available 64 reception facilities both mobile and permanent with a capacity for 30,223 long tons. MARAD is promoting the construction of additional facilities for oily waste treatment. Once the total deficit is determined efforts should be directed toward the filling of the void.

3. Traffic Control

Various traffic control systems are now in operation in ports around the world. In most instances, some type of external control of vessel movement in congested areas has been extremely beneficial in terms of the reduction of casualties. Although the idea of traffic control goes against
the aged traditions of the sea, it appears that the needs of society are now best served through some imposition on this tradition. A complete analysis of traffic control is contained in Section III-C, Part 2 of this report.

e. Overall Assessment as Applied to Puget Sound

The question in everyone's mind at this point is what can be done with the problem of vessels polluting Puget Sound as the result of an oil spill. As has been pointed out the problem is real and a definite threat, yet one that appears well on its way to solution. The magnitude of the problem requires an attack from an international level which by necessity introduces long time lags from inception to implementation of pollution reduction proposals. The full effect of these efforts will not be felt in the Puget Sound area for a number of years.

In the meantime, the transportation of oil on Puget Sound is increasing. The three tankers being built by ARCO to transport oil from Valdez to West Coast markets are virtually being built in accordance with design standards that have in their stated objectives no provisions for minimization of pollution potential. This is not the fault of any one individual or group but simply the result of setting priorities as to which objectives to achieve. Not all is lost however; for much can be done to reduce the pollution threat on the local level without the usual time delay. These proposed measures can for the most part be instituted tomorrow to achieve an interim margin of safety.