2. TRAFFIC CONTROL SYSTEMS

a. Introduction

Puget Sound is one of the world's safest waterways.[1] Commercial vessels have been calling on Puget Sound for over 100 years. For more than half of this period, tankships have been active on the Sound. In fifty years of tanker activity, there has never been a serious collision on Puget Sound involving a tankship nor has the Sound ever experienced a major oil spill as a result of collision or grounding.

This is a truly remarkable record. If, indeed, Puget Sound has never experienced a serious collision involving a tank ship, why should money be spent for elaborate control systems; or even, change the present traffic patterns and operational procedures?

No one can take issue with the fact that Puget Sound pilots are among the best in the world and that the Sound is a relatively safe waterway. But, there have been collisions involving freighters, and a statistical analysis of the Sound[2] indicates that we may be living on borrowed time with regard to a tankship incident.

To underscore the problem that exists today in many European ports, and the problem that may exist tomorrow on Puget Sound, the development of the mammoth tanker must be fully examined. These ships represent not just a new class of ship (C-2, C-5, C-5A, etc.); but, the evolvement of a whole new technology.

It has been 110 years since the first overseas shipment of oil in quantity. By the 1880s the tanker movement was underway. In 1886, the SS Gluckauf, the prototype of the modern tanker, was completed. This ship was 310 feet long with a deadweight of 3,000 tons. True to form, the Gluckauf was one of the largest ships of her time.

World War I saw the building of 18,000 dwt tankers.[3] World War II created a similar need for tankers and the United States responded with the building of over 500 T-2 tankers. These ships survived to form the bulk of the world's postwar tanker fleet, and they still exist today. Many have been "jumboized" and others have been converted to dry cargo service by building new hulls around the ship's machinery space.

The T-2 tanker and others like her effectively served the trade for decades. The period from World War I to the late 1940s did not see many innovations in tanker design. The late 1940's saw a change in the characteristics of the trade.

Increases in consumption of petroleum products made it profitable to refine the product near the consumer instead of importing the product from distant refineries. This innovation naturally created a need for more long haul bulk carriers. It became apparent to tankship operators that the tanker design must be changed to satisfy the need for economies of scale. The first of the so-called supertankers appeared in 1950 and had a dwt of 30,000 tons. In 1953, the Tina Onassis figuratively broke the dam of conservatism by the sheer weight of her 50,000 dwt.

By the late 1950s ships were being built which were eight times as large as the T-2. The mid 1960s saw the emergence of the first 200,000 dwt tanker. Today, ships fifty times the size of the T-2 are being designed. Table III-C2 presents examples of various size tankers and their operational characteristics.

The development of these tankers is not without problems. It is because of these problems that one begins to see the need for safety improvements in ship movements in confined waters.

New construction techniques had to be developed before each great leap in size could be accomplished. Of course, each increase in the size of a tanker required a proportionate increase in the size, capacity, output or strength of its component parts, such as propulsion plant, generators, pumps and propellors. Merely building everything larger, however, was the answer.

A glance at the figure comparing tank ships reveals that the crash stopping distance of a fully loaded T-2 is seven ship lengths (3500'). The stopping distance of the Universe Ireland is reasonable when compared on this basis with the T-2 (i.e. 9-1/2 ship lengths). This distance is about 10,000 feet compared with 3,500 feet for the smaller vessel.

Tank size plays an important part when one considers the need for safety requirements. The center tanks of the Universe Ireland have a

TABLE III-C2: EXAMPLES OF TANKER OPERATIONAL CHARACTERISTICS[4]

EXAMPLES OF TANKSHIPS OF VARIOUS TONNAGES

Class or Name	T-2	T-5	Pennsylvania	World Glory
Dwt	16,800	26,500	28,170	45,500
Length	523'6"	627'6"	624'7"	736'6"
Beam	68'	83'6"	84'	102'
Draft (loaded)	30'2"	32'10"	33'	37'6"
Displacement (loaded)	21,800	34,630	36,280	58,265
Capacity (bbls)	141,000	204,000	241,500	396,000
Shaft horsepower	6,600	20,460	13,750	15,000
Speed (kts.)	14.5	18	16.6	16.0
Turning Radius	3/10 mile	N/A	N/A	N/A
Crash Stop (min)	12 min.	N/A	N/A	N/A
Crash Stop (ship length)	7	8	N/A	N/A

Ship Name or Owner	Barracuda	Niarchos	ARCO	Universe Ireland
Dwt	60,000	106,000	120,000	326,000
Length	810'	949'	N/A	1,135
Beam	104'	134'	N/A	174'10" (moulded)
Draft (loaded)	41'9"	49'	N/A	80'
Displacement (loaded)	76,000	N/A	N/A	--
Capacity (bbls)	430,000	821,000	N/A	2,400,000
Shaft horsepower	25,000	43,000	N/A	37,400
Speed (kts.)	17.2	18.0	N/A	14.8
Turning Radius	4/10	6/10 mile	N/A	3/4 mile
Crash stop	14 min.	N/A	N/A	17 min.
Crash stop (ship length)	N/A	N/A	N/A	9.5

138,000 bbl capacity - almost equal to the total capacity of the T-2. Even a "minor" collision with these larger vessels could be catastrophic in the environmental sense.

An evaluation of the need for improvements in ship traffic control can best be analyzed by examining the ability of the supertanker to avoid grounding or collision should it find itself in such a condition. We have already alluded to the handling characteristics of the mammoth tankship. Let us now bring this problem into proper perspective.

The crash stopping distance of a 200,000 dwt tanker is about 10,000 feet and requires about 20 minutes. The controllability of a ship is, however, a function of two items: dynamic stability and maneuverability.[5] A ship is said to be dynamically stable if, after a slight disturbance, it returns to its original motion without the use of the rudder. A ship that has good maneuverability, responds quickly to the change of the helm. The maneuverability is dependent upon rudder effectiveness.

The controllability of a ship is markedly impaired while stopping; both the dynamic stability and maneuverability are altered, as characterized by the following:

a. The velocity of flow over the ship decreases due to the reduction of the ship speed.

b. The velocity of the flow over the rudder decreases.

c. Moreover, the flow around the ship and the rudder will be disturbed due to the deceleration of the vessel.

d. Rudder effectiveness decreases with decreasing RPM and has virtually no effect after the rotation has been reversed.

e. Dynamic stability is reduced due to lower prop RPM and thrust.

More work in this area was performed by Dr. Masataka Fujino of the University of Tokyo.[6] The following may be concluded from his work:

a. Instability of a ship in a narrow channel is mainly due to the asymmetric hydrodynamic forces and moment caused by the presence of channel walls.

b. The shallower the water, the greater the effect of wind on the unstable condition.

The supertanker, however, is affected by wind regardless of the water depth (more severely in shallow water).

It would seem that, while certain steps can be taken to improve the handling characteristics of large tankers; these ships are extremely limited in their ability to avoid a collision or grounding when maneuvering in close quarters.

Furthermore, the recent spree of large tanker strandings, burnings, collisions and explosions has shaken the previously successful argument that the fewer large ships, the lower the odds on disaster.

b. The Implementation of Traffic Control Schemes

One of the problems involved with the implementation of traffic control systems will be their acceptance. Historically, mariners have been independent, having sole responsibility for the safe conduct of their vessels. There are only two places in the world where the master relinquishes responsibility for the vessel, the Panama and Suez Canals. Everywhere but here, the master rules supreme!

Lights, shore structures, radio beacons and LORAN are all of a nature to provide navigational assistance if a mariner so desires to use them. Pilots aboard vessels in Puget Sound are there in an advisory capacity only.[7] Pilots, therefore, are employed as another aid to navigation.

As vessels become larger and their maneuverability diminishes, the process of navigation becoming too critical and complex to be left to the vessel alone. Development of shore based harbor advisory systems provides an additional source of information for the master. However, acceptance of shore developed information will depend on education and retraining of vessel personnel and agreement between information from the shore and information developed aboard ship.

It has been found that the most important prerequisites to successful introduction of sophisticated techniques and automation are detailed job analysis and comprehensive retraining of staff to operate the systems to full advantage. If one or both of these factors are neglected, then the chances of the system being both economically and operationally viable are drastically reduced. It appears that in field of navigational aids, both of these areas have been neglected to a certain degree and have resulted in over-sophisticated equipment being produced by technologists and its use being forced on under-trained operators.

An analysis recently conducted by the Liverpool Regional College of Technology, showed that a sample of 550 masters and officers who returned the questionnaire "... at most only 25% have sufficient knowledge to use their radar fully in conditions of reduced visibility and the majority of masters at sea take only partial advantage of the full potential of their equipment."[8]

There is obviously a great need for regular, formalized training and refresher courses for officers and masters, possibly of the type undertaken by airline pilots; but an equally large problem with merchant ships is that individual owners and designers tend to express their personal preferences in the selection and siting of equipment. Masters and officers also change ships regularly and take their disciplines and preferences with them. Thus, in many cases, when the officer of the watch is faced with a sudden unfamiliar situation, he has to take "ad hoc" action to deal with it and is not able to put into action a preconceived, tested and rehearsed plan in which all participants have a fully understood part to play.

A training facility under the aegis of the Master, Mates and Pilots Association has been established in Baltimore, Maryland.[9] The Maritime Institute of Technology and Graduate Studies has specially designed equipment simulating onboard experiences in automated shipping.[10]

The simulation system developed by the Link Division of the Singer Company is so realistic that trainees will actually hear fog horns and will receive engine room reports in response to their orders.[11] The equipment consists of a collision avoidance radar simulator, an automated propulsion control center, and a cargo loading trainer. The collision avoidance simulator is comprised of eight cubicles, each containing two radar stations and a control console. The radar sets will be computer programmed to trace the course of the trainees ship, plus as many as 15 other vessels. Radar will record not only passage of ships, but also, buoys and land points of key harbors and waterways. In a typical program, the trainee will be told that he is the pilot of a ship at Ambrose Light (off New York). The weather conditions are: extensive fog; visibility, one-half mile; "Bring your ship into New York Harbor."

The purpose of this training program is to raise the capability of ship's officers to a level consistent with the requirements of new technology. A regular scheduled refresher course utilizing the multimillion dollar Singer facility should be employed by all pilot associations handling the mammoth tankers on a regular basis. It would also be essential for masters and officers of new vessels to attend the simulator program prior to their sea trials.

c. New Shipboard Navigational Aids

Acceptance of traffic control schemes also relies on agreement between shorebased and shipboard information.

Marine radar has been a disappointment to those who thought that its general installation in merchant ships would drastically reduce or eliminate collisions because ships, like autos, simply go faster in poor visibility until the risk is approximately what it was before the advent of advanced radar systems. The collisions involving large tankers have focused public attention on this problem. Radar engineers, meanwhile, have been studying ways in which the new radar information can be processed and displayed to assist decision making for collision avoidance. This amounts to indicating, more or less automatically, the time to and distance from the closest point of approach (CPA) of threatening targets. All the major radar manufacturers have come up with solution of widely varying complexity and cost.

The following is a brief description of some of these navigational aids.

1. Marconi Predictor

The Predictor radar stores the raw radar picture on magnetic tape. The picture from every fourth rotation of the scanner is stored. The tape loop is arranged so that the pictures or frames are played back onto the cathode ray tube (crt) display in a different order to that in which they were recorded. Thus, each group of four frames, covering a 10 second period in real time consists of the radar pictures recorded 6, 4, 2 and 0 minutes ago, in that order. When switched to show relative (or true) tracks every target thus appears in four positions, each of which is sequentially updated every 10 seconds. These rows of dots give course and speed information and indicate changes that have occurred, or are occurring during the previous 6 minutes. In the "true tracks" mode, one's own ship remains at the center, previous positions showing astern. A "predicted relative tracks" mode is also provided to show what these would have been had one's own ship reached her present position from a different direction. This enables an avoidance maneuver to be tested before being carried out.

2. Decca Transar

The 66AC radars of this series are popular and simple. Five interscan lines or markers, of fixed length, are provided. The head of each line can be set to mark any ship that appears to present a potential risk. Once set, the markers point toward own ship and continue to do so, moving bodily across the display (true motion mode) as necessary. If a target echo moves down its own line, it is approaching on a constant bearing and so, after a few minutes the dangerous targets can be identified. The echo tails show true course, or aspect, while the relationship between the head of the marker and the echo itself gives the relative track and a visual indication of the CPA. If an avoidance maneuver is to be made the markers must be re-set.

3. Kelvin Hughes Photoplot

The "Photoplot" display stores the plan position indicator (ppi) radar pictures on 16mm film which is rapidly processed and transported for back projection onto a large screen at intervals controlled by the operator. The longer these intervals are the larger the number of scanner sweeps that will be superimposed on one display, so for moving targets, there will be longer tracks showing past history. Unlike the echo tails caused by the afterglow of a long persistence tube, these tracks give a sufficiently accurate estimate of speed as well as direction to enable the collision risk of any ship within the scope to be assessed. A transport "predictor overlay" is fitted over the projected display to facilitate the drawing of relative (or true) tracks when the set is in the true motion (or relative) mode. The effect of an alteration of course can be assessed in the same manner.

4. GEC - AEI Compact

(Compact stands for computer and automatic course tracking.) This display computes the velocity vectors of selected targets from present information. Up to 12 targets can be manually selected by laying a green circle round them which locks the computer onto them. They are then followed automatically, and their velocity vectors displayed in green. A CPA circle can also be shown round one's own ship, or round the termination of one's own ship vector in true motion. Alarm signals operate for all closing targets when they come within 11 and 9 miles, and also for targets under surveillance which will pass, on present form, within CPA distance selected by the operator. A separate green phosphor display tube is used for the indicators and this is set at an angle to the standard ppi and the image superimposed by a semi-reflecting mirror. In this set also an avoidance maneuver can be tested in advance.

5. Norcontrol Data Radar

This anti-collision function is part of a system known as Data Bridge. The full system provides Data Radar; a dead reckoning, position fixing, and great circle sailing interface; and a third function designed to improve autopilot performance. The collision avoidance function is based on the coordination of radar and computer. The system, controlled by a simple joystick, gives automatic tracking and collision thread assessment of up to 12 targets, presenting relative and true motion vector displays in an easily assimilated form, superimposed on a conventional ppi. A system of time oriented dots, superimposed on the vectors of both own ship and threatening targets enables closest approach and CPA time to be readily assessed. The system automatically gives both visual and audible alarms of collision courses, as well as calculating drift by means of reference to known positions. Data Radar also enables the officer of the watch to simulate maneuver data in the case of dangerous situations.

6. Sperry Collision Threat Assessment

The device is used as an accessory to Mark 12 solid state radars and may be adapted to other marine radars. Capable of operation in both true and relative motion displays either centered or offset. The device automatically supplies the navigator with immediate visual indication of degree of risk for every target intruding into the radar screen and obviates the need to manually track or lock onto radar echoes.

Each echo appearing on the radar display will cause a threat assessment marker (TAM) to appear. This is a 5^{o} wide segment of similar thickness and brightness to a range marker line. The TAM "visual fence" will appear at present positions determined by the officer of the watch (OOW) in light of known speed and maneuverability of their own vessel.

When the echo moves behind the TAM, the target is moving at a relative speed indicating arrival at one's own ship in a time greater than that initially selected as immediately dangerous. When the echo moves coincident with the TAM arrival at one's own ship will be close to that selected. When the echo penetrates and crosses the TAM, it represents a potential collision threat which will require action.

For any one echo, the time control may be adjusted to position the TAM over the echo and thus obtain an approximate CPA.

7. Iotron Digiplot

The "Digiplot," another separate display, can analyze and track target echoes from any standard radar. It differs from the others discussed in that the computer automatically acquires all radar targets. Having separated out the land mass targets, it selects the 40 most threatening small targets for display. The selection is made on the basis of the calculated CPA for each one, operator selected time and distance to CPA being used as a criterion. The 40 selected targets are shown with their velocity vectors and the range, bearing, course, speed and CPA time and distance of any one of them can be shown digitally when picked out by the operator by means of a light-sensitive pointer. The display is scanned 50 times a second, making it completely flicker-free. Automatic alarms are also provided and the effect of changes of course and speed can be completely simulated, the projected maneuver being speeded up 30 times.

8. James Scott Mark II Mini Radar

This device is not truly comparable to the seven other systems in terms of its application. But it is an important part of the new hardware and should be utilized if at all possible.

Several recent accidents have indicated that the inability to estimate sideways movements of ships toward a berth has led to entire jetties being offset and severe hull damage. This light weight portable radar system has been tested at British Petroleum's Finnart Ocean Terminal. The device is able to keep the pilot informed of the tanker's approach speed from an initial 50 ft/min down to 5 ft/min. The mini radar is based on the doppler system and operates from a normal 12 volt battery source. It is provided with connections for computers and data displays.

d. Evaluation of Shipboard Aids

Are these devices really worth the money and do they aid shipboard personnel in their decision making process?

Prices vary depending on which system and what accessories are chosen. The Norcontrol Data Bridge System should run about $96,000. Digiplot would appear to be the most automatic of the systems and probably is the most expensive. The price, whatever it is, is negligible in relation to the risk it is designed to reduce or eliminate. But is the risk really reduced?

Most collisions result from end-on encounters and these are sometimes caused by late course alterations. But every CPA calculation, whether the ships are on alternate courses or not, makes the implicit assumption that no one is going to change course or speed. Several of the displays referred to make provision for trying out avoidance maneuvers on the plot before making them and the explanatory literature that goes with them often includes a series of diagrams which start with ships converging on steady bearings. Disaster seems imminent. The next diagram he sees reveals the always successful trial maneuver. Nobody ever alters course or speed. How many collisions have ever occurred in which only one ship has altered course?

Another problem associated with these devices is the alarm system. Ships maneuvering in heavily congested waters would have alarms going off constantly. A better alarm would indicate course or speed alterations by another vessel. A computer could spot this before it became apparent on the display and this is the moment when maximum alertness may be required.

Of course, it would be even more valuable to know course and speed changes before they occur and this would require bridge to bridge communications.

These new shipboard devices can best be utilized, if a controller was in contact with and could make suggestions or instructions to all ships in the area. This interface between shipboard equipment and personnel, and shore based equipment and personnel is really the key to effectiveness of collision avoidance.

e. Traffic Control Systems

The following evaluates two operational traffic control systems and their effectiveness. One is located in Rotterdam, Netherlands, while the other is in San Francisco, California.

1. Rotterdam, Netherlands[12]

Pilots equipped with a 24 channel VHF set communicate with the appropriate radar stations, use the assigned channel for the radar coverage area concerned and switch to the next channel after "hand over" has taken place.[12] The information supplied to pilots consists of the position of the ship, relative to familiar landmarks and "leading lines," amplified with additional information, such as surface pictures, shipping movements in the area, possible navigational hazards, etc.

Most of this information is extracted directly from the (shore) radar-screens. Rivercraft, which are not under obligation to be piloted, usually monitor these channels to acquire information on the traffic on the river, needed for a safer passage.

The Netherlands Radar Research Establishment at Noordwijk (The Netherlands) was entrusted with the assignment in 1963 to plan and design a new automated radar system with sufficient capacity to serve the Port of Rotterdam and Europort, including present and future harbor complexes and the approaches.

It became obvious that the use of computers to automate a number of functions could also serve to incorporate an information giving capability. This was particularly desirable for coordination purposes in Rotterdam itself, but also at the Hook of Holland, where the entrance to the river and to Europort necessitates a strict traffic control.

A centralized "Plotting Center" in Rotterdam and a "Sub-Center" at the Hook must be an integral part of the system and enable interested parties to obtain filtered information, tailored to their specific activities.

The presence of port and shipping authorities, port services and other agencies at a centralized location would stimulate coordination, necessary for a port of this size.

The new system is therefore not exclusively a radar assistance service, but also a shipping information or data system, intended to facilitate the handling of ships. As an aid to shipping it has to operate at all times, irrespective of climatic conditions.

The new system consists of 10 radar stations:

1. One unmanned station, remotely controlled by the Sub-Center at Hook of Holland, on an artificial island, to cover the dredged channel, the approaches to the river entrance and the emergency anchorage of the Hook.

2. "Pilot Mass" radar station on the same island, remotely controlled by the Sub-Center at the Hook, with the main task of rendering assistance to ships, which have not yet embarked a pilot, or have disembarked their pilot at the pilot's vessel cruising station.

3. One radar station at the Hook of Holland with a triple function:
   a. to control the "island" radar stations;
   b. Sub-Center Hook of Holland and traffic control;
   c. to cover the entrance of the river and Europort, part of the river and parts of Europort.

4. Seven radar stations as part of the chain.

All radar stations are linked and supply position data to the "Plotting Center" at Rotterdam and the "Sub-Center" at the Hook.

Ships are entered and processed into the computer system at these two centers, incoming ships at the Hook and outgoing ships at Rotterdam. Pilots will supply the following ship's data by VHF radiotelephony:

a. the pilot's reference number;
b. the name of the ship;
c. destination;
d. draught;
e. nature of cargo.

All ships' data are passed to and stored in the local computer of the chain. They are also available for presentation to interested parties at the two Pilot Centers.

The Principle of Position Determination

Position determination is based on the use of:

1. a primary radar;
2. a secondary radar system, including a responder, a data-extractor and a local computer;
3. peripheral equipment such as consoles, communication buffers and other communication units.

The secondary radar is linked and synchronized to the primary radar in its identification and determination functions.

Pilots are equipped with a portable X-band responder and a VHF communication unit. This unit contains the data receiver and an "intercom" set. The responder is hoisted or attached in such a way that a free 360^o horizon is presented.

The primary radar operates on a frequency in the 9025-9225 MHz band with a beam width of 0.5 degree, if a linear antenna system is used; or a beamwidth of 0.25 degree for a product radar system, depending on the required accuracy in a given area.

The secondary radar transmits an address selective interrogating code-signal to a corresponding responder, which will answer on 8880 MHz after the primary radar's measuring pulse has triggered the responder trasnmitter and a time-gate is opened to pass the responder pulse.

A relatively short response time of 0.1 microsecond helps to eliminate unwanted reflection responses.

Normally, the interrogation sequence of the various targets is programmed by the local computer. New targets are entered by interruption the programmed interrogation during one antenna revolution, until a response has been obtained and position coordinates are processed.

In case of computer failure responder signals can be made directly visible on the screen.

Computer derived positions are presented as a circle round the "paint" of a target. Pilot reference numbers are also indicated on the radar screens outside the fairway, to the south of it for outgoing ships, and to the north of it for incoming ships.

The responder has a capacity for 500 address selective codes.

Position data are passed every 10 seconds to ships via the VHF data receiver.

Positions are supplied every 5 minutes to the two Plotting Centers at Rotterdam and The Hook.

For "hand-over" purpose[13] they are passed to adjacent radar stations. On the tote-display a number of functional indications are available related to the "handover" procedures, in addition to the relevant ship's data.

Communications

The complex automated radar assistance and data exchange system requires an extensive telecommunications network. It can be divided in:

1. VHF communications between shore based radar stations and ships for data exchange and intercommunication purposes;
2. microwave communications between the Hook of Holland Sub-Center and the unmanned artificial island;
3. line communications between the component shore based radar stations and from each of these stations to the two Plotting Centers at Rotterdam and the Hook of Holland.

2. San Francisco Harbor Advisory Radar (HAR)[14]

Placed into operation by the Coast Guard, 21 January 1970, this system does not have stand-by equipment.

This system is really on an experimental basis in an effort to provide information regarding the need for such systems.

The system uses a Raytheon Model 1640 radar located near the center of the harbor on the peak of Yerba Buena Island (elevation 400 ft). A 12 foot slotted, waveguide antenna provides 0.6 degree horizontal beam-width, and the 11 degree vertical pattern provides coverage to the base of the island. Located at the site, the radar provides coverage of the Oakland terminal complex, and surveys the harbor from the San Rafael-Richmond Bridge, to the Golden Gate Bridge, south to Hunter's Point.

A second radar site is located at Point Bonita and provides coverage from the Golden Gate Bridge to the San Francisco Light ship.

Radar video, trigger, and antenna rotation data is microwave relayed from Yerba Buena Island to the operations center at pier 45.

The ppi at Point Bonita is scanned by a TV camera and the TV signal ouput is microwaved to YBI. From YBI to the operations center at pier 45, the TV signal will be multiplexed to an existing microwave channel and demultiplexed at the Pier 45 receiving site.

The displays at the operation center are the conventional center sweep ppi, 16 inches in diameter, and ppi repeaters with 10 inch slopes. The latter have off-centering capability and the ability to electronically determine the range and bearing of two targets which are not related to the center of the display. This allows the operators to provide the range and bearing of a vessel to any selected shore aid, or to another vessel without manual plotting. The operations center shares its location with the Marine Exchange's Vessel Movement Reporting Center, providing a rapid exchange of information as vessels enter and depart the radar coverage area.

Communications with commercial vessels are via VHF-FM on channel 18A. This simplex channel is used for bridge-to-bridge communications for the entire mid-California area, from Sacramento to San Mateo, and out to the Lightship. Because of the wide coverage area, this single channel was reaching saturation prior to the introduction of HAR, and with additional vessels reporting to the HAR center, increased problems are envisioned. The primary objection to the existing voice communication network concern the use of the channel for non-navigational information, which should be passed on other available channels. Through the services of the Marine Exchange, placards are being developed which provide ready information to the vessels concerning the proper channel usage. Located on or adjacent to the transceiver, the vessel operator will be provided with education material essential to the eventual resolution of the discipline problem.

In addition to channel 18A, UHF-AM on 277.' MHz is used for U.S. Navy vessels which are not equipped with the commercial channel. Installation of both equipments at one operations center provides the first opportunity for indirect radio contact between the two classes of vessels. The transceiving equipment is located on the roof of the 12th Coast Guard District Office building in downtown San Francisco, with remote control facilities via telephone line from the operations center. Ship equipment consists either of fixed stations, or pilot transported hand talkies. A problem with the fixed equipment is that the power output is too high for harbor use. The level of radiation is sufficient to block communications at the far extremes of the coverage area, often unknowingly interfering with other bridge-to-bridge conversations.

Continuous tape recordings are made of all voice communications, with a simultaneous recording of local time. A ppi located at Yerba Buena Island is photographically recorded every three minutes on 35 mm film to provide a record of all harbor activities. This data, and data recorded on ADP cards by the watchstanders, will provide the information deemed necessary for system analysis.

The recent collision that occurred in San Francisco[15] should not be taken as proof that the Harbor Advisory Radar is ineffective. The Coast Guard radar recorded the Arizona Standard inbound for the refinery and the Oregon Standard outbound for Vancouver. The Coast Guard radioed and alerted the Arizona, but could not raise the Oregon. Pictures of the radar images of the vessels appear in the June 1971 issue of the National Geographic.[16] These pictures seem to verify that the problem was mainly with communications.

Traffic Control Advisory Systems are also in operation on the Thames River, Great Britain and the entrances to the Panama Canal. One of the reasons these systems are not in more widespread use is the very high cost. Such a system would be advisable for Puget Sound, but with cost estimates ranging around 6 million dollars, alternative solutions must be researched.

f. Traffic Separation Schemes

The Inter-Governmental Maritime Consultative Organization (IMCO) has made various recommendations. The aim of these recommendations is to produce an orderly flow of traffic for the purpose of reducing the risk of collisions and/or strandings, mainly in areas of converging routes or high traffic density.

Member governments of IMCO have been invited to advise ships under their flags to conform with the principles of traffic separation, to adhere to recommended routes, and to take account of the fact that areas to be avoided by certain classes of ships have been designated in some regions.

The use of traffic separation schemes is not compulsory; it is for ships' masters to decide, after assessing the situation and circumstances, whether or not to follow the recommended routes. It should, however, be understood that ships navigating against the recommended direction of traffic, within designated traffic lanes, are exposed to unreasonable risks because of the possibility of meeting a large number of ships on opposite or nearly opposite courses. Consequently, ships' masters not wishing to follow the recommended routes are advised to keep well outside the boundaries of established schemes and not hamper the organized traffic.

There were 58 such schemes as of 1 October 1970.[17] Traffic schemes are established on the Pacific and Atlantic Coasts of the United States, Arabian Sea, Red Sea, Persian Gulf, South Atlantic and Indian Oceans, Baltic Sea, Western European waters and the Mediterranean Sea.

It is recommended that the following basic schemes developed by IMCO be established wherever applicable on Puget Sound. Figure III-C9 depicts scheme traffic symbols while Figure III-C10 presents five different schemes.

1. Separation of Traffic by Separation Zones or Lines (Frame 1)

In such cases, the separation of traffic is achieved by introducing a separation zone or separation line; ships navigating in opposite or nearly opposite directions are advised to keep to the right-hand side of the zone or line. The outside limits in such a scheme are the outer boundaries of lanes intended for organized traffic. Beyond such limits ships may navigate in any direction.

FIGURE III-C9
TRAFFIC SCHEMES SYMBOLS

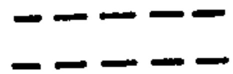
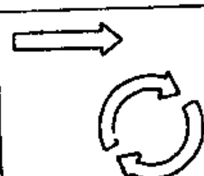
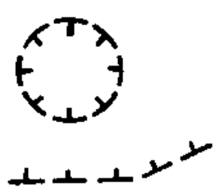
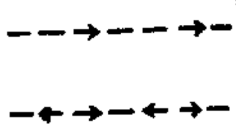
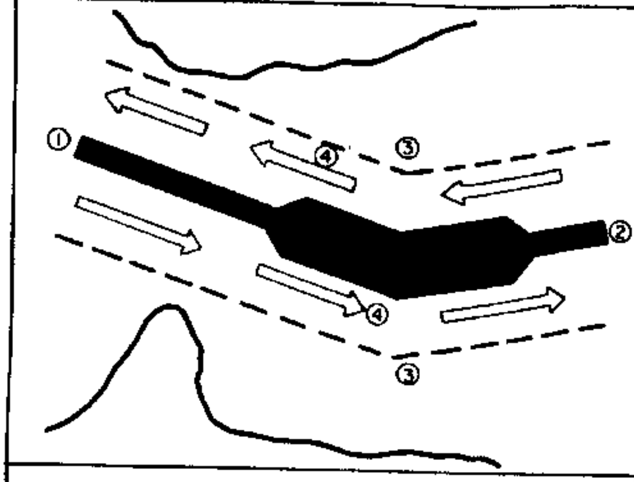
DETAIL	PRESENTATION	DESCRIPTION
Outside Limit of Traffic Lanes Inshore Zone Limit		Broken Line - The Symbol Used for Maritime Limits in General
Outside Limit of Traffic Circle		
Separation Zone (any type)		Zone will be indicated by solid colors.
Separation Line		Single Solid colored Line
Center of Traffic Circle With no separation zone inside.		Solid Colored Circle
Arrows indicating dirrection of traffic in Traffic separation schemes		Outlined arrows to Indicate general direction of traffic flow.
Boundary of areas to be avoided by ships of certain classes Limit of Sea Exploration and/or Exploitation regions which may be dangerous to free navigators		A line composed of a series of T-shaped signs down stroke points to the area in question.
Deep Draft Route		A single-dashed line in which arrow heads are inserted at regular intervals either way track, or in opposing pairs, to represent a two-way track.

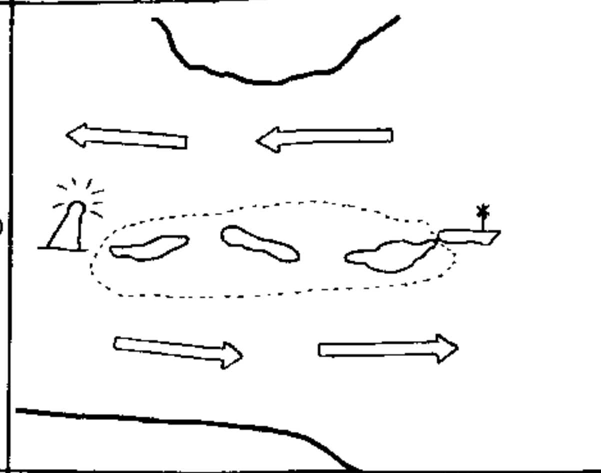
FIGURE III-C10
TRAFFIC CONTROL SCHEMES

FRAME #1



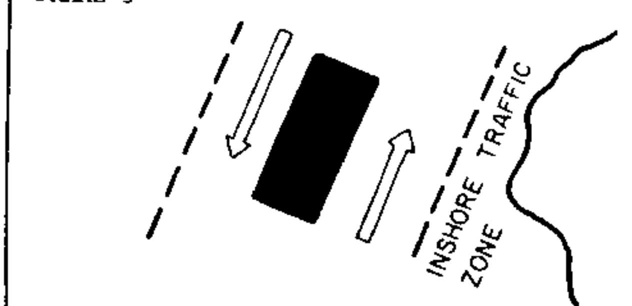
Separation by traffic Zone & Line
1) separation line
2) " " Zone
3) Outside Limits of Lane
4) Arrows indicating main traffic div.

Frame #2



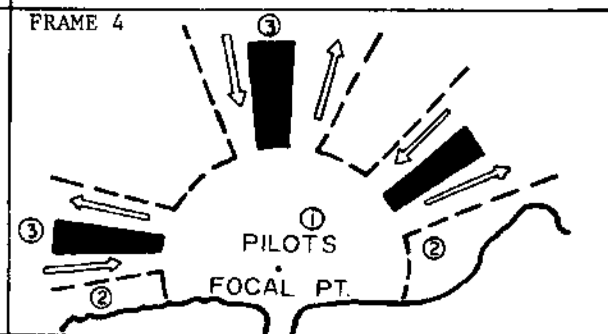
Separation by Natural Obstacles

FRAME 3



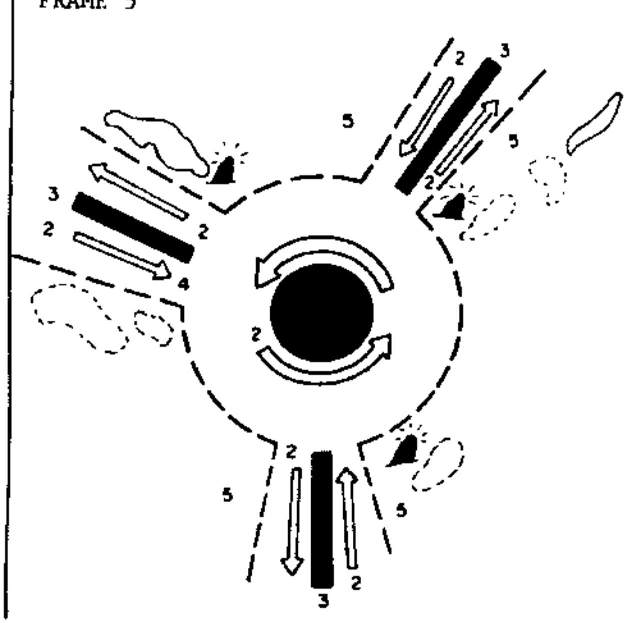
Separation of traffic by Inshore Traffic Zones

FRAME 4



Separation by use of sectors at Approaches to Focal Point

FRAME 5



(FIGURE 5)
Separation of Traffic By introduction of Traffic Circle intended to facilitate navigation at Focal Point, where recommended routes meet
1) circular separation scheme
2) Arrows indicating traffic direction
3) Separation schemes
4) Separation LIne
5) Outside limits of Lanes

The width and length of separation zones and traffic lanes are determined after careful examination of local conditions, traffic density, prevailing hydrographic and meteorological conditions, space available for maneuvering, etc., and are kept to a minimum, allowing ships which do not use the lanes to keep clear easily. In narrow passages and restricted waters a separation line may be adopted instead of a zone, for the separation of traffic, to allow for more navigable space.

2. Separation of Traffic by Using Natural Obstacles and Geographically Defined Objects (Frame 2)

This method is used in places where there is in existence a defined area with obstacles such as islands, shoals, rocks or wrecks, restricting free movement, and providing a natural division for opposing traffic streams.

3. Separation of Traffic by Establishing Inshore Traffic Zones Intended for Keeping Coastal Traffic away from Traffic Separation Schemes (Frame 3)

The term 'inshore traffic zone' is understood to cover an area between the landward boundary of the scheme and the adjacent coast, wherein ships navigating in any direction may be encountered.

Generally speaking, all traffic separation schemes are designed for through navigation. However, in areas of considerable coastal traffic, the establishment of inshore traffic zones, intended for keeping coastal shipping away from traffic separation schemes, is adopted. The inshore traffic zone may also be used by ships which prefer, for one reason or another, to keep close to the coast and which at the same time would like to avoid meeting ships using the scheme and moving in the opposite direction.

4. Separation of Traffic by the Use of Sectors at Approaches to Focal Points (Frame 4)

Such a method is used where ships converge on a point or a small area from various directions. Port approaches, sea pilot stations, positions where landfall buoys or light vessels are fixed, entrances to channels, canals, estuaries, etc., may be considered as such focal points. The number of shipping lanes, their dimensions, and directions depend mainly on the type of the local traffic.

5. Separation of Traffic by Introduction of Traffic Circles or Roundabouts Intended to Facilitate Navigation at Focal Points, Where Recommended Routes Meet (Frame 5)

At focal points where several recommended routes meet, traffic is so organized as to correspond to the rotation schemes known to motorists as traffic circles or roundabouts. To facilitate navigation in such places and to comply with steering instructions in Rule 19 of the International Regulations for Preventing Collisions at Sea (commonly called International Rules of the Road),[18] ships are advised to move in a counterclockwise direction around a specified point or zone until they reach turning points where they join the appropriate lane. The radius of the traffic circle or roundabout depends on local conditions; it is generally limited in area to avoid unduly long rotations. If the space available permits, a circular traffic separation zone is recommended at the center of the traffic circle or roundabout to keep ships at a distance from each other. It is considered desirable, where possible, to establish traffic circles or roundabouts around buoys, light vessels, or geographically defined objects.

Although these traffic separation schemes are much less expensive (less effective too) than complete traffic control systems, they do involve significant capital outlays. The Swedish National Administration of Shipping is currently involved with the establishment of a "Big Ship Corridor." They report that the surveying and production of charts are expensive and time consuming operations. The report indicates that surveys and wreck removal for deep draft vessels can easily cost $300,000 to $600,000 per wreck and modern light buoys cost at least $14,000 each plus annual upkeep.[19]

g. Recommendations for Puget Sound

The applicability of traffic control techniques to the Puget Sound waters is best summarized in a lecture presented before the study team by Rear Admiral Kenneth Ayers USN (retired), Chairman of Northwest Marine Safety Council.[20] It is recommended that these ten points be implemented immediately.

1. Use of safety lanes as proposed by IMCO. This has begun with the establishment of a channel designation system through the San Juan Islands to separate northbound and southbound traffic. A system of buoys is being established to designate the routes shipping is to take. Charts have been

prepared and some buoys are already in place. Islands are used to physically separate the routes much of the way. Such traffic separation schemes should be employed for the entire route of the large tankers.

2. Bridge-to-bridge communication system now being used by most vessels on a voluntary basis, should become compulsory for all commercial vessels in the near future. Agreements would have to be worked out with Canadians and others who share these radio circuits with the United States.

3. Speed regulations should be enforced on Puget Sound. Many vessels do not slow down even during periods of low visibility in order to arrive at their berth "on time" and make full use of the contracted-for longshore "gangs."

4. Install the very latest type of navigational aids, e.g., the latest height of fixed lights.

5. Long and short weather forecasts with the latest information should be made available to all ships entering and leaving Puget Sound.

6. Adequate tugs should be made available for the transit and docking of large tankships.

7. Puget Sound pilots should attend training similar to that offered at the Maritime Institute of Technology and Graduate Studies.[21]

8. Tank sizes should be regulated. IMCO has just made some studies in this direction by limiting the upper limits on center and wing tanks of tankships.[22]

9. Improved seamanship would certainly do much to prevent dangerous situations from becoming disasters. One recommended procedure would be to "walk-out" the anchor prior to taking arrival. This practice would insure that the anchor was free and could be dropped in the event that the ship lost steerage or the powerplant "blacked out." Another practice would be to encourage motor ships to switch from burning bunker type fuels to burning diesel fuel prior to arrival at the pilot station.

10. A mid-channel buoyage system should be established. Where both inbound and outbound ships use the same channel, a buoyage system that uses mid-channel buoys rather than buoys down either side of the channel should be

installed. It is felt that this would improve safety by separating vessel traffic traveling in opposite directions through the same channel. Some ship masters voice the opinion that the present buoyage system, where the edges of the channel are marked by buoys, tends to "crowd" ships toward the middle of the channel and in close proximity with each other.

These ten points should be employed immediately. Some of the points would require changes in current practice. Others, like the mid-channel buoyage system, would require funding. It is here suggested that the oil companies and carriers provide this capital (approximately $250,000 for safety lanes, etc.), in turn, the state should place a reasonable limit on the liability to which these carriers may be subject in the event of an oil spill.

For the long run, Puget Sound is to become a waterway regularly traversed by mammoth tankers, then a traffic control system utilizing shore based radar should be established. The first step would be to fund a study to determine what would be required for such a system on Puget Sound.

Honeywell Marine Systems has prepared a proposal for an automated traffic advisory system for Puget Sound.[23] The questions that need to be answered now are: What type of computer would be utilized? Where would be the most cost effective places for radar stations? What portion of existing hardware could be utilized? With these answers, an analysis of the cost effectiveness of the system can be achieved, and its value to Puget Sound will be determined.

3. OIL DETECTION SYSTEM

Techniques and equipment for preventing oil spills have been discussed and evaluated in Parts 1 and 2 of Section III. None of these, however, incorporate the detection of oil on water other than visual. In order to prevent a leak from becoming a large spill, or to track the behavior of a spill, some method must be available to detect oil on water that is effective under adverse conditions.

The several objectives of an oil detection system are distinct from each other, and each utilizes different techniques. To detect oil on any given body of water, local sensing methods can be used, while the tracking of an oil spill requires remote sensors to trace its time dependent behavior. Both objectives are necessary for the protection of the environment.

Oil detection systems are conspicuous by their almost total absence in the Puget Sound region. The same statement holds true for many of the oil handling regions in the United States. In fact, the state-of-the-art of oil detection techniques is still in the experimental stages. A cursory examination of displayed hardware at the 1971 API Oil Spill Conference showed almost a complete void of oil detection equipment. Those that were available were designed for monitoring specific oil transfer operations, rather than monitoring the water.

The discussion presented here is not meant to be an evaluation of the research and technology of oil detection, but to survey the available hardware and systems. It will be obvious from the text that there are few systems on the market. Thus, an initial recommendation is to investigate the adaptability of detection systems, in general, to the oil pollution problem. Aerial reconnaissance, infrared, ultraviolet, and microwave techniques are some examples.

a. Local Sensing

The development of a system of detecting petroleum products should give first priority to areas which are subject to heavy oil traffic. These include harbors, refinery docks, oil handling facilities and marinas. Such a system can utilize devices which are physically located in the vicinity of oil traffic, and can be tied into alarm devices to provide integrated warning systems.[1] Since traffic is usually heaviest on or near waterways, location of such a detection system should be on the water, and thus is dependent on the local current, wind, and other meteorological conditions. Once the optimal location is determined, floats or buoys could be anchored. These floats would house the detection device. When in place, the sensor can provide continuous monitoring of the local water conditions.

There are several local sensing detection instruments on the market which work on the principle of reflectivity. Light on water possesses certain reflective characteristics. These characteristics are significantly increased when there is oil on the water. A photometer is used to measure the reflected light intensity. The change in reflectivity can thus be utilized to signify oil spills in the water. One such device consists of the photometer and light source mounted on floating pontoons, with a remote control section that displays the monitored results plus providing the alarm function.[2] Approximate price for such a device is $3,000, and it is currently available commercially. The unit is very effective in calm waters, but may experience difficulty in rough waters.

Shell has developed and installed a prototype "oil-on-water monitor' at its Dominquez, California refinery to keep a constant surveillance of the quality of water leaving that plant.[3] This unit also works on the principle of reflectivity. The oil firm plans to integrate the monitor with a recorder to determine water quality trends.

Other local methods of sensing include vapor, conductivity, and surface tension. These devices, when combined with an alarm, can continuously monitor the water quality of regions such as Puget Sound. Their primary disadvantage is their inability to track an oil spill after its occurrence. This is due to the fixed location of the devices.

b. Remote Sensing

Another method of detecting oil spills, and a method of continually monitoring its behavior, is remote sensing. Remote sensing can be done in a variety of ways, all involving electromagnetic waves and usually the use of an aircraft.[4,5,6] During an overflight, photographs can be taken by a cluster of different cameras with different types of film. Often used film types include: Infrared Ektachrome, Panchromatic Black and White, Infrared, and Infrared Color. To produce a sharp image of an oil slick any combination might succeed, depending upon the petroleum product spilled. False color images may produce desired effects when dealing with oil on water. By taking a series of photos, or utilizing periodic overflights, an oil spill can be tracked. A camera for such picture-taking will cost between $15,000-$35,000, but one may be improvised for around $1,500. A review of aerial reconnaissance techniques to investigate their adaptability to oil detection is recommended.

Other airborne remote sensing techniques include infrared scanners,[7,8] multispectral scanners,[9] and microwave radiometers.[10,11] All work on the principle of reflected light. The reflected light is broken down into certain wavelength ranges. The right combination of wavelengths will enable oil slick images to appear clearly against a background of water. It would also be possible to predict the thickness of an oil slick by studying its image. These instruments can produce a continuous picture on a screen and record the information on tape for time behavior analysis. This is a definite advantage of these devices over the camera in that continuous sensing is accomplished. An infrared scanner will cost around $160,000 and the other two somewhat more.

The remote sensing methods described up to now have been so-called passive methods, with certain requirements of light and cloud cover. The Side-Looking Airborne Radar (SLAR)[12] is of the active type and is the only reliable method of surveillance in heavy fog and under other extreme weather conditions. SLAR can be used effectively even at night. Here too, the image can be projected on a screen or recorded. There is a possibility of adding a selector that can activate a warning signal if oil is detected on water. The radar that is used is a Four-Frequency Radar, which is in common use by the United States Navy. The smoothing effect of the oil on waves enables the device to discriminate oil from water. Oil contaminated areas appear as dark regions with water as lighter in contrast. At present, research efforts are being expended to determine the thickness of oil slicks by SLAR, and to discriminate between the different petroleum products. The cost of a SLAR is about $250,000.

When evaluating the different remote sensing systems, the SLAR stands out as the most promising, in terms of ease of obtaining information and of all weather feasibility. But it has high costs associated with it.

The availability of integrated remote sensing systems is almost exclusively in government hands due to the prohibitive costs of airplanes. However, utilization of the Coast Guard[13] or Navy to fly daily surveillance missions for a given coastal region appears feasible. At present, no costs for such services have been obtained. A future alternative for remote sensing is to monitor from satellites. This would be the ultimate mode of surveillance, but again the costs would be staggering. In the present socio-economic system, only government action and subsidies could bring about such a system.

c. Evaluation

In the final analysis, interim measures should be geared toward the utilization of local detection devices for the Puget Sound waters. When integrated with recording and warning devices, an effective system of continuous monitoring of water quality will result. This type of system is more than adequate to detect if and when an oil spill occurs. But the problem of tracking spill oil in water still remains. Remote sensing is a step in alleviating the situation. But its cost effectiveness has not yet been fully evaluated. Until it is integrated into the total monitoring system, optimal capability to protect the Puget Sound waters will not be fully realized. Given the current state-of-the-art and the ever increasing urgency of the oil issue, adaptation of existing remote sensing hardware to oil detection appears to be the most feasible approach.[14] Thus, funding should be provided to knowledgeable personnel to initiate this effort.

TABLE III-C3: SURVEY RESULTS FOR OIL HANDLING FACILITIES

Inadequacy	Number of Occurrences (11 maximum)
Unsheltered harbor	6
No lighting on water surface adjacent to dock	6
Inadequate dock construction	9
Inadequate retaining walls	2
Inadequate security system	5
Shortage of valves along pipeline	4
Insufficient personnel for fueling	2
Inadequate monitoring of quantity of transferred fuel	2
Inadequate emergency shutoff system	6
No anti-pollution checkoff list	5
Inadequate inplant communication system	3
Insufficient oil spill cleanup system	5

4. SHORESIDE OIL HANDLING FACILITIES

a. Introduction

The oil handling facilities in Puget Sound constitute a potential source of oil pollution into Puget Sound. To analyze the probability of an oil spill from an oil handling dock facility, a study was made of eleven of the major facilities on Puget Sound. Table III-C3 summarizes the findings, which are detailed in Appendix 1. The objective was to formulate some realistic recommendations that, when implemented, would be expected to reduce the probability of an oil spill.

There are some steps already taken by these eleven facilities to prevent an oil spill. These steps are listed first. They cover both the mechanical devices used and the techniques employed on the dock. Next are listed the additional devices and techniques that would even further reduce the possibility of an oil spill. The use of an oil spill prevention checkoff sheet is a good method of preventing an oil spill; the study team's recommended checkoff sheet is included at the end of this section.

b. A Summary of the State-of-the-Art in Oil Spill Prevention on Puget Sound

The present state-of-the-art in prevention will be sub-divided into two areas: prevention devices and prevention techniques. Prevention devices are mechanisms and hardware that have been installed at the various oil handling facilities to lessen the chance of an oil spill. Prevention techniques are human operations and procedures that are being used at the various oil handling facilities to lessen the chance of an oil spill. The items presented below are those witnessed during the on-site visits. No one facility possessed all the listed items. Appendix 1 delineates the particular shortcomings of each facility inspected.

1. Summary of Existing Oil Spill Prevention Devices
   a. Prevention Devices and Systems on the Vessel
      i. Have oil containment booms on barges.
         Enough boom to encircle barge.
         In ready deployment position.
      ii. Plugs for drains and scuppers.
      iii. Always man the vessel.
      iv. Lash overboard and sea-suction valves.
      v. Have drip pans available.
      vi. Have absorbent material available.

b. Connections from Ship or Barge to Shore

i. Eliminate hoses by having solid "chiksan" connection between ship and dock. These connections are solid pipes with movable joints. The "chiksan" is motorized and contains motorized valves to control fuel flow.

ii. X-ray hoses every six months to determine any cracks or fatigue of hose material.

iii. Hydrostatic check of hoses every three months to 1-1/2 normal working pressure.

iv. Hoses capped after fueling.

v. Hoses tagged with numbered seals on vessel side during product loading to identify product.

c. Prevention Devices on Dock

i. Valve system (header, riser and other valves).
- Check valve (one-way flow valve).
- Valves color coded and tagged with the name of the product.
- Clear visual markings to indicate whether valve is on or off.
- The control of all motorized valves and pumps is possible from the dock area.
- Valves locked with a locking device whenever not used for a specific fueling operation.

ii. Piping system
- More valves installed on the dock piping at critical points where a ship or barge can damage the pipes.
- Pressure relief valves along piping system.

iii. Other equipment on docks.
- Troughs under risers.
- Dock surface sealed and a drainage system installed that connects to a slop tank.
- Drip pans available for valves on dock.
- If feasible, install an oil containment boom around the whole dock permanently.
- Have oil containment boom available close to dock area in sufficient quantity to contain any spill from barge or dock.
- Have work boats on ready position during fueling operations to deploy booms and sorbents.
- Have enough sorbent available to start clean up operations until more sorbent can be delivered.
- Have direct lighting on the water surface around ship or barge. Also lighting under dock to inspect for any spilled oil.
- Have an integrated communication system between dock and other areas of the plant.
- Dock area fenced and locked at all times.
- Install a retaining wall along the shoreline wherever an oil leak can occur.

d. Piping System (from waterline to fuel tanks)

i. Block valves (preferably motorized) on the land side of the dock, with sumps and retaining wall.
ii. Include valves into the piping system that can be automatically shutoff (or have personnel available).
iii. Include relief valves into the piping system.
iv. Have sumps wherever there is a possibility of an oil spill (these sumps should be connected to the oily water sewage system).
v. Install check valves at appropriate places.

e. Tank Farm

i. Have flow meters installed and checked for accuracy.
ii. 100% retaining wall around tanks.
iii. Automatic gauging system used in conjunction with flow meter during fueling.
iv. Valve at tank always closed when not fueling.

2. Summary of Existing Oil Spill Prevention Techniques and Systems

Most of the oil handling facilities visited submitted a copy of their oil handling procedures or instructions and discussed the techniques involved in transfering oil between the dock facility and the vessel. Listed below is a summary of all the various techniques that are used at oil handling facilities here in Puget Sound.

a. Before the Fueling Operation

i. Have adequate line handlers available.
ii. Inspect the receiving tanks.
iii. Be in agreement with the vessel personnel on the quantity of each product transferred and the quantity of any flush required.
iv. Write a plan of oil transfer. Be sure both the dock and vessel personnel understand the plan. Include in this the quantities of oil transferred, their flow rates, system pressures and any expected interruptions.
v. Determine the temperature and quantity of any product already in the vessel's compartments. Inspect all compartments that will be loaded and all unassigned compartments. Record all the temperatures and gauge readings of these compartments.
vi. Set up a workable vessel-to-dock communication system.
vii. Regularly inspect the dock area around the vessel for any trace of an oil spill.
viii. When transfering fuel at night, rig lights around the pier to shine on the water surface; and make lights available on the far side of the vessel.
ix. Plug all deck scuppers on the vessel and have absorbent material available to clean up any oil spilled on the dock or the vessel.

x. Place drip pans or buckets under all hose connections and valves unless there is installed a permanent drip trough.
xi. Make sure all hoses are in good condition and have available their record of inspection.
xii. Close all sea suction and overboard discharge valves on the vessel. Have the officer in charge supervise any opening of these valves. Make sure all seals are leakproof.
xiii. Be in agreement with the vessel personnel on the lineup of valves, product lines and headers or riser valves.
xiv. Have a dock supervisor on the pier at all times. He is responsible to see that his men understand their duties and that there are sufficient personnel available to safely transfer the cargo. He is expected to take the initial action in an emergency.
xv. The dock supervisor oversees the transfer of the dock hoses to the ship and their safe connection to the vessel's valves.
xvi. These dock hoses must be checked to see that they are properly connected to the pier header or riser valves and that they are adequately supported.
xvii. Unused oil connections are to be blanked.
xviii. Make allowance for any relative motion between the dock and the vessel.
xix. Check all system pressure indicators. These include pressure recording charts and pressure gauges.
xx. Give the vessel a 5 to 10 minute warning before starting the oil transfer, changing the flow rate or stopping the oil transfer.

b. During the Fueling Operations

i. Maintain a hose watch at the header or riser valve at all times during the transfer. He shall immediately close the header or riser valve when requested or when a problem becomes apparent.
ii. The transfer operations are to begin at a slow rate. Before increasing to a normal flow rate, check all hose connections, valves and the water around the dock area for possible oil spills. The increase in flow rate is done in coordination with the vessel personnel.
iii. Stop the transfer operation if any instructions are not understood or if there is a sudden change in system pressure.
iv. Notify the vessel personnel of any sudden change in oil flow rate and be prepared to stop the transfer operation if requested.
v. Determine that there are no leaks in oil pipelines by following them back to the tank, if possible.
vi. When receiving oil from a vessel, have a man at the tank to make sure that the oil is going into the proper tanks. Gauge these tanks frequently to determine flow rates and compare these rates with the results from gauging the

vessel's tank. If any discrepancy exists, stop the oil transfer operation and resolve the problem before resuming transfer operations.

vii. When topping off a tank, station a man at its top to indicate when the tank is full. Top off one tank at a time.

c. After the Fueling Operation

i. Secure the header or riser valves.
ii. Drain and clean the hoses.
iii. Remove hoses from vessel and cap them.
iv. Make a final check of all tanks that received oil.

d. General Information

i. Both the dock and vessel personnel must be made aware of the penalties imposed by Federal and State regulations on those responsible for willful or negligent oil pollution of Puget Sound's waters.
ii. Both the dock and vessel personnel must have a clear understanding of the procedure for containing and cleaning up an oil spill.

The biggest drawback in the oil handling facility evaluation is that not once was an actual oil transfer operation witnessed. The list of items presented are commendable; but, until these devices and procedures are implemented by authorized and competent personnel, the effectiveness of the overall oil spill prevention system is very low. As an initial recommendation, it is strongly suggested that each and every facility in Puget Sound critically examine their current oil handling procedures and equipment to detect any shortcomings in their systems.

c. <u>Oil Spill Prevention Devices and Techniques that Should be Incorporated by the Facilities</u>

The following is a summary of devices and techniques that should be evident at every Puget Sound faiclity which transfers oil.

1. Prevention Devices

a. On Barges

i. During oil transfer operations, barges should have a lighting system on the far side of the barge powered by the shore facility. These lights are to be directed into the water so that any oil surface film can be visually detected.

ii. Oil containment boom on barge.

- Enough boom to encircle barge.
- In ready deployment position during fueling operations.

iii. Seal or chain-lock sea suction and overboard discharge valves in closed position during fueling operations.

b. Connections

Between the hose and the barge valve install a combination flow and pressure meter. This new device will indicate the total volume through it at any instant and the maximum pressure experienced at this connection since the beginning of the operation.

c. On Dock

i. Install a permanent containment boom around the dock. This is to contain oil spilled from dock.

ii. Have deflection booms readily available with their moorings permanently installed to deflect oil that is spilled outside the dock area (i.e., from a barge or tanker).

iii. Know the tide and current conditions near the dock so that deflection booms can be logically deployed.

iv. Install a lighting system that illuminates the surrounding water area.

v. Chain lock all valves on dock.

vi. Do not leave valves partially open. Instead, put relief valves around them.

vii. Install permanent drip troughs under header and riser valves. Drip troughs should lead into a sump which empties into the waste oil separator system.

viii. Portable vacuum pumps (i.e., truck powered) and hoses with a suction head should be available near fueling area to skim up spilled oil. There should be a pipeline to take this oil to a separator facility.

ix. Have an oil detection device permanently installed under the dock area that can appropriately monitor any oil spilled from the dock.

x. Pave or cement all oil handling areas. These areas should be graded to drain oil into sumps, which can then be pumped to the separator system.

xi. Have an integrated communication system between dock and other areas of the plant.

xii. There should be a retaining wall along the shoreline wherever oil spillage can occur.

xiii. Block valves for the piping system on dock should be installed on the land side of the dock with an appropriate retaining wall and sump system which will take spilled oil to the separator as shown in Figure III-C11.

xiv. Notification to personnel of inoperative equipment on dock.

- Tag equipment
  List reasons why equipment is inoperative; and state when the equipment will be operative again.
- List all defective equipment on spill prevention checkoff list.

2. General Oil Spill Prevention Systems

a. There should be a minimum of two men handling oil transfer operations. One man should be located on the dock area at all times. The other man should inspect the piping connections, tank farm. A specific and comprehensive work schedule should be made for these men by the company that will most appropriately cover the specific problem area of the particular oil handling facility.

b. Have the Coast Guard set up a series of oil spill prevention lectures and oil cleanup methods that are required for all oil handling personnel.

c. An effective inplant communications system should be set up that connects the vital areas of the oil handling facility.

d. The oil handling facilities should have a good fence system and adequate surveillance at all times.

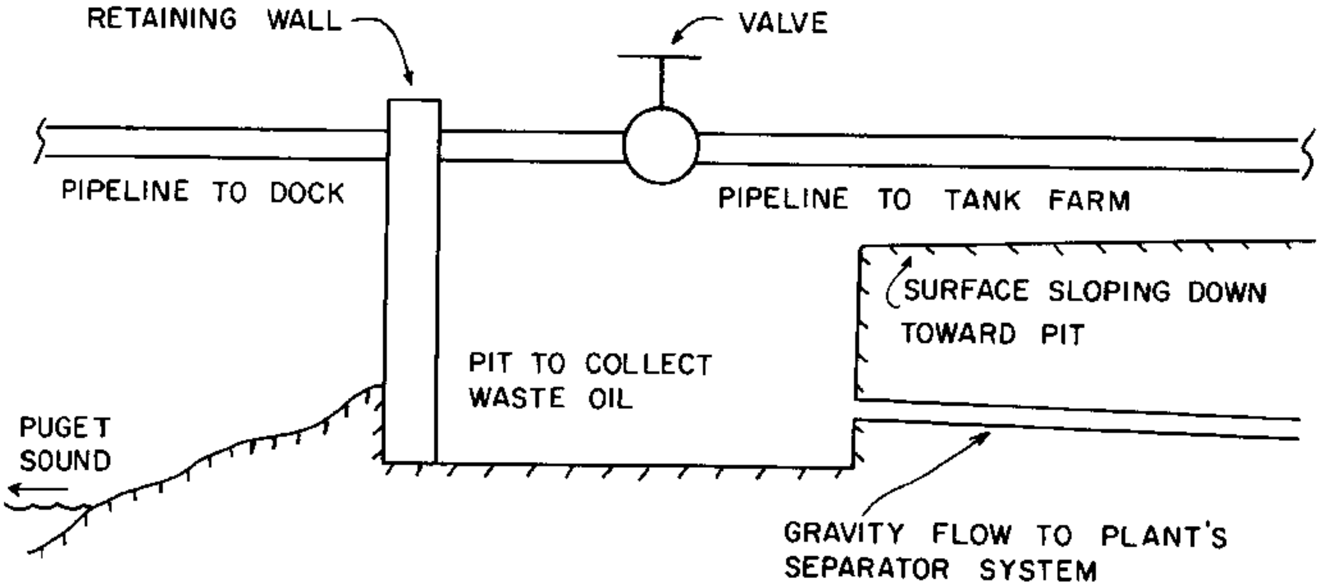


FIGURE III-CII
PROPOSED DOCKSIDE OIL SPILL
PREVENTION SYSTEM

e. The oil handling facilities should develop a comprehensive oil pollution prevention and cleanup system plan that could be incorporated into the oil handling procedures plan. Such a plan has been implemented at Shell Oil Company's Harbor Island facility.

f. The Phillips 66 facility in Seattle should be used as a central receiving depot for all oil skimmed off the water by either vacuum trucks or barges during the course of cleaning up a major oil spill in Puget Sound. This additional task could be performed without interrupting their normal operations. The facility has the largest and most extensive gravity separator system of any oil handling facility visited during the course of this study. They have a rather long dock, 650 feet, with a number of unused pipelines. They also have an oil barrel filling building that they are no longer using which could be turned into a facility to incinerate the unrecoverable waste products. Also, the facility is rather large considering the amount of oil they handle.

d. Proposed Oil Spill Prevention Checkoff Sheet

Many shore installations have their own set of standard operating procedures or general instructions, but few have step-by-step checkoff sheets designed to minimize the possibility of an oil spill. In addition to any such written or verbal operating instructions, an oil spill prevention checkoff sheet should be used when transfering oil to or from a vessel.

The following checkoff list is not meant to be blindly followed or thought of as the minimum steps needed to perform the operation. It is not to supersede one's judgement or technical knowledge; rather, it is to work in harmony with one's ability and experience. The two are to be used together making a unified approach in the oil transfer process. The emphasis should be on the man undertaking the fueling operation; he should always think prevention. This is stressed since most oil spills are due to human error and not equipment breakdown.

The first page of this checkoff sheet is an emergency guide data sheet and should be kept with the dock personnel at all times. In the event of an emergency, this sheet is to be given to the supervisor of the crew fighting the emergency. Any special handling precautions are to be checked and discussed in the "REMARKS" section.

OIL SPILL PREVENTION CHECKOFF SHEET

EMERGENCY GUIDE

Name of vessel: ____________________

Berth: ____________________

Date: ____________________

Terminal receiving cargo ______

or (check one)

Vessel receiving cargo ______

CARGO	FLASH PT.	COLOR	ODOR	QUANTITY
1.				
2.				
3.				
4.				
5.				

SPECIAL PRECAUTIONS

FIRE_____ VAPOR_____ ACIDIC_____ CAUSTIC_____ EXPOSURE_____ WEATHER_____

Remarks: ____________________

IN CASE OF EMERGENCY

FIRE: Call 911 (Say FIRE and give location).

OIL SPILL: Activate your oil spill response plan. Call M.O.P.S.

OIL TRANSFER IS NOT TO BEGIN UNTIL ALL QUESTIONS HAVE BEEN ANSWERED AND ALL STATEMENTS UNDERSTOOD WITH THE APPROPRIATE SIGNATURES.

1. When receiving cargo, have the receiving tanks been inspected to ensure adequate storage of received cargo?

____
Tank Farm Personnel Signature

2. Is there an agreement as to the quantity of cargo to be transferred?

Dock Personnel Signature

3. Has a plan of oil transfer been written and clearly understood? Include in this plan the flow rates, system pressures, and any expected interruptions.

Dock Personnel Signature

4. When fueling a vessel, is there agreement as to where on the vessel the cargo is to be loaded and have these spaces been inspected?

Dock Personnel Signature

5. Set up a ship-to-shore communication system.

6. Regularly inspect the dock area around the ship for possible oil spills.

7. During night transfer operations, have the lights been rigged around the pier to shine on the water and are lights rigged on the far side of the vessel?

Dock Personnel Signature

Vessel Personnel Signature

8. Are the deck scuppers plugged (leakproof) and are drip pans or buckets placed under valves?

Dock Personnel Signature

Vessel Personnel Signature

9. Use cargo hoses that are in good condition and make available their record of inspection.

10. Have all overboard discharge valves and sea suction valves been closed and sealed?

Vessel Personnel Signature

11. Have the dock hoses been checked for proper connection, are they properly supported, and do they have adequate drip pans beneath them?

Dock Personnel Signature

12. It is the dock supervisor's responsibility to see that there are adequate personnel available during the entire cargo transfer operation, that they thoroughly understand their duties, and that they remain on duty.

DURING THE FUELING OPERATION, INSURE THAT THE FOLLOWING PROCEDURES ARE UNDERSTOOD:

1. Give the vessel 5 to 10 minutes of warning before changing the flow rate. Warn the vessel immediately of any sudden change in flow rate.

2. Stand by the pier valve at all times in order to immediately close it in an emergency.

3. Oil transfer operations are to be stopped if any instructions are not understood or if any pressure valves show a dangerous system pressure increase.

Dock Personnel Signature

AT THE COMPLETION OF THE TRANSFER OPERATION:

1. Secure valves; then drain, clear, and cap the hoses.

2. Properly dispose of waste oil collected in the drip pans.

Dock Personnel Signature

OIL SPILL PREVENTION IS YOUR RESPONSIBILITY

1. Do both the dock and vessel personnel know the penalties imposed by Federal and State regulations on those responsible for oil pollution of the waters of Puget Sound?

2. Are both the dock and vessel personnel aware of any oil response plan and the steps taken to contain and cleanup an oil spill?

Dock Personnel Signature

Vessel Personnel Signature

e. Conclusion

As with all projects of this type, time works against you; and this was found to be true here. So, it is appropriate to state here those areas not covered and the work that needs further attention. The obvious first remark is that not enough oil handling facilities were visited. Attempts were made to tour the major shore installations (either refineries or distribution centers) but there was not enough time to visit the small boat fueling docks. While at the facilities, there was no oil transfer in progress. It would have been desirable to visit the facilities while a vessel was actually receiving or discharging oil. Understanding the terminology used in the oil handling business would have made some interviews more productive.

A survey of both the biology and the current and tide conditions of the dock area should be carried out. The biological survey would be used to determine the effect an oil spill would have on the environment near the facility. The current and tide information is necessary to predict the movement of any oil spill. This would involve the installation of current and tide meters at the various dock facilities.

One area not covered was the transfer of oil from a barge to a ship anchored in the Sound or moored at a pier. There is a significant amount of oil bunkered by this technique, especially in the central part of Puget Sound. Section II-C of this report showed that thirteen facilities, having a total capacity of 121,050 barrels bunkered vessels from barges.

ENDNOTES SECTION III-C, Part 1

[1]Defined as having more than 100 parts of oil per million parts of water.

[2]1962 Conference for the Prevention of Oil Pollution at Sen, London April 4-11, 1962.

[3]Resolution of Extraordinary Session, 1968, & 1969 IMCO Assembly, 6th Regular Session.

[4]NATO Committee Challenges of Modern Society -- Colloquim on Pollution of the Seas by Oil Spills, Brussels, November 2, 1970, opening session.

[5]Data for IMCO Conventions, originally drawn up in 1948, but not actuated until 1959.

[6]1968 & 1969 sessions, Annex III.

[7]Oil spill in Buzzard Bay, Off West Falmouth, Massachusetts on September 16, 1969.

[8]Blumer M., Sass, J. & Souza, G. "Hydrocarbon Pollution of Edible Shellfish by an Oil Spill", Marine Biology, Vol. 5, 1970, pp. 195-202.

[9]Systems Study of Oil Spill Cleanup Procedure. Vol I., Analysis of Oil Spills and Control Material, Dilligham Corporation, February 1970, pp. 7-28.

[10]The term "low energy impact" refers to an impact of such energy that only a local puncture or rupture results, whereas a "high energy impact" is one that causes considerably more damage than a break in the container.

[11]For further discussion, see Marine Technology. July 1970.

[12]MARAD Pollution Abatement Plan For Oil, p. 5-14a.

[13]Recent explosions due to tank cleaning operations have occurred to a number of vessels. In December 1969 the supertankers Marpessa, Mactra, and Kong Haakin VII suffered explosions. As recently as the tankers suffered explosions while cleaning tanks. Presently the problem is under intensive investigation.

[14]Presently the Coast Guard has developed an air deliverable anti-pollution transfer system employing rubber bags into which oil can be pumped from damaged tanks. It is anticipated this system will be implemented by December, 1972.

[15]This may not be true in Puget Sound waters because their depth does not constrain the passage of these large vessels.

[16]MARAD Pollution Abatement Plan For Oil.

[17]Testimony by Dr. Max Blumer before the Antitrust and Monopoly Subcommittee, August 4-6, 1970; the Conservation and Natural Resources Subcommittee on Air & Water Pollution, June 30, 1970, in Machias, Maine.

[18]See Table III-A5 of this report.

[19]The Liverpool Underwriters Association statistics show that for the period June 1964 to April 1967 there were 196 collisions involving 238 tankers with 22 cases of oil spillage and 91 groundings with 17 cases of spillage or leakage.

[20]The 1954 International Convention for the Prevention of Pollution of the Sea by Oil prohibits the dumping of oil within 50 miles of any coastline of the world excepting Eastern Canada, Australia, and Europe where the prohibited zone extends further offshore. In 1969, IMCO established more rigid amendments with the prohibition of all oil discharge subject only to certain specified exceptions. These exceptions restrict the rate of discharge of oil not to exceed 60 litres per mile.

[21]MARAD, report, p. 5-5a.

[22]Dillon, E. S., Ship Design Aspects of Oil Pollution Abatement, U.S. Department of Commerce, Maritime Administration.

[23]April 26, 1971 oil spill off Texaco Refinery, Anacortes.

[24]There existed nothing more at the dock than a pressure gauge to measure the flow of oil into the barge. The nearest accurate knowledge of the flow was at the blending plant 3 miles away. The only connection to the plant from the dock was via telephone. Since the loading was taking place at night some time elapsed before oil was discovered on the water and noticing a film on the water.

[25]Dillon, p. 1.

[26]Ibid., p. 19.

[27]Ibid, p. 10.

[28]Ibid., p. 21.

[29]Ibid., p. 24.

[30]Ground Casualty Statistics, IMCO Subcommittee of Ship Design & Equipment, 5th Session.

[31]Dillon, p. 42.

[32]R. I. Price, USCG,"International Activity Regarding Ship Control", March 22, 1971, Annex II.

ENDNOTES SECTION III-C, Part 2

[1]Conversation with Captain F. Smith of the Puget Sound Pilot's Association, May 1, 1971 at the University of Washington. This statement is also documented in Ship Movements and Petroleum Transportation on Puget Sound Area, State of Washington, a white paper by the Seattle Chamber of Commerce, p. 2.

[2]See Section II-B5 for a discussion of collision probabilities for Puget Sound.

[3]This is about the size of the T-2 tankers, such as the Arizona Standard and Oregon Standard, which collided in San Francisco Bay on January 18, 1971.

[4]H. S. Bell, Petroleum Transportation Handbook, McGraw Hill New York.

[5]Dr. J. P. Hooft, "The Steering of a Ship During the Stopping Maneuver," International Shipbuilding Progress, Vol. 17, June 1970, #190, p. 191.

[6]Dr. Masataka Fujino, "Experimental Studies on Ship Maneuverability in Restricted Waters, Part II," International Shipbuilding Progress, Vol. 17, February 1970, #186, p. 45.

[7]Conversation with Rear Admiral Ken Ayers, Chairman of Northwest Marine Safety Council, at the University of Washington on February 11, 1971.

[8]Shipbuilding and Shipping Record, November 1970, Special Supplement, p. 15.

[9]Master, Mate and Pilot, October 1970.

[10]Ibid.

[11]Ibid.

[12]Untitled paper discussing Rotterdam traffic control system.

[13]Hand over - as a ship passes from one radar control area to the next, details of his position and course are transferred to the next areas control station.

[14]T. H. Baetsen, Cdr., USCG, "San Francisco Advisory Radar."

[15]Collision of Arizona Standard and Oregon Standard tankers in San Francisco Bay, January 18, 1971.

[16]National Geographic Magazine, June 1971, Vol. 139, no. 6, p. 868.

[17]U.S. Hydrographic Office Chart #50.

[18]International Rules of the Road.

[19] Shipbuilding and Shipping Record, January 1, 1971, p. 35.

[20] Conversation with Rear Admiral Ken Ayers, Chairman of Marine Safety Council, at University of Washington, on February 11, 1971.

[21] Master, Mate, and Pilot, October 1970.

[22] IMCO Proceedings Maritime Safety Committee, 23rd Session, March 18, 1971.

[23] A Proposed Automated Marine Traffic Advisory System for Puget Sound, Honeywell Marine Systems Center, Doc K03/70, November 6, 1970.

ENDNOTES SECTION III-C, Part 3

[1]. D. K. Phelps and G. Fain, "Instrumenting a Buoy for Estuarine Monitoring," Oceanology International, December, 1970.

[2]Model 1479 On-on-Water Detector, manufactured by Hallikainen, 750 National Court, Richmond, California.

[3]"Oil-on-Water Monitor," an unpublished paper provided by Mr. P. H. Walton, of the Shell Oil Company, March 1, 1971.

[4]L. G. Swaby and A. F. Forgiati, "Remote Sensing in Oil Slicks," API Publication No. 4040, pp. 297-307.

[5]G. A. Helgeson and D. S. Ross, "Remote Sensor Imaging for Oceanography," Oceanology International, September 1970.

[6]"Remote Sensors Map Barrier to Oil Slicks," Oceanology International, April 1970.

[7]Kaye, D.N., "Designing for the Pollution Free Industrial Era," Electronic Designs, May 13, 1971.

[8]N.W. Guinard and C. G. Purres, "The Remote Sensing of Oil Slicks by Radar," U.S. Coast Guard, April 1970, project no. 714104/A/004.

[9]Carns, M., "Multispectral Sensing-New Environmental Tool," The MBA, January 1971.

[10]A. L. Edgerton and D. T. Trexler, "Radiometric Detection of Oil Slicks," January 1970, U.S. Coast Guard, Report No. AGC-SD-1335-1.

[11]J. C. Aukland and D. T. Trexler, "Oil Pollution Detection and Discrimination by Remote Sensing Techniques," U.S. Coast Guard Office of R & D, October 1970, report no. 714104/A/006-1.

[12]A. S. Lewis and H. C. MacDonald, "Interpretive and Mosaicking Problems of SLAR Imagery," Remote Sensing of Environment, December 1970.

[13]The Seattle Coastal Region contingency plan of USCG lists various techniques of remotely sensing available, though no specific details are given. See Annex XII, 2202-2203 of that report.

[14]Two papers presented at the Marine Technology Society's 7th Annual Conference and Exposition, Washington, D.C., August 16-18, 1971, should be of value, though they were not available at publication time. These include:

a) "Oil Spill Reconnaissance Using Remote Sensing Techniques," by Watson, Terry, and Buckmeier of Texas Instruments, Inc.

b) "Passive Remote Sensing System for Estuarine Pollution," by D. T. Hodder of North American Rockwell.