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REPORTS ON NINE STUDIES

Attached hereto is a copy of the final report of Study No. IV - Clean tanks for ballast prior to vessel sailing - submitted by the Government of France.

Due to the limited number of copies available, only one copy per delegation of the report (in English or French) will be distributed during the Conference.

REPORT ON POSSIBILITIES
OF CLEAN BALLASTING BEFORE
SAILING FROM DISCHARGING PORT

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. NETHERLANDS
. OIL COMPANIES INTERNATIONAL MARINE FORUM

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for :
SECRETARIAT GENERAL DE LA MARINE MARCHANDE
DIRECTION DE LA FLOTTE DE COMMERCE ET DE L'EQUIPEMENT NAVAL

REPORT ON POSSIBILITIES OF CLEAN BALLASTING BEFORE SAILING FROM DISCHARGING PORT

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INTRODUCTION

This report has been prepared for submission to the 12th session of the Sub-Committee on Marine Pollution of the O.M.C.I. in the frame of Study IV.

The purpose of Study IV is to determine procedures, and assess their costs, in order to prevent tankers from leaving discharging ports with dirty ballast.

This report, after a comprehensive analysis of the pollution problem resulting from changing of ballast at sea, suggests two procedures for achieving clean ballasting before sailing from discharging port and makes an assessment of the costs related to their application.

The study has been undertaken with the understanding that following concepts and assumptions have been adopted:

1. The traffic and trade to take into consideration is the crude oil traffic which represents between 82 and 89 % of all petroleum traffic. The petroleum products trade has completely different features which do not render the procedure under examination applicable to this type of traffic. The discharging port for crude-oil is in most cases the charging port for petroleum products. Therefore facilities of treatment of ballast for petroleum products tankers are provided by the loading port.

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2. Any correct assessment of costs and economic consequences requires first that an analysis of the crude oil traffic and the composition of the related tanker fleet should be made. This analysis shall forecast the situation for 1975 and 1980. The object of the two initial chapters of the present report is to reach reliable figures indicating the number of ships of each class and the corresponding number of voyages for the crude - oil trade in 1975 and 1980. It is suggested that the methodology of this study and the figures arrived at should be discussed by the Sub-Committee in order to reach an agreement on the datas on which assessments related to the pollution problem should be based.

3. A detailed analysis of the procedures presently employed for changing of ballast and for pre-repair tank-cleaning is then made. This will be the object of chapters 3 and 4. Chapter 5 makes an evaluation of incurred pollution in the basic assumption of full efficiency of other pollution prevention methods (processing of effluents through slop tanks).

4. A description of three suggested procedures follows in chapter 6 :

- procedure A : tank washing and subsequent clean ballasting at discharging berth after discharging
- procedure B : same as procedure A but washing would be undertaken while discharging
- procedure C : minimum ballasting at discharging berth after discharging and subsequent change of ballast at a special berth or tank cleaning station

This description, before a cost calculation, shows that procedure C is prohibitive and subsequent cost estimates are prepared for procedure A and B only.

This report involves an attempt to quantify the problem by trying to depart from the usual qualitative approach. The complexity of the situation makes imperative to operate within a rather wide margin of approximation when setting up average values. The figures which are adopted or established are obviously open to discussion and this is one of the purpose of the present work.

1. THE CRUDE OIL TRADE IN 1975 AND 198[illegible]

1.1. GENERAL

The two initial chapters of this report have the purpose to establish basic datas for the assessment of the incurred pollution and of the actual magnitude of the problem.

Several studies have been already made on this subject. This new approach has been undertaken with a view to reach results which are particularly relevant to the pollution problem, irregardless of the contemplated solution.

The main results which are of interest for any study are the number of ships (divided into appropriate classes) and the related number of voyages. The unit element of pollution by tankers is the voyage and an assessment of their number and distribution is a perequisite for an appropriate analysis.

Chapter 1 deals with the quantities of crude-oil to be transported by sea in 1975 and 1980, and establishes the basis for the composition and distribution of the tanker fleet for crude-oil trade.

Attention is drawn on the classification of tankers which will be used throughout this report.

1.2. CLASSIFICATION OF TANKERS

The following classification of tankers (and OBO) has been adopted throughout this study :

class 30	:	less than 50,000 tdw
class 60	:	50,000 tdw to 80,000 tdw
class 100	:	80,000 to 150,000 tdw
class 210	:	150,000 to 240,000 tdw

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class 260 : 240,000 to 300,000 tdw
class 320 : 300,000 to 350,000 tdw
class 500 : giant tankers, mean capacity 500,000 tdw

The number designating each class corresponds roughly to the mean capacity of the ships belonging to that class. The capacity of the upper class (class 500) which does not yet exist has been arbitrarily taken at 500,000 tdw. The number of ships belonging to this class which will be estimated in this study will be based on that mean capacity of 500,000 tdw and could be easily calculated in proportion to any other mean capacity which could be considered more appropriate.

1.3. POINTS OF ORIGIN AND DESTINATION

The analysis of the traffic will be made with the consideration of the following points of origin and destination :

- 6 points of origin : Persian Gulf
  Eastern Mediterranean
  North Africa
  Caribbean
  West Africa
  Others
- 5 points of destination : Northern Europe
  Mediterranean Europe
  USA
  Japan
  Others (including Eastern Europe)

The points of origin are the object of the following remarks:

Persian Gulf : Exports of all countries bordering the Persian Gulf excepting quantities carried by pipe-lines ending on the Eastern Mediterranean coast.

Eastern Medit.	:	Quantities brought by pipe-lines (from Iraq and Saudi Arabia) plus Syrian and Egyptian productions.
North Africa	:	Algeria and Lybia
Caribbean	:	Crude exports from Venezuela mainly, oil products are not included.
West Africa	:	mainly Nigeria and Gabon
Others	:	include USSR, Indonesia and miscellaneous producers.

The following remarks can be made about points of destination :

Northern Europe	:	includes all ports on the European Atlantic façade
Mediterranean	:	includes all mediterranean ports including quantities to be carried by pipe-lines originating on the mediterranean coast (Marseilles, Genua Trieste)
USA	:	do not include traffic from Alaska, which is considered as internal traffic.

1.4. PROJECTION OF TRAFFIC FOR 1975 AND 1980

The assessment of the quantities of crude oil to be transported by sea cannot be made easily just by extrapolation of past figures.
An extrapolation is only valid when forecasting oil consumption. When shipping is considered several corrective factors shall be taken into consideration:

a) The policy which will be adopted by the USA for its power needs shall have a determining influence. The influx of crude oil from the Eastern Hemisphere to the USA can be by anywhere between 100 and 300 million tons in 1980. This could alter considerably the needs of tankers.

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b) Eastern Europe will enter the market with ever increasing amounts. The own resources of the Eastern Block are not likely to cover all the foreseen consumption which is likely to grow fast.

c) Efforts will be undertaken to diversify the sources of supply. Important developments outside the traditional arab and persian gulf countries are to be expected. The situation in West Africa, Alaska and the North Sea could alter the picture of the tonnage needs.

d) Consumption and refining outside Western Europe, Japan and USA is likely to expand and this will lead to a diversification of traffic routes.

e) Last but not least, the opening of the Suez canal would have an influence that should not be underestimated, but this influence will apply on the fleet and not on the quantities to be transported. This aspect shall be discussed in para.1.6.

Taking all above mentioned remarks into account, and trying to stay within reasonable limits, the French Delegation is suggesting the following matrices :

SCHEDULE 1

MILLION METRIC TONS OF CRUDE OIL TO BE TRANSPORTED BY SEA IN 1975

	Pers	E.M.	N.A.	Car.	W.A.	Others	Total
N.E.	310 (1)	30	100	25	70	5 (2)	540
Med.	140 (1)	50	130	5	20	15	360
USA	80		10	30 (3)	20		140 (4)
Japan	290					60	350
Others	180	20 (5)	10	30	10	10	260
Total	1000	100 (6)	250	90	120	9	1650

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SCHEDULE 2

MILLION METRIC TONS OF CRUDE OIL TO BE TRANSPORTED BY SEA IN 1980

	Pers	E.M.	N.A.	Car.	W.A.	Others	Total
N.E.	390 (1)	40	90	10	160	10 (2)	700
Med.	210 (1)	90	140	-	50	10	500
USA	170	-	10	60(3)	10	-	250 (4)
Japan	450	-	-	-	-	100	550
Others	270	50 (5)	10	30	10	30	400
Total	1490	180 (6)	250	100	230	150	2400

Pers = Persian Gulf EM = Eastern Mediterranean
N.A. = North Africa Car. = Caribbean W.A. = West Africa
N.E. = Northern Europe Med. = Mediterranean Europe

Notes (1) Part of these quantities could be shipped via Suez if the canal is opened and/or via Suez pipe-lines (see para.1.6. schedule 3)

(2) Does not include North Sea production

(3) Does not include petroleum products

(4) Does not include any traffic Alaska-USA considered as internal traffic

(5) Mainly to Eastern Europe

(6) Does not include quantities in transit through Suez pipe-lines.

1.5. CLASSIFICATION OF ROUTES

The routes to be considered are in most cases those between points of origin and points of destination. The problem is however complicated by the existence of several possible routes between considered points. This particularly applies to the traffic between the Persian Gulf on one side and Europe and USA on the other side.

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For simplification a "typical port" has been choosen for each zone of origin and destination. For example Rotterdam for Northern Europe, Genua for Mediterranean, Mena al Ahmadi for the Persian Gulf, Sidon for Eastern Mediterranean, Newport News for the USA, Yokohama for Japan, Ibadan for West Africa, Gabes for North Africa, Maracaibo for Caribbean. For other routes the port changes, depending on the route, for example other-other could be Batum/Habana, Persian Gulf-other could be Mena al Ahmadi-Perth, etc...

For the routes originated from the Persian Gulf it is necessary to distinguish :

- A route via Cape both ways. This will be noted CC for example Persian Gulf-Northern Europe will be noted Pers-N.E/CC
- A route via Cape loaded and via Suez on ballast. This will be noted CS (for example Pers-Med/CS)
- A route via Suez both ways, noted SS (for example Pers-USA/SS)
- A route via the pipe-lines which run parallel to the Suez canal on the Egyptian or Israeli side. This will be noted PS. However as the sea transportation needs are concerned, this route is in fact divided in two stretches : one Persian Gulf-Suez and one which is equivalent to the routes originating in the Eastern Mediterranean.

Theoretically, it is noted also that the routes between Persian Gulf and Japan could be different according to the size of the tankers. The difference is however small and the approximation with which this analysis is made does not warrant to take it into account.

With all alternate routes above mentioned, a total of 31 routes have to be taken into account. A classification of these routes into categories according to the length of the voyage has been adopted for the simplification of the analysis. This classification appears on schedules 6 and 7.

1.6. INFLUENCE OF THE OPENING OF THE SUEZ CANAL

The following basic assumptions have been adopted, would the canal be opened in 1975 and 1980 :

- For 1975	Northbound (loaded) maximum size	class 100
	Southbound (ballasted) maximum size	class 210
- For 1980	Northbound (loaded) maximum size	class 210
	Southbound (ballasted) maximum size	class 260

These assumptions are based on the development programmes likely to be undertaken as soon as the canal will be opened.

The evaluation of the distribution of the quantities of crude oil which will transit through the canal is a very difficult if not inextricable matter. This distribution is influenced by the composition of the fleet but the reverse is also true, the composition of the fleet will influence the choice of routes. Any maximization calculation would be senseless in the intricate situation of tomorrow's shipping and charter rates situation and still unknown Suez canal rates.

Another factor, apart from size limitation, would be also the capacity of the waterway which would restrict the traffic irregardless of the size of the ships.

We are therefore suggesting the following figures, which are the result of tentative assessment integrating all factors, but which should be considered only as a possible solution among many others.

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SCHEDULE 3

BREAKDOWN OF TRAFFIC ORIGINATED IN THE PERSIAN GULF

Million m.t. crude oil

	Pers-N.E.	Pers-Med.	Pers-USA
Suez closed :			
route Cape Cape (CC)	300	80	80
route via pipes (PS)	10	60	-
Suez opened :			
route Cape Cape (CC)	190	25	10
route Cape Suez (CS)	100	40	30
route Suez Suez (SS)	10	15	40
route via pipes (PS)	10	60	-
1975 TOTAL	310	140	80
Suez closed :			
route Cape Cape (CC)	380	150	170
route via pipes (PS)	.10	60	-
Suez opened :			
route Cape Cape (CC)	210	30	50
route Cape Suez (CS)	130	60	60
route Suez Suez (SS)	40	60	60
route via pipes (PS)	10	60	-
1980 TOTAL	390	210	170

2. THE DISTRIBUTION OF THE FLEET IN 1975 AND 1980

2.1. GENERAL

In this chapter two approaches will be used :

- first the traffic needs, corresponding to the figures adopted in chapter 1, will be assessed
- second the capacity of shipyards and the present situation of orders will be considered.

For 1975, the second approach will prevail since deliveries until 1975 are already known and the composition of fleet can be accurately forecasted on this basis. The analysis of the needs will be however important to reach an evaluation of the distribution of tankers on the different route categories.

For 1980 both approaches shall be jointly undertaken and different alternatives shall be considered (giant tankers, opening of Suez canal etc...) with, in each case, an influence which does not yield to a simple analysis.

2.2. CONCEPT OF UNIT DEADWEIGHT

We suggest to call unit deadweight (Udwt) the deadweight tonnage needed to transport 1 million metric ton of crude oil on a given route.

The assessment of the tanker tonnage needs will then easily be calculated by multiplying Utdw values by the quantities of crude oil to be shipped and already evaluated in chapter 1.

The calculation of Udwt values will be based on the following assumptions :

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- distance is taken between points indicated in para.1.5. with 5 % margin for detours
- average speed 15 knots
- ship on duty 348 days per year (deducting off-hire time of 17 days per year)
- combined duration of stay in loading and unloading port : 3 1/2 days

The calculation leads to the following values :

SCHEDULE 4

UNIT DEADWEIGHT VALUES

,000 tdw needed to transport 1 million t of crude oil between indicated points.

	Pers.	E.M.	N.A.	Car.	W.A.	Others
North.Eur.		63	46	83	80	73
via Cape/Cape	197					
Cape/Suez	155					
Suez/Suez	115					
Medit.Eur.		35	23	89	43	42
via Cape/Cape	192					
Cape/Suez	140					
Suez/Suez	86					
USA			83	37	92	
via Cape/Cape	203					
Cape/Suez	179					
Suez/Suez	153					
Japan	120					63
Others	100	75	58	72	66	100

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2.3. PROJECTION OF TONNAGE NEEDS 1975 AND 1980

The multiplication of Utdw values and quantities of crude oil to be shipped (Q) is shown on schedule 6 and 7 in the following pages. In these schedules, the Utdw values are those of schedule 4 and the quantities of crude oil Q are those of schedules 1, 2 and 3.

The quantities from the Persian Gulf towards Europe carried through the Suez pipe-lines are shown twice (on a Persian Gulf-Suez route and on routes from Eastern Med.).

The schedules 6 and 7 show a classification of routes according to their length which is self explanatory.
These results can be summarized as follows (figures being rounded) :

SCHEDULE 5

SUMMARY OF TONNAGE NEEDS (million tdw) IN 1975 AND 1980

	Suez canal closed		Suez canal opened	
	1975	1980	1975	1980
Long routes CC	90.7	138.2	44.3	57.3
Long routes CS			26.5	39.3
Long routes SS			8.6	19.0
Long routes misc.	53.9	84.3	53.9	84.3
Medium routes A	13.9	16.4	13.9	16.4
Medium routes B	11.9	15.0	11.9	15.0
Short routes A	7.2	8.7	7.2	8.7
Short routes B	6.9	8.5	6.9	8.5
	184.5	271.1	173.2	248.5

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SCHEDULE 6

PROJECTION OF TONNAGE NEEDS 1975-1980

SUEZ CANAL CLOSED

Routes	Unit tdw (1)	Q 1975 (2)	Need ,000 tdw (3)	Q 1980 (2)	Need tdw (3)
Pers-USA	203	80	16,240	170	34,510
Pers-NE	197	300	59,100	380	74,860
Pers-Med	192	80	15,360	150	28,800
TOTAL LONG CC		460	90,700	700	138,170
Pers-Jap.	120	290	34,800	450	54,000
Oth-Oth	110	10	1,100	30	3,300
Pers-Oth	100	180	18,000	270	27,000
TOTAL LONG M		480	53,900	750	84,300
WA-USA	92	10	920	10	920
Car-Med	89	5	445	-	-
Car-NE	83	25	2,075	10	830
NA-USA	83	10	830	10	830
WA-NE	80	70	5,600	90	7,200
EM-Oth	75	20	1,500	50	3,750
Oth-NE	73	5	365	10	730
Car-Oth	72	30	2,160	30	2,160
TOTAL MEDIUM A		175	13,890	210	16,420
Wa-Oth	66	10	660	10	660
Oth-Jap	63	60	3,780	100	6,300
EM-NE	63	40 (4)	2,480	50 (4)	3,150
Pers-Suez	62	70	4,340	70	4,340
NA-Oth	58	10	580	10	580
TOTAL MEDIUM B		190	11,840	240	15,030
NA-NE	46	100	4,600	90	3,940
WA-Med	43	20	860	50	2,150
Oth-Med	42	15	630	10	420
Car-USA	37	30	1,110	60	2,220
TOTAL SHORT A		165	7,200	210	8,730
EM-Med	35	110 (5)	3,850	150 (5)	5,250
NA-Med	23	130	2,990	140	3,220
TOTAL SHORT B		240	6,840	290	8,470

Notes (1) ,000 tdw needed to transport 1 Mt of crude oil (from sched. 4)
(2) Million m.t. of crude oil to be shipped (from schedules 1, 2 & 3)
(3) multiplication of (1) by (2)
(4) includes 10 Mt from Pers. via Suez pipes
(5) includes 60 Mt from Pers. via Suez pipes

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SCHEDULE 7

PROJECTION OF TONNAGE NEEDS 1975 - 1980

SUEZ CANAL OPENED

Route		Unit tdw (1)	Q 1975 (2)	1975 Needs ,000 tdw (3)	Q 1980	1980 Needs ,000 tdw
Pers. USA CC		203	10	2,030	50	10,150
Pers. NE CC		197	190	37,430	210	41,370
Pers. Med. CC		192	25	4,800	30	5,760
TOTAL LONG CC			225	44,260	290	57,280
Pers.USA CS		179	30	5,370	60	10,740
Pers.NE CS		155	100	15,500	130	20,150
Pers.Med. CS		140	40	5,600	60	8,400
TOTAL LONG CS			170	26,470	250	39,290
Pers.USA SS		153	40	6,120	60	9,180
Pers.NE SS		115	10	1,150	40	4,600
Pers.Med. SS		86	15	1,290	60	5,160
TOTAL LONG SS			65	8,560	160	18,940
TOTAL LONG	M	(4)	480	53,900	750	84,300
TOTAL MEDIUM	A	(4)	175	13,890	210	16,420
TOTAL MEDIUM	B	(4)	190	11,830	240	15,030
TOTAL SHORT	A	(4)	165	7,200	210	8,730
TOTAL SHORT	B	(4)	240	6,840	290	8,470

Notes :

(1) Unit tdw : ,000 tdw needed to transport 1 Mt of crude oil (from schedule 4)

(2) Million m.t. of crude oil (from schedules 1, 2 and 3)

(3) Multiplication of (1) by (2)

(4) see schedule 6

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It should be noted that the influence of the opening of the Suez canal would not be very important in 1975. The situation may be different in 1980. But those results have been obtained by assuming that the Suez canal would be able in 1980 to accept loaded ships of the 210 class and ballasted ships of the 260 class. The influence of these possibilities are therefore felt to an appreciable extent. Different assumptions would lead to different tonnage needs, but the figures would likely be comprised between 250 and 270 million tdw in 1980. We shall adopt these figures of 250 and 270 as representating the needs in 1980, depending of the opening of the Suez canal.
On account of these results, we suggest to disregard for 1975 the case of opening of the Suez canal. However in 1980 the analysis will still be made in both cases.

2.4. COMPOSITION OF THE FLEET IN 1975

The fleet of 1975 can be considered as already known from the existing situation of ships in service and in order.

The fleet which has to be taken in account in our analysis is that part of the tanker (and OBO) fleet which is used for the transportation of crude oil.

A basic assumption will be made now that ships belonging to the class 30 shall be disregarded. This means that it is assumed that crude oil traffic by ships of less than 50,000 tdw will be negligible in 1975.

The 1975 fleet of tankers and OBO above 50,000 tdw will be as follows :

SCHEDULE 8

TANKERS AND OBO ABOVE 50,000 tdw IN 1975

	Tankers		OBO	
	Nb	Mtdw	Nb	Mtdw
Class 60	488	30	93	7
Class 100	324	35	141	17
Class 210	271	59	73	12
Class 260	174	46	14	4
Class 320	14	4		
	1271	174	321	40

2.5. COMPARISON BETWEEN NEEDS AND AVAILABLE TONNAGE IN 1975

We have assessed in para.2.3. the needs of tonnage to 184 million tdw in 1975. The available tonnage of tankers and OBO above 50,000 tdw will be 214 million tdw.
The needs could be fulfiled by :

- 100 % of tankers of classes 320, 260, 210 and 100
- 60 to 80 % of tankers of class 60
- 60 to 70 % of OBO carriers

This shows that the assumption made previously, that a negligible number of ships below 50,000 tdw will be used in crude oil traffic, is valid.

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2.6. DISTRIBUTION OF THE FLEET IN 1975

A tentative analysis of the distribution of the fleet involves the application of ships to the different routes.

On account of the anarchic situation in this field which is not likely to be improved in 1975, this application will be the result of the influence of economic factors rather than of a combined decision making. Therefore considerable variations could be expected from a situation in which the optimum use of the whole fleet would be achieved.

The main guide-line will be however that larger ships will be used on longer routes.

Using the route categories shown in para.2.3., the following distribution can be established :

SCHEDULE 9

DISTRIBUTION OF THE 1975 FLEET (TANKERS AND OBO) CRUDE OIL TRAFFIC

	Number of ships of classes				
	60	100	210	260	320
Long routes CC	30	178	190	110	8
Long routes M	60	50	120	70	6
Medium routes A	80	68	6	4	
Medium routes B	115	40	5		
Short routes A	55	39			
Short routes B	35	48			
	375	423	321	184	14

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2.7. NUMBER OF VOYAGES - 1975

For the purpose of this study, the number of voyages is of importance, because the pollution depends chiefly of this concept. The determination of the number of voyage is in fact the basic result to be reached in all the above analysis.

Using for each category of routes a mean number of voyages per year and per ship, as indicated in schedule 10, the number of voyages per class of tankers is simply calculated from the number of ships used as shown in schedule 9.

SCHEDULE 10

NUMBER OF VOYAGES IN 1975 CRUDE OIL TRAFFIC

	Nb.voy.	Nb.of voyages per class of ships				
	p.a.&p.s.	60	100	210	260	320
long routes CC	5.1	153	908	969	561	41
long routes M	8.9	534	445	1068	623	54
medium routes A	13.0	1040	884	78	52	
medium routes B	16.0	1840	640	80		
short routes A	23.0	1265	897			
short routes B	35.0	1225	1720			
		6057	5494	2195	1236	95

On account on the approximative character of the whole analysis, it is suggested to adopt the following rounded figures :

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SCHEDULE 11

SUMMARY OF NUMBER OF SHIPS AND VOYAGES FOR 1975 CRUDE OIL TRAFFIC

		Nb.of ships	Nb.of voyages	voy/year
Ships of class	60	373	6,000	16.1
	100	423	5,500	13.0
	210	321	2,200	6.8
	260	184	1,200	6.5
	320	14	100	7

These results will be used in this study when assessing the magnitude of the pollution problem. They could also be useful for any evaluation in this field irregardless of the pollution control procedure under consideration.

It is therefore suggested that a critical examination of these results be undertaken in order to reach a consensus among members of the study group.

The amount of cargo carried by ships of each class is determined easily :

class 60	6,000 x 60 =	360 Mt
class 100	5,500 x 100 =	550
class 210	2,200 x 210 =	462
class 260	1,200 x 260 =	312
class 320	100 x 320 =	32
		1716 Mt

This is in good concordance with the total amount of crude oil shipped by sea, shown in schedule 1, (i.e. 1650 Mt), taking into account that 70 Mt transiting via Suez pipe lines have to be carried in two sea voyages.

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For the inter-mediterranean traffic corresponding to short routes B (traffic between Eastern Mediterranean and North Africa on one side and Mediterranean Europe on the other side), the number of ships and voyages for which pollution is bound to be located in the Mediterranean sea is :

	Nb. of ships	Nb. of voyages
Class 60	35	1,225
100	48	1,720

2.8. COMPOSITION OF THE FLEET IN 1980

The tonnage needs for crude oil traffic, as established in para.2.3. are :

270 M tdw	(Suez closed)
250 M tdw	(Suez opened)

The assessment of the number of ships in service in 1980 will take into account the following basic assumptions :

(i) ships of class 60 will be eliminated from the crude oil traffic in 1980, just as ships of class 30 are out in 1975

(ii) 60 % to 70 % of the OBO fleet will be used for crude oil traffic

The fleet of 1975, excluding ships of class 60 will represent :

tankers	144 M tdw
OBO	30 M tdw

We shall then start from an existing capacity of 160 M tdw in 1975.

The additional needs between 1975 and 1980 shall then be :

110 M tdw	(Suez closed)
90 M tdw	(Suez opened)

These figures shall serve as a basis for the assessment of the composition of the 1980 fleet.
These additional tonnages shall theoretically be found in ships of the larger classes. We shall however somewhat refine our analysis, by taking into account the following remarks :

a) progresses in classes 100 and 210 shall essentially be in the OBO category, for which the needs of ore transportation allow to conceive smaller ships. The launching of 15 ships in class 100 and 20 ships in class 210 can be contemplated every year. Thus for the 5 year period between 1975 and 1980, the fleet will include :

- 75 new OBO, class 100, i.e. 8 M tdw, of which 5 M tdw would be taken into account for crude oil traffic

- 100 new OBO, class 210, i.e. 21 M tdw, of which 15 M tdw for crude oil traffic

Thus new OBO ships in classes 100 and 210 would satisfy 20 M tdw of additional needs.

b) 70 to 90 M tdw have still be built which would represent between 260 and 330 ships of 280,000 tdw or 50 to 70 ships per year. The shipyards of the world will supply between 1971 and 1975 about 90 ships per year in the classes 210 and 260. The additional needs between 1975 and 1980 would therefore be easily satisfied by the existing ship building capacity.
The need of ships of 500,000 tdw or more would not be a consequence of the situation of shipbuilding capacity.

It shall be contemplated only for transportation cost reasons.

We suggest then to consider two cases :

- limitation of the size of tankers to 350,000 tdw (apart from negligible exceptions). This case will be called "case 320"
- construction in appreciable number of giant ships : "case 500".

2.8.1. Case 320 (1980)

Taking into account the remarks previously expressed for the OBO ships, the picture of the 1980 fleet could be as follows :

SCHEDULE 12

COMPOSITION OF THE 1980 FLEET, CASE 320

	Tankers		OBO	
	Nb.	Mtdw	Nb	Mtdw
class 100	330	33	200	20
210	300	63	170	37
260	300	78	50	13
320	160 (1)	51 (1)		
	100 (2)	52 (2)		
	1090 (1)	225 (1)	420	70
	1030 (2)	206 (2)		

(1) Suez closed

(2) Suez opened

Considering that 60 % to 70 % of the OBO shall be used for crude oil traffic, this fleet composition is adequate for the fulfilment of the needs (270 to 250 Mtdw)

The number of new ships to be built between 1975 and 1980 would be as follows :

.../...

SCHEDULE 13

NEW SHIPS TO BE BUILT BETWEEN 1975 AND 1980 (Case 320)

	Tankers	OBO	Total	Mean. per year
class 100	16	72	88	18
class 210	29	97	126	25
class 260	112	36	148	29
class 320	160 (1)		160 (1)	32 (1)
	100 (2)		100 (2)	20 (2)
	317 (1)	205 (1)	522 (1)	104 (1)
	257 (1)	205 (2)	462 (2)	92 (2)

(1) Suez closed

(2) Suez opened

This programme is well within the existing shipbuilding capacity.

2.8.2. Case 500 (1980)

The introduction of giant ships will probably not occur in an isolated manner. As soon as navigational, insurance and terminal harbour problems would receive satisfactory solutions for this class of ships, these vessels will appear in number.

Another size for these giant ships can be contemplated instead of 500,000 tdw. The number of ships could be deducted by a simple proportion.

The fleet of 1980 could have the following composition :

.../...

SCHEDULE 14

COMPOSITION OF THE 1980 FLEET, CASE 500

	Tankers		OBO	
	Nb.	Mtdw	Nb.	Mtdw
Class 100	330	33	200	20
210	290	61	170	37
260	250 (1)	65 (1)	50	13
	270 (2)	71 (2)		
320	50 (1)	16 (1)		
	30 (2)	10 (2)		
500	100 (1)	50 (1)		
	60 (2)	30 (2)		
	1020 (1)	225 (1)	420	70
	980 (2)	205 (2)		

(1) Suez closed

(2) Suez opened

This fleet composition would be adequate for the fulfilment of the needs.

It should be noted that in case the Suez canal is opened, the number of ships of the class 260 could be appreciably more numerous since those ships would be more versatile and could use the canal on ballast.

New ships to be built between 1975 and 1980 would amount to a smaller total than in case 320.

.../...

SCHEDULE 15

NEW SHIPS TO BE BUILT BETWEEN 1975 AND 1980 (CASE 500)

	Tankers	OBO	Total	Nb.p.a.
Class 100	16	72	88	18
210	19	97	116	23
260	62 (1)	36	98 (1)	20 (1)
	82 (2)		118 (2)	24 (2)
320	50 (1)		50 (1)	10 (1)
	30 (2)		30 (2)	6 (2)
500	100 (1)		100 (1)	20 (1)
	60 (2)		60 (2)	12 (2)
	247 (1)	205 (1)	452 (1)	91 (1)
	207 (2)	205 (2)	412 (2)	83 (2)

(1) Suez closed
(2) Suez opened

2.9. DISTRIBUTION OF THE 1980 FLEET

An analysis undertaken in a similar manner than for 1975 would lead to a distribution scheme indicated in schedule 16 hereafter. This calls for the same observations and remarks expressed in para.2.6.

Case 500 has been considered only, as this case seems more likely to occur.

SCHEDULE 16

DISTRIBUTION OF THE 1980 FLEET (TANKERS AND OBO) CRUDE OIL TRAFFIC

	Number of ships of classes				
Suez closed	100	210	260	320	500
Long routes CC	82	220	170	30	60
Long routes M	93	120	90	20	40
Medium routes A	62	30	15		
Medium routes B	61	30	10		
Short routes A	67	10			
Short routes B	85				
	450	410	285	50	100
Suez opened					
Long routes CC		60	120	10	20
Long routes CS		100	70		
Long routes SS	62	60			
Long routes M	93	120	90	20	40
Medium routes A	62	30	15		
Medium routes B	61	30	10		
Short routes A	67	10			
Short routes B	85				
	430	410	305	30	60

2.10. NUMBER OF VOYAGES 1980

Using the same procedure as in para.2.7. the following schedules have been prepared :

.../...

SCHEDULE 17

NUMBER OF VOYAGES 1980 CRUDE OIL TRAFFIC

	Nb.voy. p.a.& p.s.	Nb. voy. per class of ships 100	210	260	320	500
Suez closed						
Long routes CC	5.1	418	1122	867	153	306
Long routes M	8.9	828	1068	801	178	356
Medium routes A	13.0	806	390	195		
Medium routes B	16.0	976	480	160		
Short routes A	23.0	1541	230			
Short routes B	35.0	3170				
		7739	3290	2023	331	662
Suez opened						
Long routes CC	5.1		306	612	51	102
Long routes CS	6.4		604	448		
Long routes SS	8.0	496	480			
Long routes M	8.9	828	1068	801	178	356
Medium routes A	13.0	806	390	195		
Medium routes B	16.0	976	480	160		
Short routes A	23.0	1541	230			
Short routes B	35.0	3170				
		7817	3558	2216	229	458

All above results are summarized in schedule 18.

SCHEDULE 18

SUMMARY OF NUMBER OF SHIPS AND VOYAGES FOR 1980 CRUDE OIL TRAFFIC

	Suez closed Nb.ships	Suez closed Nb.voy.	Suez opened Nb.ships	Suez opened Nb.voy.
Ships of class 100	450	7739	430	7817
210	410	3290	410	3558
260	285	2023	305	2216
320	50	331	30	229
500	100	662	60	458

3. BALLASTING REQUIREMENTS

3.1. VOLUME OF BALLAST

From informations supplied by shipowners and shipyards, the following figures have been adopted as average values :

SCHEDULE 18

VOLUME OF BALLAST

,000 cu.m.

	Clean perman. ballast (1)	Dirty ballast good w.	Dirty ballast bad w.	Total ballast good w.	Total ballast bad w.
Class 60 (50-80.000 tdw)	10	15	25	25	35
Class 100 (80-150.000 tdw)	15	25	40	40	55
Class 210 (150-240.000 tdw)	30	45	80	75	110
Class 260 (240-300.000 tdw)	35	50	95	85	130
Class 320 (300-350.000 tdw)	40	70	120	110	160

(1) including forepeak and ballast compartments other than tanks used for perm.ballast.
Some ships carry practically no clean permanent ballast, all main tanks being designed to receive cargo.

Bad weather involves about 40 % more total ballast than good weather, but all additional ballast being dirty ballast, the increase of dirty ballast when switching from good to bad weather conditions is about 70 %.

.../...

The frequency of bad weather occurence is an important factor. In the scope of this study, the ship has to leave discharging port under conditions that would match the weather likely to be met en route.

For long voyages, such as Persian Gulf - Europe via Cape, rough seas are likely to be encountered in any season, either in Europe or around the Cape.

Therefore we suggest to adopt the following percentages when trying to reach average values :

- ships of class 210 and above : bad weather occurences 80 % of all cases
- ships of class 60 and 100 : bad weather occurences 60 % of all cases

3.2. CHANGING OF BALLAST

On any routine voyage, the ship has to reach the loading port with clean ballast. This involves an operation of changing of ballast en route. This operation is normally made in two main steps :

- washing dirty tanks intended for clean ballast
- deballast tanks loaded with dirty ballast and simultaneously ballast washed tanks.

In order to assess the duration and other relevant parameters of this operation, an examination of washing procedures shall be first undertaken. A second important factor is also safety conditions and explosion hazards.
The next two paragraphs shall therefore deal with the above mentioned subjects.

3.3. WASHING PROCEDURES

A distinction has to be made between routine washing and pre-repair washing. This last procedure is so important that a special chapter will be devoted to it (chapter 4).

Routine washing is carried out mainly in order to clean tanks which are intended for ballast. An additional washing of certain other tanks may be also routinely undertaken, but ships are practically never thoroughly washed on routine voyages.

The main requirement is to enable rejection at sea of clean ballast at the loading port. This involves removal of residual oil and also of sediments from tanks to be used for clean ballast. Washing procedures are usually sufficient to wash out most of the sediments in center tanks. (This is not true in wing tanks). Additional bottom washing is often required and attention is given to prevent accumulation of sediments.

For this reason ships equipped with free flow system usually wash on each ballast voyage the aft center tank in which sludges and sediments are accumulated. On standard ships, empty tanks may be washed in turn so that the all tanks would be washed after 3 to 6 routine voyages. In addition, time is sometimes too short to undertake any washing other than the tanks intended for ballast.

Routine washing, which is under consideration in this chapter, is normally undertaken with cold water. Hot water is a standard procedure in pre-repair washing only. Experience shows that cold water is usually sufficient to meet the routine washing requirements. In addition cold water reduces corrosion and increases the safety conditions as compared with hot washing, with the notable exception of tankers equipped with inert gas. The advantage of inert gas in washing procedures and speed of operations is such that this subject should be dealt within a special sub-paragraph (see 3.4.1.). This problem will be examined in conjonction with safety requirements which play an important part in washing procedures.

3.3.1. Main parameters governing washing procedures

These main parameters are indicated in schedule 19 together with the average values suggested for different classes. These figures are the result of the examination of the characteristics of a number of ships in which many variations have been observed. The indicated values should be therefore construed as approximatives.

SCHEDULE 19

MAIN PARAMETERS GOVERNING COLD WASHING

	Ship class				
	60	100	210	260	320
Unit discharge of washing machines c.m.p.h. m = mobile machines g = fixed guns	30 (m)	30 (m)	50 (m) 150 (g)	160 (g)	180 (g)
Number of washing machines in simultaneous action	6 (m)	8 (m)	10 (m) 4 (g)	4 (g)	4 (g)
Total maximum discharge of washing water c.m.p.h.	180	240	600	640	720
Total maximum stripping discharge c.m.p.h.	300	500	850	900	1000
Volume of slop tanks c.m.	1,500	3,000	6,000	12,000	15,000

These datas should be read in conjunction with the following remarks :

(i) Some big ships are not equipped with guns and some ships of class 100 have guns. In many cases on big ships, centre tanks are equipped with guns and wing tanks which are more difficult to wash are intended for mobile machine washing.

(ii) Unit discharge of washing machines may vary to some extent. Guns may have a discharge of less than 150 c.m.p.h.

(iii) The absolute bottleneck in washing is the total stripping discharge. Production of washing water should not exceed this value. The pumps feeding the washing system have usually a combined discharge which is inferior to the total stripping discharge.

.../...

When washing with hot water, the bottleneck is usually the heating discharge. (this depends further on open or closed circuit procedure). Stripping discharge means net discharge of stripping system not taking into account the volume of circulating water in case of ejectors.

(iv) Ships are not always equipped with slop tanks. Standard cargo tanks are sometimes used in small ships as settling tanks, the residual oil being subsequently mixed with the new cargo (load on top). The figure indicated in the schedule is the combined volume of two slop tanks, when the ship is equipped with those especially designed tanks. However this volume shows a wide margin of variation in ships of the same class.

3.3.2. Time analysis. Description of typical cycles

After completion of discharging at the unloading terminal, the ship still berthed alongside, takes dirty ballast. This operation has an average duration which is comprised between 2 and 6 hours.

The following operations are then undertaken at sea

a) Preparation of washing

- flushing and/or rinsing of lines, flushing of strippings
- washing slop tanks and filling slop tanks with clean water

the duration of this operation is assessed in average terms at :

class 60	:	3 hours
class 100	:	5 hours
class 210 & 260	:	8 hours

b) Washing of tanks intended for clean ballast

Standard procedure consists of pumping water from the sea into the washing system. Dirty water from washing is sent to the port slop tank.

.../...

Interconnection between port and starboard slop tank displaces into the sea an equivalent volume of "clean" water from the starboard slop tank.

A close circuit procedure is sometimes used, in which washing water comes from the starboard slop tank. This procedure is recommended only when the tank atmosphere is either inerted or over rich.

The duration of washing one center tank in ships of class 210 and 260 is in the average 6 hours (it can vary from 4 to 8 hours). Good weather ballasting, involving 2 center tanks, will then lead to 12 hours washing time.

For bad weather ballasting, 4 center tanks are very often used, as it is not always possible to ballast 3 center tanks only, on account of trim and stress requirements. Total time involved is therefore 24 hours for ships of the same classes.

For smaller ships the washing time is not substantially less, because washing devices are not as efficient as in larger ships. However when ships have many small size tanks, balance is easier to achieve and bad weather ballasting may not involve twice the number of tanks of good weather ballasting.

The average datas are shown in schedules 20 and 21 hereafter.

c) Changing of ballast

Ballasting and deballasting are conducted simultaneously. The main bulk of dirty ballast up to the 2 or 3 meters upper layer is rejected directly to sea. The upper layer is processed through slop tanks.

The duration of this operation can be assessed as follows :

(hours)		good w.	bad w.
	Class 60	10	15
	100	12	20
	210	16	26
	260	18	30

In some cases, the bottom layer of dirty ballast (about 1 m) is also processed through slop tanks, on account of sediments.

d) Duct washing

After change of ballast, the next step is to clean the ducts in order to make sure that while deballasting at the loading port no trace of oil will appear. The effluent is processed through the slop tanks.
The duration is as follows :

Class 60	4 hours
Class 100	5 hours
Class 210 and 260	7 hours

The summary of changing of ballast operations is shown on schedule 20.

.../...

SCHEDULE 20

SUMMARY OF OPERATIONS OF CHANGING OF BALLAST

Hours	Class of ship			
good weather	60	100	210	260
(a) preparation of washing	3	5	8	8
(b) washing	10	10	12	14
(c) changing of ballast	10	12	16	18
(d) duct washing	4	5	7	7
total time at sea	27	32	43	47
add 10 % contingencies	3	3	4	5
	30	35	47	52
bad weather				
(a) preparation of washing	3	5	8	8
(b) washing	15	20	24	28
(c) changing of ballast	15	20	26	30
(d) duct washing	4	5	7	7
total time at sea	37	50	65	73
add 20 % contingencies	7	10	13	14
	44	60	78	87

Changing of ballast can be also undertaken before tank washing is completed. It is always possible as soon as the first tank is washed to ballast it while continuing washing of other tanks.

This procedure which could be applied for short voyages reduces appreciably the total required time. The total duration of washing and changing of ballast is therefore equal to the latter operation plus washing of the first tank. The results appear on the following schedule :

.../...

SCHEDULE 21

DURATION OF CHANGING OF BALLAST. REDUCED PROCEDURE

Hours	Class of ship			
good weather	60	100	210	260
operations at sea				
(a) preparation of washing	3	5	8	8
(b) washing of 1st tank	3	4	6	7
(c) continuation of washing and changing ballast	10	12	16	18
(d) duct washing	4	5	7	7
total at sea	20	26	37	40
add 10 % contingencies	2	3	4	4
	22	29	41	44

bad weather				
operations at sea :				
(a) preparation of washing	3	5	8	8
(b) washing of 1st tank	3	4	6	7
(c) continuation washing and changing ballast	15	20	26	30
(d) duct washing	4	5	7	7
total at sea	25	34	47	52
add 20 % contingencies	5	6	9	10
	30	40	56	62

Remark :

After cleaning of ducts, an operation sometimes called "reducing of slop tanks" is undertaken. This involves :

- completion of settling in the "dirty" slop tank
- adding emulsion breaking additives in some instances
- discharging "clean" water from "clean" slop tank
- processing through a specially designed separator.

.../...

The final situation would be usually to have all residual oil in the dirty slop tank with a water content of about 50 %. The target, which is not always achieved, is to have the "clean" slop tank empty.

This final operation requires a duration which is depending mainly of the characteristics of the emulsion of oil and water and of the settling and separation efficiency. In average the whole procedure may last from 24 to 64 hours.

3.4. SAFETY, INERT GAS

3.4.1. General

Recent explosion have led to recommand washing procedures which can be summarized as follows :

(a) atmosphere control :
- preferably inert gas (see para.3.4.2.)
- too lean (below Lower Explosive Limit or LEL) this involve interruption of washing procedure and ventilating as soon as atmosphere is above 20 % of LEL
- over rich (above Upper Explosive Limit or UEL).

(b) interdiction of close cycle procedure. Close cycle procedure involve circulation of washing water through slop tanks and therefore washing with polluted water.

(c) interdiction of use of detergents

(d) hot washing shall be preceded by cold washing as first step and ventilation.

All precautions (b) (c) and (d) are intended for ships without inert gas system. This involve a constant watch of the atmosphere situation of the tanks and raises the problem of adequate controlling and measurement devices. The situation in this respect will not be discussed in this report, but it cannot be considered as 100 % reliable, although substantial progress has been made.

.../...

The net result of these precautions is presently to substantially increase the duration of washing operations for ships without inert gas system. If over rich procedure is choosen, oil is to be spread in the tanks by washing machines, as an initial step before washing, in order to enrich the atmosphere. This increases the washing task. If too lean procedure is choosen frequent interruptions for ventilation are likely to occur.

3.4.2. <u>inert gas</u>

Inert gas provides the best answer to all safety and washing problems :

(a) by putting tank atmosphere always out of the explosive range

(b) by allowing fastest washing procedures
- use of guns to the full extent
- use of hot water
- use of detergents
- use of close cycle procedures

(c) by reducing corrosion (the use of inert gas was originally conceived for this purpose).

The generation of inert gas is a simple problem for the ship, since combustion provides an ample supply of a mixture which has, in average, the following composition :

O_2	2.5 to 3.5 % in volume
CO_2	13 to 14 %
SO_2	0.2 to 0.3 %
H_2O	7 to 9 %
N_2	75 to 77 %
soots	0.5 g/m^3

.../...

The discharge of combustion gas at the stack is considerable

	Class 100	Class 210
at harbour	16.000 m^3/h	25,000 m^3/h
at sea	36,000	45,000

This discharge is always higher than the needs of the ship. The only treatment to be undertaken is to get rid of SO_2 and of soots and dust. This is achieved in one washing operation through a "scrubber" in which water is pulverized in a venturi shaped column. The reduced condensation carries away 95 % of SO_2 and solid particles.

The capacity of the installation is therefore geared to the capacity of the scrubber unit, of the ventilating fans and of the ducts. This capacity should correspond to the maximum discharge capacity of the cargo pumps since inert gas concentration shall be maintained in tanks while discharging. The capacity shall be therefore around 10,000 m^3/h for a ship of class 100 and 20,000 m^3/h for a ship of class 210 and 260, the capacity could reach 30,000 m^3/h for ships of class 320. A simple rule of thumb could be to have a capacity of inert gas generation which would be expressed in cubic meter per hour about 1/10 th of deadweight value.

The ship should be permanently under inert gas conditions irregardless of the situation in the tanks (whether loaded, empty, ballasted, washed, discharging or loading). The movement of the inert gas accompanies the movement of liquids. During discharging operations, the generation of inert gas should be maximum. In other cases easy evacuation or simple maintenance of the atmosphere is required. The problem is to keep the inert gas pressure at 10 m bars and to keep the oxygen content below 8 %.

Inert gas can be maintained in the tank even when washing with mobile machines operated by the crew. Butterworth holes are in this case equipped with appropriate covers (leaving space for the duct) in order to reduce losses.

The investment cost involved in an inert gas system can be assessed as follows :

Thousands US dollars (1972)	Class of ship				
	60	100	210	260	320
New ship	200	250	350	400	500
Transformation of existing ship	300	350	500	600	700

4. PRE-REPAIR TANK CLEANING

4.1. GENERAL

The ship has to be thoroughly cleaned to enter drydock or repair yard. This means not only clean ballast but also all tanks including slop tanks washed and cleaned.

The state of the ship is materialized by a "free gas certificate" which is delivered by the authorities of the repair harbour. An additional state of cleanliness is achieved by removing all sludges and sediments which lead to the delivery of a "hot work certificate". This is usually performed after entering drydock or repair yard after delivery of the "free gas certificate".

A basic difference between pre-repair washing and routine washing is that the ship should ultimately contain no slops and no residual oil. The slops have therefore to be disposed of somehow and somewhere.

4.2. WASHING PROCEDURES

Washing with cold water is very seldom sufficient and hot water washing is usually the only way to remove oil residues.
Before 1969 and the issuance of recommendations following explosions, the fastest and most efficient procedure was to use hot water right from the start of operations. This is still possible under inert gas conditions (or over-rich atmosphere).

The production of hot water (at 80°C) is a critical requirement and is so power consuming that the ship has to reduce speed during hot water generation. For this reason washing in close cycle was prefered, in which the washing water is taken from the "clean" slop tank and rejected after washing in the "dirty" slop tanks.

.../...

The slop tanks are equipped with heating coils and the heater has only to supply make-up heat. Some ships prefer to use water at a lower temperature (50°C or 60°C).

The procedure was frequently improved by the use of detergents.

The figure of next page shows a typical close cycle washing system.

When inert gas conditions are not established, recirculation and detergents are prohibited. Hot water washing should be preceded by cold water washing as a first step.

The main parameters governing pre-repair washing are those indicated in para. 3.3.1. (schedule 19). Hot water generation capacity shall be added :

class 60 and 100 : hot water generation is about 120 to 180 m^3/h

class 210 and 260 : 600 to 900 m^3/h

Pre-repair tank cleaning involves two main steps (or more correctly should always involve two main steps)

- washing at sea until all tanks are cleaned, except at least one slop tank
- discharging slops at repair harbour and washing slop tank.

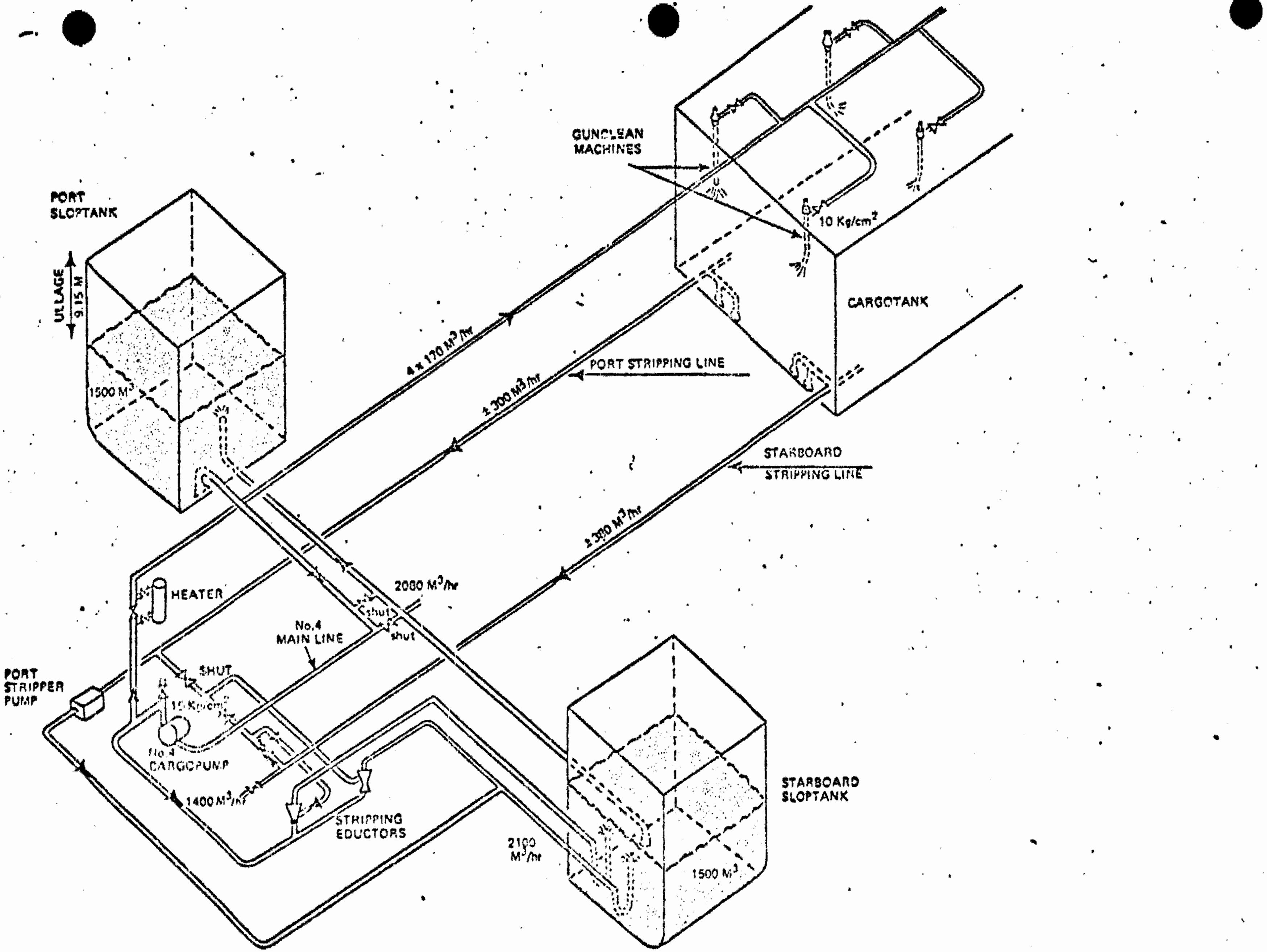
Experience and records by large repair harbours (for example Lisbon or Marseilles) show that more than one half of the ships entering drydock are completely clean, including slop tanks, and do not berth at the tank cleaning station. This important aspect of pollution control is examined in para. 5.3.4.

4.3. TIME ANALYSIS DESCRIPTION OF TYPICAL CYCLES

4.3.1. Tank cleaning at sea

A description of typical succession of operations and of corresponding time is shown in schedule 22 for a ship of class 210 equipped with inert gas, in schedule 23 for a ship

.../...



CLOSED CYCLE TANK CLEANING SYSTEM WITH DUAL SLOPTANKS of the same class not equipped with inert gas. In the first case hot washing is undertaken right from the start. In the second case cold washing has to be conducted first.

SCHEDULE 22

TYPICAL ANALYSIS OF PRE-REPAIR TANK CLEANING, 210,000 tdw SHIP EQUIPPED WITH INERT GAS (GOOD WEATHER)

	Duration	Time schedule	
Filling slop tank, washing ducts	7	H+ 0	H+ 7
Washing 5 C	6	H + 7	H + 13
Washing 2 C	6	H + 13	H + 19
Deballasting 1 C and 4 C	11	H + 15	H + 26
Ballasting 5 C and 2 C	11	H + 15	H + 26
Washing 5 W	10	H + 19	H + 29
Washing 1 W	10	H + 29	H + 39
Washing 1 C	6	H + 39	H + 45
Washing 4 C	6	H + 45	H + 51
Washing 2 W	10	H + 51	H + 61
Washing 4 W	10	H + 61	H + 71
Washing 3 C	6	H + 71	H + 77
Rewashing bottom of wing tanks	4	H + 77	H + 81
Washing pump room	3	H + 81	H + 84
Reduction of slops (deballasting one slop tank)	3	H + 84	H + 87
Washing 1 slop tank	3	H + 87	H + 90
Rinsings	6	H + 90	H + 96

Note : In case of bad weather ballasting, ballasting of additional center tanks may be performed during washing of wing tanks and do not require additional time.

.../...

SCHEDULE 23

TYPICAL ANALYSIS OF PRE-REPAIR TANK CLEANING 210,000 TDW

SHIP NOT EQUIPPED WITH INERT GAS (GOOD WEATHER)

	Duration	Time schedule	
Filling slop tanks, washing ducts	7	H + 0	H + 7
Cold washing 5 C and 2 C	12	H + 7	H + 19
Hot washing 5 C and 2 C	6	H + 19	H + 25
Deballasting 4 C and 1 C	11	H + 25	H + 36
Ballasting 5 C and 2 C	11	H + 25	H + 36
Cold washing 5 W, 1 W, 2 W, 4 W	40	H + 36	H + 76
Cold washing 1 C, 4 C, 3 C	18	H + 76	H + 94
Hot washing 5 W, 1 W, 2 W, 4 W.	16	H + 94	H + 110
Hot washing 1 C, 4 C, 3 C	12	H + 110	H + 122
Washing pump room	3	H + 122	H + 125
Reduction of slop (deball.1 slop tank)	3	H + 125	H + 128
Washing 1 slop tank	3	H + 128	H + 131
Rinsings	6	H + 131	H + 137

Notes : Ventilations are undertaken within total alloted time and is not shown in the schedule.

Bad weather ballasting may be performed during total alloted time.

.../...

At the end of this operation the ship should have all tanks cleaned included the "clean" slop tank. However discharging of the "clean" slop tank at sea is not always possible and ships have to discharge and clean quite frequently 2 slop tanks instead of just one at the repair harbour. For a 210,000 tonner the "dirty" slop tank at the end of the washing operation would contain 1200 t of oil and 1800 t of water.
The total (theoretical) duration is then, from the above schedules, 96 hrs to 137 hrs for a 210,000 tdw ship. For other ship sizes the theoretical durations are assessed as follows :

SCHEDULE 24

THEORETICAL TIME (HOURS) FOR PRE-REPAIR TANK CLEANING BEFORE DISCHARGING SLOPS

Hours	Class of ships				
	60	100	210	260	320
. with inert gas	65	72	96	105	120
. without inert gas	80	120	137	145	160

It is interesting to notice that the presence of inert gas leads to a reduction of more than 30 % of the duration of tank cleaning operations.

4.3.2. Discharging slops at repair harbour

A typical operation for a 210,000 tdw can be analysed as follows :

.../...

SCHEDULE 25

ANALYSIS OF SLOP DISCHARGING OPERATION AT REPAIR HARBOUR

(210,000 tdw ship)

	Duration	Time schedule	
Berthing, connecting lines	2	H + 0	H + 2
Discharging 1 slop tank	3	H + 2	H + 5
Washing 1 slop tank	8	H + 5	H + 13
Rinsing of ducts	1	H + 13	H + 14
Delivery of gas free certificate			H + 15

Additional time in case of discharging and washing two slop tanks instead of one .... 9 hours

For this class of ships the duration of slop discharging lasts between 15 and 24 hours and requires special shore facilities (see chapter 4.4.).

For other ships of other classes the total time for slop discharging is not basically different and remains between 12 and 24 hours, depending on the amount of slops and sludges.

4.4. REQUIREMENTS FOR SHORE FACILITIES

Repair harbours should be equipped with facilities enabling ships to discharge at least their slops. Shore facilities for other washing requirements are recommended also but are not as absolutely necessary as slop receiving installations.

This means in most cases a special berth with connecting lines to shore separation settling and storage tanks. In some cases shore facilities are replaced by barge or even special converted tankers (Lisnave has now 3 converted T2 tankers).

The capacity of shore facilities are usually designed for operations which are more elaborate than simple slop discharging and therefore requirements are easily met.

.../...

Slop discharging involves total quantities of water which seldom exceeds 6,000 cum of a mixture which could contain up to 50 % of oil. In addition water from slop tank washing should be also directly received ashore. For these operations a capacity of separation of abou 1200 t/hr and a capacity of storage of 2,500 cum can be considered as sufficient. These capacities correspond to the minimum required and are usually found in most repair harbours.

Shore facilities able to undertake complete washing and deballasting require more capacities and higher investment costs. This problem will be partially examined when describing procedure C (see para.6.5.

5. POLLUTION INCURRED

BY CHANGE OF BALLAST AND TANK CLEANING

5.1. GENERAL ASSUMPTIONS

The purpose of this study being to assess the feasibility of a given procedure (clean ballasting before sailing from discharging port) the pollution to take into account is the pollution that would be avoided by the application of said procedure. It should not include the pollution that can be already avoided by other simpler procedures.

A consequence of this basic approach is to consider

a) that all tankers use load on top and/or keeping most of residual oil aboard in slop tanks

b) that all tankers when sailing to repair harbour shall discharge the content of their slop tanks at harbour and not at sea.

It is however a fact that preventing a ship to sail with dirty ballast would also eliminate pollution arising from a faulty application of other procedures such as discharging at sea polluted water in excess of given limits This additional feature can only be assessed in a very approximate manner.

5.2. CHANGING OF BALLAST

5.2.1. Amount of oil displaced

During operations of changing ballast, which are analysed in chapter 3, the oil residues which are displaced, and which are to be found for the most part in slop tanks, corresponds to the oil which was present in tanks ballasted dirty upon departure and in tanks subsequently washed and ballasted clean.

At the end of the operation most of this oil shall be found in slop tanks mixed with an amount of water which is approximately 50 % of the amount of oil (after reduction).

The relevant figures are indicated in schedule 26 hereafter.

.../...

SCHEDULE 26

AMOUNT OF OIL DISPLACED DURING CHANGE OF BALLAST

m.t.

	Class of ship				
	60	100	210	260	320
1. Total oil retained in ship					
0.6 % of dwt cargo	360	600	1260	1560	1920
2. Oil from dirty ballast tank					
(good weather)	70	120	250	310	400
(bad weather)	105	180	380	460	600
3. Oil from washed tanks					
(good weather)	90	150	320	390	500
(bad weather)	135	300	640	780	1000
4. Total oil displaced during change of ballast (2 + 3)					
good weather	160	270	570	700	900
bad weather	240	480	1020	1240	1600
5. Amounts of slops 150 % of 4					
good weather	240	400	860	1050	1350
bad weather	360	720	1500	1850	2400

5.2.2. Amount of water used

The movements of water fall into three main categories :

- water from dirty ballast rejected directly at sea
- water for washing which is processed via slop tanks and subsequently rejected at sea from "clean" slop tank. The upper part of dirty ballast falls in this category
- water originating from the last operation of reduction of slops after settling in slop tank and in some cases processing through separators.

An assessment of the quantities under study is shown on schedule 27 (on following page).

It can be seen in this schedule that the proportion is in all cases around :

. water rejected directly at sea	72 %
. water processed via slop tanks	20 %
. water from reduction of slops	8 %

The importance of the first item is striking and when this operation is carried on, the main problem is to stop appropriately when oil content increases beyond the theoritical limit of 100 ppm.

This should be done with the assistance of adequate measuring devices, and not by simply watching if the discharged water "turns black".

Recommendations regarding measurement and control procedure should be contemplated. This problem is outside the scope of this study.

SCHEDULE 27

CHANGE OF BALLAST

AMOUNT OF WATER USED

cu.m.	Class of ship				
	60	100	210	260	320
A. Good weather					
Water used for :					
1 - initial rinsing	200	300	600	700	1,000
2 - washing tanks (1)	1,800	2,400	7,000	9,000	12,000
3 - deballasting at sea	13,000	23,000	40,000	50,000	63,000
4 - processing of ballast upper layer	2,000	2,000	5,000	5,000	7,000
5 - flushing ducts	400	600	1,200	1,400	2,000
6 - reduction of slops	1,200	1,600	5,100	10,900	13,600
B. Bad weather					
water used for :					
1 - initial rinsing	200	300	600	700	1,000
2 - washing tanks (1)	2,700	4,800	14,000	18,000	24,000
3 - deballasting at sea	22,000	41,000	72,000	87,000	110,000
4 - processing of ballast upper layer	3,000	4,000	8,000	8,000	10,000
5 - flushing ducts	400	600	1,200	1,400	2,000
6 - reduction of slops	1,100	1,300	4,500	10,000	12,600
TOTALS :					
Good weather					
water rejected directly (item 3)	13,000	23,000	40,000	50,000	63,000
water processed via slop tanks (items 1+2+4+5)	4,400	5,300	13,800	16,100	22,000
reduction of slops (item 6)	1,200	1,600	5,100	10,900	13,600
Bad weather					
water rejected directly	22,000	41,000	72,000	87,000	110,000
water processed via slop tanks	6,300	9,700	23,800	28,100	36,000
reduction of slops	1,100	1,300	4,500	10,000	12,600

(1) for ships washing in close cycle no rejection at sea occurs during tank washing. The figures above indicated do not take into account circulation water.

5.2.3. <u>Oil rejected at sea during change of ballast</u>

The assessment of oil rejected at sea derives directly from the amount of water pumped overboard.

Theoretically the amount of oil should never exceed 100 ppm. The fulfilment of this requirement has been the subject of some difference of appreciation. Most authorities think that this is usually achieved for the dirty ballast rejected directly at sea and also for the water processed through slop tanks. More doubts are expressed for the water effluent from the reduction of slops.

Other authors (1) consider that the clean part of dirty ballast usually contains much more than 100 ppm and 300 ppm is considered by some as a more likely figure.

A thoroughly comprehensive investigation of this problem could be recommended. It does not fall within the scope of this study.

We suggest in the present state of our information to adopt the following values :

- for "clean" part of dirty ballast	50 ppm	(2)
- for "clean" water from slop tank	150 ppm	
- for water effluent from reduction of slops	200 ppm	

In addition we will take into account a 25 % coefficient for contingencies.

The corresponding figures, which derive from figures shown in schedule 27, are shown on schedule 28 next page.

(1) for instance Porricelli and Storch in a paper recently presented to OMCI.

(2) Tests conducted by oil companies tend to prove than "clean" part of dirty ballast remains below 50 ppm.

SCHEDULE 28

OIL REJECTED AT SEA DURING CHANGE OF BALLAST

liters

	Class of ship				
	60	100	210	260	320
GOOD WEATHER					
- 50 ppm of ballast rejected at sea	650	1,150	2,000	2,500	3,200
- 150 ppm of water processed via slop tanks	660	800	2,100	2,400	3,300
- 200 ppm of reduction of slops	240	320	1,020	2,180	2,720
TOTAL	1,550	2,270	5,120	7,080	9,220
BAD WEATHER					
- 50 ppm of ballast rejected at sea	1,100	2,050	3,600	4,400	5,500
- 150 ppm of water processed via slop tanks	950	1,400	3,600	4,400	5,400
-200 ppm of reduction of slops	220	260	900	2,000	2,500
TOTAL	2,270	3,710	8,100	10,800	13,400
YEARLY AVERAGE PER VOYAGE (1)	2,000	3,000	7,500	9,500	12,500
ADD 25 % contingencies	500	750	1,900	2,400	3,100
TOTAL (liters)	2,500	3,750	9,400	11,900	15,600
TONS PER VOYAGE (YEARLY AVERAGE)	2.1	3.2	8.0	10.0	13.3

(1) yearly average calculated by taken 60 % occurences of bad weather for class 60 and 100 and 80 % for class 210 and above.

.../...

It is interesting to compare the total amount of oil rejected at sea (last line of schedule 28) and the total amount of oil displaced during change of ballast (line 4 of schedule 26). For some assumptions of bad weather occurences, the following comparison can be made :

	Oil displaced t	Oil rejected t	%
Class 60	208	2.1	1.0
100	396	3.2	0.8
210	930	8.0	0.9
260	1150	10.0	0.9

This means that the efficiency of slop tank processing methods allows only 0.9 % of oil displaced to be rejected at sea ; 99.1 % is kept aboard.

5.2.4. Total pollution incurred in 1975 and 1980

In 1975

The results arrived at in para.2.7. and schedule 28 lead to the following assessment :

SCHEDULE 29

TOTAL POLLUTION INCURRED IN 1975 BY CHANGE OF BALLAST

	Nb.of voyages	Pollution per voyages - t	Total pollution - t
Class 60	6,000	2.1	12,600
100	5,500	3.2	17,600
210	2,200	8.0	17,600
260	1,200	10.0	12,000
320	100	13.3	1,300
			61,100

A total pollution of 60,000 t in round figures appears to be less than estimated by certain authors. This is the result of the assumptions adopted in para.5.2.3. about the oil content of effluents and mainly of the clean part of the dirty ballast. If water rejected at sea contains three times more oil, as estimated by some authors, the total incurred pollution would be clearly about 200,000 t.

The pollution hereabove estimated occurs during the transportation of 1750 Mt of crude oil. It represents therefore about 1/29,000 th of the cargo. This is within the limits which have been adopted by certain shipowners.
These limits are :

- 100 ppm
- 60 liters per mile
- 1/15,000 th of the total cargo

Since the limit of 100 ppm can always be achieved by increasing the amount of water in effluents, the limit of 1/15,000 th of the cargo appears to be a more stringent constraint.
Adopting this limit, the transportation of 1750 Mt of crude oil would entail a pollution of :

$$\frac{1,750,000,000}{15,000} = 117,000 \text{ t}$$

It should be recalled also that :

- pollution recorded hereabove relates to the transportation of crude oil only. Shipping of petroleum products is not accounted for (see introduction). In this respect the method of calculation employed in this study is more accurate and more representative of the real situation than a method which would take into account the whole registered tanker fleet, as is often done.

- pollution control through load on top and slop tank processing is supposed to be fully efficient.
- pollution related to inter-mediterranean traffic would be about 9,000 t in 1975.

- the number of inerted tankers are presently increasing, involving an increase of the use of close cycle washing procedures. In this case less water from slop tanks would be rejected at sea and total incurred pollution would be reduced accordingly.

In 1980

The figures arrived at in para.2.10 will serve as the basis of the assessment.
The introduction of tankers of class 500 in 1980 implies that a unit figure of pollution per voyage has to be established for these ships. Pending practical experience in this matter, it seems reasonable to adopt a value which would be twice of that related to class 260. We estimate then that pollution per voyage for 500,000 tdw ships would be 20 t.
The results are shown in schedule 30 hereafter.

SCHEDULE 30

TOTAL POLLUTION INCURRED IN 1980 FROM CHANGE OF BALLAST

	Nb. of voyages		Pollut. per voy. t	Total pollution (,000 t)	
	Suez closed	Suez opened		Suez closed	Suez opened
Class 100	7739.	7817	3.2	24.8	25.2
210	3290	3558	8.0	26.3	28.5
260	2023	2216	10.0	20.2	22.2
320	331	229	13.3	4.4	3.0
500	662	458	20.0	13.2	9.1
				89.0	88.0

The same remarks as those related to the 1975 assessment can be made here. It is remarkable to note how the opening of the Suez canal would have little effect on total pollution.

5.3. POLLUTION INCURRED DURING PRE-REPAIR CLEANING

5.3.1. Amount of oil displaced

This amount shall be in this case the total residual oil retained in the ship after discharging. Relevant figures are indicated in the first line of schedule 26, which are recalled

		Total oil retained in ship 0.6 % of dwt cargo
Class	60	360 t
	100	600
	210	1260
	260	1560
	320	1920

5.3.2. Amount of water used

The amount of water used falls, as for changing of ballast, into three main categories :

- "clean"part of dirty ballast rejected directly at sea
- water from washing processed via slop tanks plus "dirty" part of dirty ballast
- water from slop reduction

Comparison between analysis of change of ballast operations and complete tank cleaning operations shows that the main difference will be in the quantity of water for washing. Taking into account that wing tanks are usually more difficult to wash than center tanks (a pair of wing tanks would require in washing water volume and duration often twice as much as for center tanks).

Volume of water for washing would be then in case of complete cleaning under inert gas 6 times (good weather) and 4 times (bad weather) the volume used in case of change of ballast.

Washing in two sequences (cold and then hot) without inert gas would require about 50 % more water.

Taking these factors into account, the figures of schedule 27 can be used and appropriately corrected. This leads to schedule 31 hereafter.

.../...

SCHEDULE 31

AMOUNT OF WATER USED. PRE-REPAIR TANK CLEANING

cu.m.

	Class of ship 60	100	210	260	320
Unit values					
Good weather, inert gas					
1. Initial rinsing	200	300	600	700	1,000
2. Washing tanks	10,800	14,400	42,000	54,000	72,000
3. Deballasting at sea	13,000	23,000	40,000	50,000	63,000
4. Processing of ballast upper layer	2,000	2,000	5,000	5,000	7,000
5. Flushing ducts	400	600	1,200	1,400	2,000
6. Reduction of slops	700	1,500	3,000	6,000	7,500
TOTALS					
Inerted tanks good weather					
Water rejected at sea (it.3)	13,000	23,000	40,000	50,000	63,000
Water processed via slop tanks (items 1+2+4+5)	13,400	16,900	48,800	61,100	82,000
Reducting of slops (it.6)	700	1,500	3,000	6,000	7,500
Inerted tanks bad weather					
Water rejected at sea	22,000	41,000	72,000	87,000	110,000
Water processed via slop tanks	14,400	18,900	51,800	64,100	85,000
Reduction of slops	700	1,500	3,000	6,000	7,500
Non inerted tanks good weather					
Water rejected at sea	13,000	23,000	40,000	50,000	63,000
Water processed via slop tanks (items 1+2x1.5 +4+5)	18,800	24,100	69,800	88,100	118,000
Reduction of slops	700	1,500	3,000	6,000	7,500
Non inerted tanks bad weather					
Water rejected at sea	22,000	41,000	72,000	87,000	110,000
Water processed via slop tanks	19,800	26,100	72,800	91,100	121,000
reduction of slops	700	1,500	3,000	6,000	7,500

5.3.3. Amount of oil rejected at sea

As in the analysis of changing of ballast, the main factor is the oil content in the water rejected at sea.
Here again the same discussion as in para.5.2.3. may take place and we would once again consider that the oil content does not exceed 50 ppm for the clean part of dirty ballast and 150 ppm for the effluent of clean slop tank.
The effluent from slop reduction in this case would be cleaner than in case of routine change of ballast because the slops are intended to be discharged at the repair harbour and no comparable concentration is needed as in the case of subsequent load on top. In some instances no slop reduction is undertaken and the content of both slop tanks are discharged at the repair harbour.

The picture is further complicated by the fact that many tankers will be inerted in the future and will undertake washing operation in close circuit, thereby reducing the amount of water rejected at sea after processing via slop tanks. The large volume of washing water shown in schedule 31 has a great influence on the total amount of oil rejected at sea. Any accurate calculation seems therefore difficult and we suggest to adopt the same average result arrived at in para. 5.2.3. whereby the amount of oil discharged at sea is approximately 1 % of the total oil displaced during the operation (or in this case 0.006 % of the dwt cargo).

5.3.4. Total pollution incurred 1975 and 1980

It seems safe to assume that all ships will undertake a complete cleaning once a year. Although it has been claimed that with modern paintings ships will drydock only once every 18 months or even every 2 years, the experience so far shows that on account of breakdowns, incidents and other contingencies, ships undergo a repair work in average every year.

.../...

.../...

This is also confirmed by statistical results obtained by Fearnley and Egers when assessing total off-hire period for big tankers. This period has shown a notable increase since delivery of VLCC in great numbers.

The number of voyages in this case would be therefore equal to the number of ships.
This leads to the following results, if all ships when sailing to repair harbour keep their slops on board.

SCHEDULE 32

TOTAL POLLUTION FOR 1975 AND 1980

COMPLETE TANK CLEANING, ALL SLOPS KEPT ON BOARD

		Nb.voy.	Poll.per voy.	Total poll.
1975				
	Class 60	373	3	1,119
	100	423	6	2,538
	210	321	12	3,852
	260	184	15	2,760
	320	14	20	280
				10,549
1980				
	Class 100	450	6	2,700
	210	410	12	4,920
	260	285	15	4,275
	320	50	20	1,000
	500	100	30	3,000
				15,895

.../...

But this should be considered as a theoretical situation. Statistics made at some of the main european repair centers, such as Lisnave or Marseille, show that a great percentage of ships arrive at the repair harbour completely cleaned without any slops to discharge.

In the present situation, this is rendered possible by the existence of zones in which rejection of oil is not forbidden. One of these zones begins off the Portuguese coast and ships coming from Northern Europe en route to Lisnave or to repair centers of the Mediterranean or further South have the opportunity to discharge at sea. This saves in the average one day at the tank cleaning station plus the cost of related services supplied by the shore.

No questions are usually asked by repair yards about the procedure of disposal which has been used by the ship. In addition, facilities for tank cleaning are often inadequate for handling all tankers intending to drydock.

This situation has to be radically corrected if any initial progress is to be made in sea pollution control. Based on the datas obtained in repair harbours South of Brest, more than 50 % of all tankers arrive clean at the repair yard.
It is noted that restrictions concerning pollution imposed by oil companies to chartered ships do not apply to pre-repair voyages.
Let suppose that a similar situation would prevail in 1975 and that the percentage of ships cleaning themselves completely at sea would be 40 % of all ships of class 60 and 100 and 30 % of all ships of classes 210 and 260.

.../...

The number of polluting voyages will therefore be as shown on schedule 33 hereafter. The total pollution is easily deducted

SCHEDULE 33

TOTAL POLLUTION IN 1975 IF 30 % TO 40 % OF SHIPS DISCHARGE SLOPS AT SEA ON PRE-REPAIR CLEANING

	Nb. of pollut. voy.	Pollut. per voy.	Total t
Class 60	150	360	54,000
100	170	600	102,000
210	96	1260	121,000
260	55	1560	86,000
			363,000

The incurred pollution would be therefore about , to 6 times as much as pollution from routine tank cleaning. It can be assessed in the present situation (beginning 1972) that pre-repair tank cleaning represents more than 80 % of all pollution generated by tankers as the result of their normal exploitation.

This shows the importance of prohibition of any rejection during pre-repair tank cleaning operation and the setting up of adequate control and enforcement measures.

6. SUGGESTED PROCEDURES FOR CLEAN BALLASTING AT DISCHARGING PORT

6.1. TENTATIVE DEFINITION OF CLEANLINESS

Three notions of clean tanks have been already met in this report :

- clean tank for clean ballast
- clean tank for gas free certificate
- clean tank for hot work certificate

From our investigation among shipowners and repair yards, the main difference between these different notions is geared to the presence of sediments.

Classified in an order of stringency, the cleanliness attached to the issuance of a gas free certificate appears to be the less constraining notion. In this case sediments could remain in the tank, as long as these sediments do not generate hydrocarbon gases (which is not always the case). Experience shows that when drydocking does not involve welding work in the tank a ship can be in a gas free state with a sizeable amount of sediments remaining in the tanks.

Coming second in the same classification would be the tank receiving clean ballast. Here the notion of cleanliness is not attached to the tank itself but to the ballast when rejected at the loading port. The problem for the ship is to be allowed to discharge ballast within the requirements of the loading port. If the ballasted tanks contain much sediments, these sediments can become mixed with the ballast and washed at least partly away when discharging. The "clean" ballast would be tinted and would appear unsatisfactory to the loading port authorities.

.../...

For this reason, tanks intended for clean ballast should be reasonably free of sediments. Experience shows here that most of sediments in centre tanks are washed away in the washing procedure, as presently conducted by the ship at sea. If the same state of tanks has to be achieved at the discharging port, the application of the same washing procedure would provide the same results.

The removal of sediments from wing tanks is usually not achieved easily through simple washing and for this reason most tankers use their center tanks for clean ballast.

When work has to be performed in the tanks, then all sediments must be removed for the issuance of a hot work certificate. This procedure usually implies that removal of sediments must be made by hand, after the achievement of a gas free state. This is usually a tedious performance which is undertaken at the repair harbour with the assistance of labor from the shore. In some repair yard (Lisnave for example) removal of sediments by hand is performed after entering drydock. In some other yards the removal is performed at the tank cleaning station.

As a conclusion, it seems presently sufficient to say that the procedure to be used at the discharging port should have the same features and the same effects than the procedure presently used at sea by the ship when washing for clean ballast. The related problem of inspection will be discussed in chapter 8.

6.2. GENERAL APPROACH

The basic datas being established in preceding chapters, it becomes possible to contemplate how clean ballasting can be achieved before sailing from discharging port.

Three procedures will be examined :

- Procedure A : At discharging berth, tank washing will be undertaken as soon as discharging is completed, then ballasting will begin as soon as first tank intended for ballast is cleaned. It should be noted that this procedure, already today, is sometimes followed by tankers when additional time is available at the discharging pier.

- Procedure B : At discharging berth, tank washing will be undertaken before discharging is completed, in order to achieve readiness for ballasting in clean conditions as soon as discharging is finished. This case would not imply any additional time to spend at discharging berth, but requires special equipment aboard the ship.

- Procedure C : The ship will take the minimum dirty ballast at discharging berth and will undertake changing of ballast and clean ballasting at a special tank cleaning station.

In each of these three cases, the feasibility of the operations will be examined, a time analysis will be made, with the description of the cycle of operations. Finally an assessment will be made of all direct and indirect costs implied.

6.3. TANK WASHING BEFORE BALLASTING AT DISCHARGING BERTH

(procedure A)
As soon as the discharging operations (including stripping) are completed, the ship usually undertakes ballasting. In this case, he will begin washing tanks intended for ballast and ballasting would begin as soon as the first tank is washed.

6.3.1. Example of time schedule (210,000 tdw)

Under bad weather condition (the most frequent occurence) the ship has to ballast 2 center tanks completely (2 C and 5 C) and 2 center tanks partly (1 C and 4 C).

.../...

Succession of operations would be as follows :

	Duration	Time schedule	
Completion of discharging		H + 0	
Rinsing of lines	2	H + 0	H + 2
Washing 5 C	6	H + 2	H + 8
Washing 2 C	6	H + 8	H + 14
Washing 4 C	6	H + 14	H + 20
Washing 1 C	6	H + 20	H + 26
Ballasting 5 C and 2 C	4	H + 20	H + 24
Ballasting 4 C	2	H + 24	H + 26
Ballasting 1 C	2	H + 26	H + 28
Sailing			H + 28

The duration of the operation, after rinsing of lines, equals the washing time of all tanks plus ballasting time of the last tank. Good weather conditions in which only 2 center tanks have to be ballasted would then last 16 hours.

6.3.2. Duration of operations for different ship sizes

Using the same method, the following figures can be established :

SCHEDULE 34

DURATION OF IMMOBILISATION AT DISCHARGING BERTH WHEN WASHING AFTER DISCHARGING

hours	Class of ship 60	100	210	260	320
Flushing rinsing	1	1	2	2	2
Washing good weather	10	10	12	13	16
bad weather	15	20	24	26	32
Ballasting of last tank	1	1	2	2	3
TOTAL TIME good w.	12	12	16	17	21
bad w.	17	22	28	30	37
DIRTY BALLASTING TIME					
good w.	2	2	4	4	6
bad w.	3	3	6	6	9
ADDITIONAL TIME					
good w.	10	10	12	13	15
bad w.	14	19	22	24	28

The last two lines are indicative of the additional time to be spent at the discharging berth as compared with the present conditions.

The implementation of this procedure involves that the ship, after sailing, still has to rinse lines, wash pump room etc... But these operations can be undertaken at sea and water processed through slop tanks. This involves negligible pollution.

6.3.3. Safety

The operation of washing is, as recent explosions demonstrated, a safety hazard. Harbour authorities would be therefore reluctant to allow ships to undertake washing at discharging berth.

.../...

The only solution to this problem is to conduct washing operations under inert gas.
This would be already achieved by tankers equipped with inert gas systems. We shall now examine how this problem could be solved for tankers which do not supply their own inert gas. This deserves a special paragraph.

6.3.4. Supply of inert gas to non-inerted tankers

As shown in para.3.4.2. above, inert gas is merely washed combustion gas, without too stringent requirements about oxygen content (less than 4 %). Any modern burner would be able to generate inert gas appropriately.
The problem is therefore to have, either ashore or on a barge, a generation of inert gas which could be supplied to the ship by an adequate duct. In many instances where the discharging berth is located near a refinery, inert gas is readily available. The only additional investment to implement consists of pipes and connections.
But the generation of inert gas in all cases could have a cheap origin : the burning of slops which are rejected ashore by the ship during the washing operations under review.

The operational procedure for supplying inert gas should be to connect inert gas duct to the tank before discharging in order to let inert gas flow in as the cargo flows out. This means that the maximum discharge of inert gas should be equal to the cargo pump discharge. The maximum could be set at 20,000 c.m.p.h.

This procedure would be much better than supplying inert gas after discharging, and replacing afterwards the atmosphere of the tank by inert gas. In aspects of speed, safety and air pollution the introduction of inert gas while discharging has all the advantages.

.../...

After discharging of the inert tanks is completed, the requirement would be to maintain inert conditions until after the washing.
This means that inert gas supply should involve at least two ducts :

- one high discharge pipe to be connected to the unloading tank. This pipe has to move from one tank to the other, meaning that tanks intended for clean ballast have to be discharged one after the other. Between successive discharging of the tanks to be cleaned, an other tank can be discharged, allowing time to make the new connection of inert gas pipe.
- one smaller pipe easy to handle for the purpose of maintaining inert conditions after discharging and while washing. This pipe could be moved als from one tank to the other. In the practice, this pipe could be connected to the tank undergoing washing. This means that the two pipes could be operated separately.

To sum up the requirements implied by inert gas supplied to non inerted tanker, the following features can be indicated :

- maximum discharge 20,000 c.m.p.h.
- connection of gas supply when discharging
- maintenance of inert conditions until completion of washing
- generation of gas by an installation either on shore or on a barge, in which slops (after adequate treatment) could be economically burnt.

The washing of tanks to be ballasted would then be undertaken on non-inerted ships, under conditions of safety which are never met when this operation is undertaken by the ship itself at sea. This may be a compensating advantage to take into account in the economy of the procedure.

It is important to notice also that the purification of the inert gas generates sulfuric acid which has to be disposed of. If the purification is undertaken aboard the ship the effluent from the scrubber should not be rejected in the harbour unless it is neutralized. If the operation is made ashore the same problem has to be solved and neutralization of the sulfuric acid may be an element of the cost.

For tanker equipped with inert gas installation, the requirements as they already exist today, would not be different if washing is undertaken alongside the discharging pier. This means that in many cases the contemplated procedure would not involve additional constraints.

6.3.5. Receiving capacities ashore for polluted water

When washing is undertaken, polluted water from washing should be pumped directly ashore (by stripping pumps). The shore installation shall then be able to receive, separate and store the effluents from washing.
The volume to be treated derives from figures already established in schedules 26 and 27.

SCHEDULE 35

POLLUTED WATER TO BE SENT ASHORE WHEN WASHING AT DISCHARGING BERTH

	Size of ship				
m.tons	60	100	210	260	320
Total water					
good weather	1,800	2,400	7,000	9,000	12,000
bad weather	2,700	4,800	14,000	18,000	24,000
Oil contained					
good weather	90	150	320	390	500
bad weather	135	300	640	780	1,000
Rate of discharge c.m.p.h.	300	500	850	900	1,000

.../...

This polluted water appears to contain approximately 5 % of oil. But this will not be constant. Oil content will be higher at the beginning of the operation. From the informations available at tank cleaning stations the following concentrations could be expected :

- first 10 % of water would contain				20 % of oil
- subsequent	20 %	"	"	10 %
- "	30 %	"	"	2 %
- "	40 %	"	"	1 %

As separation installations have a better efficiency with low oil content, it is suggested that the first part of water from washing could be pumped into settling tank and the rest would be processed through separators.
The separating capacity should be then superior or at least equal to the rate of discharge, this means a separation capacity of 1,000 to 1,500 c.m.p.h., quite a standard value.

The storage capacity should be of the order of 2,000 c.m. for storage/settling tank; Final capacity of separated oil storage should be around 1000 c.m. All these figures are corresponding to a small size tank cleaning station.

The washing being done under inerted conditions, close cycle procedures could be used. This means that the effluent to send ashore could be even much less than indicated hereabove.

In the practice it should be possible to contemplate a procedure by which the content of the slop tanks would be sent ashore as soon as the washing is completed. This can be done while ballasting of the last tank takes place. The total amount of mixture of water and oil would not in this case be superior to the capacity of the slop tanks i.e. :

.../...

Class	60	1,500 cu.m.
	100	3,000
	210	6,000
	260	12,000
	320	15,000

This is much less than the quantities involved by an open cycle procedure, as contemplated previously and the capacity of separation and storage ashore indicated hereabove can be considered quite adequate.

As a conclusion the features of the installations ashore can be limited to :

- separation capacity 1,000 cu.m. per hour
- storage/settling capacity 2,000 cu.m.

Oil issued from the separation could have an easy utilisation at the refinery which is, in many cases, adjacent to the discharging berth. It can be used also for inert gas generation as indicated in para.6.2.4.

Many discharging ports are already equipped with storage and separation facilities which are intended for the petroleum products trade. Discharging ports for crude oil are usually also loading ports for petroleum products. For this kind of trade,tankers often return to the loading port with dirty ballast that has to be pumped ashore before loading a new cargo. The problem is then to determine in each case if the existing facilities could have additional available capacity.

An indication of existing facilities in some main european petroleum harbours are given hereafter :

.../...

Marseilles		
Lavera	14,650	cu.m.
	14,650	
Fos	14,650	
	14,650	
Le Havre	10,000	
	13,000	
Rotterdam		
Shell Europoort	16,000	
Shell Pernis I	4,000	
Shell Pernis II	7,000	
Chevron Europoort	10,000	
Chevron Pernis II	7,000	
Gulf Europoort	10,000	
Mobil Europoort	25,000	
BP Europoort	50,000	
Europak Europoort	28,000	
Matex Europoort	10,000	

Similarly, terminal is often already equipped with lines and pipes for receiving water from ships. Additional facilities would not be required in most cases.

6.4. TANK WASHING WHILE DISCHARGING (procedure B)

The difference between this procedure and procedure A is that washing would be undertaken (under inert gas) on tanks intended for clean ballast, while other tanks are being discharged. In this case the tanks to be washed have to be unloaded and stripped first.

.../...

The possibility to undertake this operation depends primarily on the characteristics of the stripping systems of tankers. This system is presently used, inter alia, for stripping cargo while discharging other tanks through cargo pumps. In all cases which have been examined, the use of stripping lines for water while discharging is impossible.

Therefore this procedure would require the installation of a new separate stripping network on tankers

This new stripping system would have to be installed only on those tanks which are intended for clean ballast, i.e. center tanks only. Appropriate stripping pumps with a rate of discharge equal or superior to the rate of discharge of the washing machines have to be provided. This means a discharge ranging from 300 to 1,000 c.m.p.h. depending on ship's size.

Separate connections with the terminal have to be provided also, but terminal is very often already equipped with appropriate lines.

All other factors examined for procedure A : inert gas supply and shore receiving capacities are the same in this case.

As can be seen in schedule 34 the total time for washing is of a duration which is somewhat inferior to the usual duration of stay alongside discharging pier. The difference is however small and this means that washing shall begin as soon as possible if no additional time is to be spent alongside pier.

In this case the first tank to be discharged and stripped should be a tank intended for clean ballast and the washing operation should be undertaken immediately. This implies a correct isolation of the tanks undergoing washing from the tanks being discharged. A risk of a faulty operation can always remain and some reluctance can be expressed from harbour and custom authorities and from refineries. The succession of operations has to be tightly watched and controlled and this would be an additional constraint for the ship's crew.

However it seems that with adequate precautions and close control, the washing of tanks intended for clean ballast can be undertaken while discharging if the ship is equipped with an additional stripping system. In this case the washing of 2 to 4 center tanks can be completed at the same time as the discharging of the cargo and ballasting will then take place in clean tanks. (1)

The problem is to see if the additional investment of a new stripping system can be balanced against immobilization of the ship. This calculation is made in chapter 7.

6.5. CHANGE OF BALLAST AT A SEPARATE BERTH

(procedure C)

6.5.1. General

In this case the ship leaves the unloading pier with the minimum dirty ballast corresponding at the maximum to good weather conditions, and undertakes washing and change of ballast at a separate berth, at a tank cleaning station.

The case in which the ship anchors within the harbour area to wash and cleaning by herself will not be considered, because rejection of dirty ballast cannot be authorized in harbour waters and has to be pumped ashore in any case.

6.5.2. Time analysis

After leaving the unloading terminal, the following operations would be conducted, as an example for a 210,000 tdw charging dirty ballast in 1 C and 4 C tanks upon leaving terminal :

(1) The requirements would be more complicated for the ships using the free-flow system. Separation of tanks to be washed should be in this case specially provided.

.../...

	Duration	Time schedule	
Displacement to new site, mooring	3	H + 0	H + 3
Rinsing and flushings	2	H + 3	H + 5
Washing 5 C	6	H + 5	H+ 11
Deballasting 4 C ashore	4	H + 9	H+ 13
Ballasting 5 C	2	H + 11	H + 13
Washing 2 C	6	H + 11	H + 17
Deballasting 1 C ashore	4	H + 15	H + 19
Ballasting 2 C	2	H + 17	H+ 19

As shown in this schedule deballasting of a dirty ballast tank is undertaken while washing the next tank intended for clean ballast. Deballasting can be therefore undertaken at a lower discharge rate. This is important for the reception capacity of the tank cleaning station.

It can be seen also that 3 different operations have to be undertaken at the same time (H+ 11 - H + 13) on three different tanks :

- ballasting
- washing
- deballasting

For some tankers the line and pump system would render this procedure impossible. In this case an additional delay of 2 hours shall be taken into account. As displacement time and mooring at a new site is depending on harbour configuration and can have in many cases an important duration, it is suggested to add in all cases 2 hours to the described procedure in order to be on the safe side.

From this example and from previous unit values, the following figures have been established for different ship's sizes.

.../...

SCHEDULE 36

DURATION OF IMMOBILIZATION AT DISCHARGING HARBOUR FOR CHANGING OF BALLAST AT A SEPARATE STATION

hours	Class of ship 60	100	210	260	320
Displacement, mooring, rinsing ...	4	4	5	5	6
Washing deballasting and ballasting					
good weather	10	12	16	18	20
bad weather	16	20	28	30	34
Total time					
good weather	14	16	21	23	26
bad weather	20	24	33	35	40
Additional time					
good weather	14	16	21	23	26
bad weather (1)	19	22	31	33	37

(1) deduct difference of time between good and bad weather dirty ballasting

Additional time is in this case about 50 % as much as for procedure A.
The major part of this additional time is spent at the new berth and this involves the availability of new expensive facilities.

The receiving capacity of the station should be also much more important than in procedure A, because in this case dirty ballast as well as washing water has to be sent ashore.
The total amount of water and oil would be as follows :

.../...

SCHEDULE 37

WATER AND OIL SENT ASHORE WHILE CHANGE OF BALLAST AT A SEPARATE STATION IN UNLOADING PORT

m.t.	Class of ship				
	60	100	210	260	320
Dirty ballast	15,000	25,000	45,000	50,000	70,000
Washing water :					
good weather	1,800	2,400	7,000	9,000	12,000
bad weather	2,700	5,000	14,000	18,000	24,000
Oil from dirty ballast	70	120	250	310	410
Oil from wash.water					
good weather	90	150	320	390	500
bad weather	135	300	640	780	1,000
Total water					
good weather	16,800	27,400	52,000	59,000	82,000
bad weather	17,700	30,000	59,000	68,000	14,000
Oil - good weather	160	270	570	700	910
bad weather	205	420	890	1090	1410

This would involve following requirements for the station

- capacity of separation 5,000 c.m.p.h.
- storage/settling capacity 5,000 c.m.

These requirements are approximately 3 to 4 times those needed in procedure A.

In very good weather conditions, the volume of ballast needed for movements within harbour area may be less than those indicated hereabove, but even in exceptional good conditions this procedure shall cost substantially more in time, investment and operating expenditures as procedures A or B.

.../...

The same is obviously true if the ship is anchored in the harbour area and undertakes washing by herself and then proceeds to a special berth for unloading dirty ballast and washing water.

A choice can be therefore made right now to disregard this procedure in subsequent cost calculations and to prepare estimates for procedures A and B only.

7. COST ESTIMATES

7.1. GENERAL

In this chapter all assessment of costs will be made for procedure A (washing at discharging berth after discharging) and procedure B (washing while discharging).

Unit costs shall be established first and it should be emphasized that it is only possible to reach approximate average values, as harbour conditions, features of ships and economic conditions may vary to a great extent.

On the basis of unit costs, and using economic calculations procedures suggested by paper n°MP/XI/2/3 submitted to the OMCI, the economic consequences of the suggested measures will be assessed.

7.2. COST OF IMMOBILIZATION OF THE SHIP

The fact that the ship has to spend more time at discharging berth involves additional cost. This is usually assessed taking into account time-charter rates. In 1972, the incurred cost is as follows, depending on ship's size and time-charter rates.

SCHEDULE 38

IMMOBILIZATION COST PER DAY

		Size of ships				
US dollars		60	100	210	260	320
Time-charter rate	W 100	6,000	12,000	25,000	33,000	42,000
	W 80	5,000	10,000	20,000	27,000	34,000
	W 50	3,000	6,000	12,000	14,000	22,000

.../...

We suggest to take into account the hourly costs indicated hereafter. These costs are based on W 80 conditions.
The multiplication by the average additional time spent at discharging berth gives additional cost involved per ship and per voyage.

SCHEDULE 39

ADDITIONAL COST PER SHIP AND PER VOYAGE FOR IMMOBILIZATION

	Class of ship				
	60	100	210	260	320
Immob.cost per hour ($)	210	420	840	1,120	1,400
Average add.time (hr)(1)	13	15	20	22	26
Incurred immob.cost per ship per voy.	2,700	6,300	16,800	24,600	36,400

(1) figures deriving from schedule 34 with :

60 % bad weather for class 60 and 100
80 % bad weather for class 210 and above

7.3. COST OF WASHING

7.3.1. Washing by ship without assistance

The handling of washing machines (if mobile machines are used) is in this case undertaken by the ship's crew, in similar conditions as at sea. No additional cost is involved.

7.3.2. Washing with assistance from shore

This could well be the practical case because, if washing is completed at discharging port, no further washing would be necessary en route in routine voyages.

This could lead to reductions of the ship's operational costs. The cost of assistance from the shore will be therefore balanced by savings in crew expenses. Although savings may actually amount to more than costs of assistance for washing it is assumed here that it compensates equally. No additional cost will be therefore taken into account.

7.4. COST OF INERT GAS SUPPLY

This would apply to non-inerted tankers only. As described in para.6.3.4. inert gas, when not available at the nearby refinery, could be generated by burning of slops discharged from ships. Therefore no fuel costs will be taken into account.

A generating plant would be a rather simple installation either with a simple burner and combustion chamber, followed by a scrubber. In addition waste heat could be used to generate steam which could find a number of utilizations, among which production of hot water for washing machines.

The generating plant can serve two berths and would be connected with appropriate ducts and handling facilities on the pier.
The costs related to such a facility could be assessed to the following amounts :

- Investment costs :	generating plant	$ 120,000	(1)
	connections	80,000	
- Operating costs per year :	labor	40,000	
	other costs	20,000	

This investment would be amortized in ten years. This means a yearly equivalent of about 20 % per year (with a 10 % yearly discount rate). Yearly costs would then be :

. depreciation	40,000
. operating costs	60,000
	100,000

(1) This does not include the cost of boiler which could be balanced by supply of steam and hot water.

As indicated, the installation could serve two adjacent berths and therefore treat about 300 ships per year. However taking into account terminals with less traffic and inerted tankers for which this installation would not be of use, it seems safe to assume that this facility would handle 60 operations per year. This gives a mean average amount of $ 1,300 per ship. This can be modulated as follows :

Class 60	per ship per voyage	$ 1,000
Class 100		1,300
Class 210		1,600
Class 260		2,000
Class 320		2,500

7.5. ADDITIONAL COST FOR THE HARBOUR (procedure A)

7.5.1. General

The additional cost for the harbour would derive from :

- additional time spent thus requiring additional facilities
- cost of receiving and treating effluent water from washing
- cost of inert gas supply (already accounted for in para.7.4.)

7.5.2. Need for additional facilities

Comparing time spent at the discharging pier, in the present situation and under conditions of procedure A, the following schedule can be established.

SCHEDULE 40

ADDITIONAL TIME SPENT ALONGSIDE DISCHARGING PIER

hours	Presently (average)	Additional time with procedure A (average)	% increase
Class 60	30	13	44 %
100	30	15	50 %
210	32	20	62 %
260	34	22	65 %
320	36	26	72 %

This means that harbour facilities will be on the average used from 44 to 70 % more. This means that corresponding additional facilities have to be provided.

However harbour terminals are not always saturated and additional capacity is often available. This would be particularly the case in terminal handling less than 10 million t of crude oil per year.

Judging from the conditions of exploitation in major petroleum ports, such as Rotterdam, Marseilles or Le Havre, one discharging berth can be considered as saturated when the frequentation reaches 170 ships per year, which means an occupation of 5,000 hours or 56 % occupation. (See schedule n°40a of occupation of unloading piers in Marseille and Le Havre).

All existing piers do not yet reach this level and in many cases additional available capacity would permit to postpone the immediate implementation of additional facilities.

However the need for additional facilities would be fully felt on development programmes and development would have to be implemented 60 % faster than presently contemplated.

The cost increment deriving from an acceleration of development programmes is very much depending on the distribution of traffic between harbours and differences in traffic growth among major ports.

SCHEDULE 40 a

OCCUPATION OF DISCHARGING PIERS

OCCUPATION OF DISCHARGING PIERS MARSEILLES 1970

n° pier	nb ships	Duration Total	Duration per ship	Total disch - Mt.
721	84	3142	37	2,1
722	104	3610	35	3,0
723	112	3653	33	4,0
724	110	3387	31	4,6
725	163	4920	30	8,9
726	159	4883	31	9,0
800	71	2067	29	3,0
802	176	4969	28	14,5
803	112	3137	29	10,3

.../...

OCCUPATION OF DISCHARGING PIERS LE HAVRE 1970

n° pier	Nb. ships	Duration Total	per ship	Total disch. - Mt.
103	131	4339	33	4.5
105	84	2628	31	1.4
106	137	3708	27	6.9
107	153	5080	33	10.7
108	159	4592	29	14.0
110	54 (1)	1906	35	7.2

(1) operating since July 1970

An approach to the problem of cost can be made as follows :

a) Taking direct and indirect costs into account, the investment required for discharging of 1 t of crude oil can be assessed today at US $ 0.25
This means that a discharging berth capable of handling 20 Mt of crude oil would cost US $ 5 M.
A twin pier was recently built in Rotterdam for 17 M fl (5,4 M $).

b) Using a yearly equivalent of 12 % of the investment (which means a 20 year amortization with a 10 % discount factor) the yearly equivalent per ton of crude oil would be :

$$0.25 \times 0.12 = 0.03 \text{ US \$ per t per year}$$

This amount is more of what is presently charged by harbours authorities for occupation of berth after discharging and prior sailing. In Rotterdam the charge is about 0.03 fl per

GRT or 0.02 fl (0.007 US $) per t.
The charge for discharging crude oil in Rotterdam is 0.10 US $ per GRT or about 0.06 $ per t. But this charge includes also operating costs.
Similarly occupation of berth at Rotterdam tank cleaning station is 250 fl per hr for 100,000 tdw. For 30 hours the total would be 7,500 fl or 2,500 US $ or 0.025 $ per ton.
We think therefore that 0.03 $ per t can be considered an acceptable figure.

c) The additional cost incurred for longer occupation of discharging berth per ship per voyage would be then simply calculated by multiplying the dw tonnage by 0.03 and by the percentage of increase shown in schedule 40. This gives the following rounded figures :

Class 60	$ 800
100	1,500
210	3,900
260	5,100
320	6,900

7.5.3. Cost for receiving water effluents

This cost will be very much dependant on available capacities in existing installations which are intended for receiving dirty ballast and water effluents from tankers in the petroleum products trade.
Therefore any assessment is difficult. A short cut may be found by taking into account the rates charged by tank cleaning stations for similar operations. This is supposed to take appropriately into account all incurred costs.

The cost of slop discharging at some important tank cleaning stations appears as follows (in round figures)

Rotterdam (Verolme Tank Cleaning)

60,000 tdw	220 fl/h x 20 :	4,400 fl	(1,400 $)
100,000 tdw	360 fl/h x 20 :	7,200 fl	(2,200 $)
210,000 tdw	360 fl/h x 24 :	8,640 fl	(2,700 $)

Hamburg (Hansamatex) 3 DM per cu.m. effluent

100,000 tdw	2,000 cu.m. x 3 :	6,000 DM	(1,900 $)
200,000 tdw	3,000 cu.m. x 3 :	9,000 DM	(2,800 $)

Marseilles (Tanker Service) lump quotation

100,000 tdw	9,000 F	(1,800 $)
200,000 tdw	12,000 F	(2,400 $)

We suggest therefore to take into account the following figures per ship per voyage :

Class	60	1,500
	100	2,000
	210	2,800
	260	3,200
	320	4,000

7.6. RECAPITULATION. TOTAL COST PER SHIP AND PER VOYAGE for procedure A

The results arrived at in preceding paragraphs are summed up in the following schedule :

SCHEDULE 41

TOTAL ADDITIONAL COST PER SHIP PER VOYAGE FOR PROCEDURE A

	Class of ship				
	60	100	210	260	320
Immobilization	2,700	6,300	16,800	24,600	36,400
Inert gas supply	1,000	1,300	1,600	2,000	2,500
Add. facilities	800	1,500	3,900	5,100	6,900
Reception of effluents	1,500	2,000	2,800	3,200	4,000
	6,000	11,100	25,100	34.900	49,800
per tdw	0.10	0.11	0.12	0.13	0.15

The cost is somewhat smaller for tankers equipped with inert gas for which no inert gas supply has to be provided.

The result can be summarized as follows :

	Ship with inert gas	Ship without inert gas	% (1)	Average
Class 60	5,000	6,000	30	5,700
100	9,800	11,100	40	10,600
210	23,500	25,100	50	24,300
260	32,900	34,900	60	33,700
320	47,300	49,800	60	48,300

(1) percentage forecasted of number of ships equipped with inert gas in 1975 and after.

7.7. TOTAL COST WORLDWIDE FOR PROCEDURE A

The results arrived at in the precedent paragraph and the figures established previously lead to schedule 42.

SCHEDULE 42

TOTAL COST WORLDWIDE FOR PROCEDURE A (1975)

	Average cost per ship per voy $	Nb. of voy	Total cost M $
Class 60	5,700	6,000	34.2
100	10,600	5,500	58.3
210	24,300	2,200	53.5
260	33,700	1,200	39.4
320	48,300	100	4.8
			190.2

TOTAL COST WORLDWIDE FOR PROCEDURE A (1980)

	Average cost per ship per voy $	Nb. of voy (1)	Total cost M $
Class 100	10,600	7,700	81.9
210	24,300	3,300	77.5
260	33,700	2,000	67.4
320	48,300	330	15.9
500 (2)	60,000	660	39.6
			282.3

(1) Suez closed round figures

(2) Extrapolated unit cost for class 500

It appears from these results that for the total tonnage of oil transported by sea, the additional cost per ton of oil would be :

In 1975 $\frac{190.2}{1720} = 0.112$ $

In 1980 $\frac{282.3}{2470} = 0.113$ $

7.8. COST OF POLLUTION PREVENTION - procedure A (1975)

As established in para.5.2.4. total pollution incurred by tankers when changing ballast at sea is at the minimum 60,000 t per year. This pollution would be prevented at a cost of

$$\frac{190,200}{60} = \underline{3,170 \text{ US \$ per ton}}$$

(If any other value is adopted for total pollution, the cost of prevention could be easily established).

The cost for each class of ship would be as follows :

SCHEDULE 43

COST OF POLLUTION PREVENTION (procedure A - 1975)

	Class of ship				
	60	100	210	260	320
Cost per ship per voy. ($)	5,700	10,600	24,300	33,700	48,300
Pollution per ship per voy. (t)	2.1	3.2	8.0	10.0	13.3
Cost of prevention $ per ton	2,700	3,310	3,040	3,370	3.630

7.9. INTEREST OF INSTALLING INERT GAS SYSTEMS ABOARD SHIPS

Comparison between cost of supply of inert gas at discharging port and yearly equivalent for investing inert gas systems aboard newly built tankers is shown in the following schedule :

SCHEDULE 44

COMPARISON OF COSTS FOR INERT GAS

,000 of US dollars	Class of ship				
	60	100	210	260	320
Investment for inert gas system	200	250	350	400	500
Yearly equivalent (12 %)	24	30	42	48	60
Cost of gas supply at port	1	1.3	1.6	2.0	2.5
Number of voyages per year	16.1	13.0	6.8	6.5	7.0
Yearly cost	16.1	16.9	10.9	13.0	17.5

This would mean that, for the only purpose of avoiding the cost of supply of inert gas at the discharging harbour, it would not pay to install inert gas system aboard ships.

7.10 NEEDS OF ADDITIONAL TONNAGE

The additional time spent in discharging port leads to an increase of the tanker fleet.

This can be assessed by taking into consideration the total additional time lost for each class of ships, and then by considering that a new ship would be needed for 348 x 24 = 8350 hours.

The needed tonnage is then easily deducted. The results appear in the following schedule :

SCHEDULE 45

ADDITIONAL TONNAGE NEEDS, procedure A, 1975

	Class of ship				
	60	100	210	260	320
Add.time per ship per voy.	13	15	20	22	26
Nb. of voyages	6,000	5,500	2,200	1,200	100
Total add.time (hours)	78,000	82,500	44,000	26,400	2,600
Nb.of new ships needed	9.3	9.9	5.3	3.2	0.3
Corresponding tdw (000 tdw)	558	990	1113	832	96

.../...

The total of last line is 3,589,000 tdw (which can be achieved with a different distribution of ship's size).
Compared with the estimated total for 1975 (184 M tdw)
The increase of tonnage should be approximately 2 %
This is less than the approximation used when assessing the tonnage and composition of the fleet in 1975 and considerably less than the possible ajustments to the market provided by combined carriers (OBO).

7.11 COST ESTIMATES FOR PROCEDURE B

7.11.1. General

The basic difference between procedure A and procedure B is that the feasibility of procedure B is entirely dependant on the implementation of a new equipment aboard the ship (new stripping network) as indicated in para. 6.4.
Once the ship is equipped, the total time spent at discharging berth will remain the same as today. Therefore cost of immobilization and cost for additional harbour facilities will not be taken into account any more.
The only remaining items of cost will be :
- yearly equivalent for new equipment aboard the ship
- inert gas supply (for ship not equipped with inert gas systems)
- reception of water effluents.

7.11.2. Cost of newstripping line

This new equipment shall serve the whole line of central tanks. Assessment of investment cost is as follows :

SCHEDULE 46

INVESTMENT COSTS FOR NEW STRIPPING LINE

,000 US dollars	Class of ship				
	60	100	210	260	320
Investment cost for new ship	200	300	400	500	600
Yearly equivalent (12 %)	24	36	48	60	72
Investment cost for existing ship	300	400	600	700	900
Yearly equivalent (20 %)	60	80			
(15 %)			90	105	135

It has been estimated in the above schedule that the remaining life of existing ships of class 60 and 100 would be less than for ships of class 210 and 260. Hence the different ratios for the calculation of yearly equivalents.

It can be estimated further that in 1975 the percentage of new ships among the fleet is as follows :

Class	60 :	3 %
	100 :	20 %
	210 :	45 %
	260 :	70 %

The average yearly equivalent per class of ship will be therefore (in rounded figures)

Class 60	$ 60,000
Class 100	70,000
Class 210	70,000
Class 260	70,000
Class 320	100,000

Taken into account average number of voyages per year, the cost per ship and per voyage will be :

SCHEDULE 47

COST PER SHIP AND PER VOYAGE FOR NEW STRIPPING LINE

		Yearly equi.	Nb. voy.	Cost per ship per voy.
Class	60	60,000	16.1	3,700
	100	70,000	13.0	5,400
	210	70,000	6.8	10,300
	260	70,000	6.5	10,800
	320	100,000	7	14,000

7.11.3. Total cost per ship per voyage for procedure B

The results appear on the following schedules :

SCHEDULE 48

TOTAL COST PER SHIP PER VOYAGE FOR PROCEDURE B

NON INERTED TANKERS

	Class of ship				
	60	100	210	260	320
New stripping line	3,700	5,400	10,300	10,800	14,000
Supply of inert gas	1,000	1,300	1,600	2,000	2,500
Reception of effluents	1,500	2,000	2,800	3,200	4,000
	6,200	8,700	14,700	16,000	20,500

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.../...

TOTAL COST PER SHIP PER VOYAGE FOR PROCEDURE B

INERTED TANKERS

	Class of ship				
	60	100	210	260	320
New stripping line	3,700	5,400	10,300	10,800	14,000
Reception of effluents	1,500	2,000	2,800	3,200	4,000
	5,200	7,100	13,100	14,000	18,000

Taking into account the percentage of ships equipped with inert gas in 1975 as already indicated in schedule 41a, the average total per ship per voyage will be :

SCHEDULE 48a

TOTAL AVERAGE COST PER SHIP PER VOYAGE FOR PROCEDURE B

Class 60	5,900	US $
100	8,200	
210	13,900	
260	14,800	
320	19,000	

7.11.4. Total cost world wide for procedure B

SCHEDULE 49 (1975)

	Average cost per ship per voy. $	Nb. of voy.	Total cost M $
Class 60	5,900	6,000	35.4
100	8,200	5,500	45.1
210	13,900	2,200	30.6
260	14,800	1,200	17.8
320	19,000	100	1.9
			130.8

.../...

SCHEDULE 49a (1980)

	Average cost per ship per voy. $	Nb. of voy.	Total cost M $
Class 100	8,200	7,700	63.1
210	13,900	3,300	45.9
260	14,800	2,000	29.6
320	19,000	330	6.3
500	30,000	660	19.8
			164.7

(Schedule 49a takes into account an extrapolated cost for class 500)

Cost per ton of oil transported :

in 1975 $\frac{130.8}{1720} = 0.077$ $ per ton

in 1980 $\frac{164.7}{2470} = 0.066$ $ per ton

The difference between 1975 and 1980 is representative of the better economy of the procedure for large tankers.

7.11.5 Cost of pollution prevention procedure B (1975)

Pollution accruing to 60,000 t will be prevented at a cost of :

$$\frac{130,800}{60} = \underline{2,180 \text{ US \$ per ton}}$$

The cost of each class of ship would be as follows :

../...

SCHEDULE 50

COST OF POLLUTION PREVENTION PER CLASS OF SHIP

(1975 procedure B)

	Cost per ship per voy.	Pollution per voy.	Cost per ton
Class 60	5,900	2.1	2,810
100	8,200	3.2	2,560
210	13,900	8.0	1,740
260	14,800	10.0	1,480
320	19,000	13.3	1,430

The cost of pollution prevention for procedure B decreases with the size of the ship.

7.12. COMPARISON BETWEEN ESTIMATES FOR PROCEDURE A AND PROCEDURE B

The results which have been established in this chapter can be summarized and compared as shown in the following schedules :

SCHEDULE 51

COMPARISON OF COST PER SHIP PER VOYAGE

,000 US dollars

	proc. A	proc. B	% gain for B
Class 60	5,700	5,900	- 4 %
100	10,600	8,200	23 %
210	24,300	13,900	43 %
260	33,700	14,800	54 %
320	48,300	19,000	60 %

SCHEDULE 52

COMPARISON OF TOTAL WORLD WIDE COST

		proc. A	proc. B	% gain for B
Total worldwide				
million US $	(1975)	190.2	130.8	31 %
	(1980)	282.3	164.7	42 %
Cost per ton of oil transported				
US cents	1975	11.2	7.7	31 %
	1980	11.3	6.6	42 %

SCHEDULE 53

COMPARISON OF COST OF POLLUTION PREVENTION

US $

		proc. A	proc. B	% gain for B
World average				
per ton	(1975)	3,170	2,180	31 %
Per class of ship per ton				
Class 60		2,700	2,810	- 4 %
100		3,310	2,560	23 %
210		3,040	1,740	43 %
260		3,370	1,480	54 %
320		3,630	1,430	60 %

The interest of procedure B is clearly increasing with the size of the ship.

8. MISCELLANEOUS ASPECTS RELATED TO CONTEMPLATED PROCEDURES

8.1. CONTROL AND REGULATIONS

The procedures of control related to the interdiction of sailing from the discharging port with dirty ballast are not easy to implement.

The verification that the ballast is clean will be made essentially a posteriori when the ship reaches the loading port. There is no clear and obvious way to control the cleanliness of the ballast upon sailing.

The control of the tanks to be ballasted is not easier. As suggested in this report the tank washing should be undertaken under inert gas. This means that the tanks will be completely inerted before ballasting and this renders any gas free measurement irrelevant and it prevents an easy visual examination.

Any checking on the state of the tanks or of the "clean" ballast seems to be therefore impossible or unreliable.

The only control which can be contemplated is to verify that washing operations are undertaken under normal conditions and within limits of normal duration before ballasting.

As an example the ship shall state how many center tanks are intended to receive ballast and verification shall be made that washing operation is being conducted on those tanks. When reaching the loading port another verification shall take place in order to check that the ballast is still in those same tanks and that no other tanks have been ballasted.

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8.2. THE PROBLEM OF WASHING AT SEA

The contemplated procedure implies that the ship has to forecast the weather conditions likely to be encountered en route.
It should be emphasized however that if a ship takes additional ballast en route, this ballast can be charged in washed tanks and the additional pollution resulting from additional ballasting would be generated from washing the tanks intended for additional ballast and not from discharging dirty ballast. The situation in this respect would be the same if a ship cleans some of her tanks without ballasting them.

The problem appears then to be wether any washing at sea should be forbidden. If not, additional ballasting at sea in previously washed tanks shall be also permitted.

The interdiction of any washing at sea is clearly a stringent constraint and would result in accumulation of sediments and sludges.

If washing is permitted at sea, a verification of the slop tanks at the loading port should demonstrate that the washing operations have been conducted in the appropriate manner.

As stated in chapter 5, the main polluting factor is the effluent from the slop tanks, rather than the bulk of the dirty ballast. If therefore a ship sails from discharging port with clean ballast in center tanks but with all other tanks dirty and reaches loading port without additional ballast but with some of the wing tanks cleaned, the incurred pollution would not be negligible as compared with the pollution which has been prevented by cleaning tanks at discharging port before ballasting.

A consequence of any interdiction to wash at sea would be the necessity for ships at given intervals to clean the tanks which are not usually used for ballasting at a special tank cleaning station. This problem is not special to this study :

.../...

if ships are to be designed with permanent ballast and without any possibility to ballast tanks intended for cargo, these tanks have still to be washed, just as the tanks which are not used for ballast in present conventional ships. It could be interesting to know if ships designed with separate systems (water and cargo) would ever be allowed to wash cargo tanks at sea.

We suggest that this problem should be discussed and it seems that a special study could be undertaken with a view to assess the consequences of an interdiction of any tank cleaning at sea. This problem is clearly independant of the ballasting procedure.

8.3. SIDE CONSEQUENCES FOR THE SHIP

Washing at the discharging port instead of en route could have some advantages :

- the ship may not have to undertake any further washing at sea. This would save operating costs and possibly crew expenses.
- non inerted ships would undergo washing operations under inert gas at discharging berth, thus in better conditions of safety than at sea by themselves. For those ships corrosion will be also reduced.
- the additional stripping system could have other uses and improve the sequences of operation at the loading port.

8.4. THE PROBLEM OF HARBOUR POLLUTION

As suggested the discharging port will receive effluents from the washing of the tanks intended for ballast. These effluents will be se parated ashore and the "clean" part will be rejected in harbour waters.

.../...

The problem is to know how really clean this "clean" part could be. An investigation carried at some major tank cleaning stations in Western Europe seem to indicate that the "clean" part rejected in the harbour waters contains about 30 ppm of oil.

This could become a problem for harbours having an important crude oil traffic. Rotterdam receives presently about 1,000 crude oil tankers per year. This traffic would show a steady increase, the increase being more related to the size of the ships than to the number of the ships. Let suppose for example that Rotterdam would receive in 1975 :

Class	60	400 ships
	100	400
	210	200
	260	100

The effluent pumped ashore during washing operations at discharging berth would be, according to schedule 35 :

class	60	400 x 2,700	=	1,080,000 cu.m.
	100	400 x 4,800	=	1,920,000
	210	200 x 14,000	=	2,800,000
	260	100 x 18,000	=	1,800,000
				7,600,000 cu.m. per year

At a concentration of 30 ppm this represents about 230 t of oil rejected in the harbour waters per year.

It shall be remembered that this operation was conducted in order to prevent the rejection at sea of an amount of oil which in the example under consideration would have been (using figures of schedule 28) :

.../...

Class 60	400 x 2.1	=	840
100	400 x 3.2	=	1280
210	200 x 8.0	=	1600
260	100 x 10.0	=	1000
			4720 t

This means that instead of rejecting 4,720 t of oil at sea, 230 t will be rejected in harbour waters. This could be expressed also by saying that about 5 % of the oil which is not rejected at sea will be rejected in the harbours.

The problem is then to know wether this pollution of a confined area is not far worse than sea pollution.

Another problem of harbour pollution would be related with the disposal of sulfuric acid generated from the scrubbers of the inert gas installation. Rejection in the harbour water would compell neutralization.

However it should be emphasized that harbour waters are already heavily polluted by quite a number of effluents, the additional pollution contemplated here is probably small compared with the present situation.

As far as air pollution is concerned, it seems that the contemplated procedure would not lead to a worsening of the present situation. The amount of hydrocarbon gas sent into the atmosphere would not be different in this case than when the ship takes dirty ballast and displaces therefrom an equivalent volume of gas in the atmosphere.

The fact that the tanks will be clean when ballasting could even lead to a reduction of hydrocarbon gases sent to the atmosphere as compared with the present situation. This air pollution seems to be very small compared with the gas effluents of industrial installations and of ship stacks in harbour areas.

9. SUMMARY AND CONCLUSIONS

9.1. THE CRUDE OIL TRAFFIC IN 1975 AND 1980

The traffic to be taken into consideration in this study is clearly the crude oil traffic, as the petroleum products trade does not involve the same pattern of constraints related to discharging ports.
The number of ships and number of voyages for crude oil shipping have been assessed as follows for 1975 and 1980 :

	1975 (1)		1980 (1)	
	Nb ship	Nb voy.	Nb ship	Nb voy.
Class 60 (50/80,000 tdw)	373	6,000		
Class 100 (80/150,000 tdw)	423	5,500	450	7739
Class 210 (150/240,000 tdw)	321	2,200	410	3290
Class 260 (240/300.000 tdw)	184	1,200	285	2023
Class 320 (300/350,000 tdw)	14	100	50	331
Class 500			100	662

(1) Suez canal closed
(an alternative assessment has been made also for Suez canal opened).

.../...

9.2. POLLUTION INCURRED FROM CHANGE OF BALLAST

The operations of changing of ballast at sea generates pollution on three main counts :

(a) by rejection directly at sea of the main part of dirty ballast

(b) by rejection at sea of the overflow from "clean" slop tanks when dirty water is processed through slop tanks

(c) by rejection at sea of the effluents of the "reduction" of slops in order to reach loading port with slops containing minimum water.

The oil content in water rejected at sea has been taken at the level of 50 ppm for (a), 150 ppm for (b) and 200 ppm for (c). These values are the result of an investigation among shipowners. This is, of course, opened to discussion and agreement on accepted values seems to be desirable.

Therefore the total amount of oil rejected at sea per ship per voyage is as follows (average)

Class 60	2.1 t
100	3.2
210	8.0
260	10.0
320	13.3

This assessment is made in the assumption that all ships use the load on top procedure (involving processing via slop tanks) with full efficiency.

The multiplication of pollution per ship per voyage by the number of voyages previously established give the total worldwide pollution per year from the crude oil trade :

in 1975	61,000 t
in 1980	89,000 t

.../...

This appears to be less than estimated by certain authors and it is clearly resulting from the assumptions related to unit oil content of effluents.

9.3. POLLUTION INCURRED FROM PRE-REPAIR TANK CLEANING

Pre-repair tank cleaning is presently a very polluting operation because a great number of ships do not discharge their slops at the repair harbour. The experience at major repair yards in Southern Europe shows that up to 50 % of all ships arrive at the repair harbour completely cleaned including slop tanks.
This leads to a pollution 5 to 6 times that of routine changing of ballast. It seems therefore important that an adequate control should be applied in the future in order to prevent ships from discharging at sea all the residues and sludges when en route to repair yard.

9.4. CONTEMPLATED PROCEDURES FOR CLEAN BALLASTING AT DISCHARGING PORT

Three procedures can be contemplated :

Procedure A : after completion of discharging operations the ship undertakes washing of the tanks intended for ballast, then ballast.
In this case the safety requirements would impose that the washing operations are conducted under inert gas. This means that the shore has to supply inert gas when the ship is not herself equipped with an inert gas system.
This procedure involves also that the shore is able to receive the effluents from the ship when washing is undertaken.

Procedure B : The washing operation would be undertaken while discharging in order to complete those operations at the same time as discharging is completed. Thus no additional time would be spent alongside discharging pier.

.../...

This operation is presently impossible and would require that the ship is equipped with a new stripping system. Requirements for inert gas supply and receiving capacities for effluents are the same as for procedure A.

Procedure C : The ship takes minimum ballast after discharging and proceeds to separate berth where washing and change of ballast are undertaken. Part of the operation can also be made while the ship is anchored in the harbour area. This operation involves 50 % more time than procedure A and leads also to more additional expenditures for harbour facilities. Therefore this procedure can be disregarded off-hand and costs estimates have been prepared for procedures A and B only.

9.5. TIME REQUIREMENTS AND COSTS ESTIMATES

The main figures arrived at in this report are summarized in the following schedules :

9.5.1. Additional time alongside discharging berth (procedure A)

hours		Bad weather	Good weather	Average
Class	60	14	10	13
	100	19	10	15
	210	22	12	20
	260	24	13	22
	320	28	15	26

Average values are calculated by taking 60 % occurences of bad weather for ships of classes 60 and 100 and 80 % for ships of classes 210 and above.
This leads to the following increase in percentage, as compared with present duration alongside discharging pier :

class	60	44 %
	100	50 %
	210	62 %
	260	65 %
	320	72 %

9.5.2. Cost per ship per voyage for procedure A

US dollars	Class of ship				
	60	100	210	260	320
Immobilization of ship	2,700	6,300	16,800	24,600	36,400
Add. harbour charges	800	1,500	3,900	5,100	6,900
Reception of effluents	1,500	2,000	2,800	3,200	4,000
Total for inerted tanker	5,000	9,800	23,500	32,900	47,300
Inert gas supply	1,000	1,300	1,600	2,000	2,500
	6,000	11,100	25,100	34,900	49,800
Total average	5,700	10,600	24,300	33,700	48,300

Notes :

- immobilization of ship is calculated on the basis of time charter rates W 80
- additional harbour charges correspond to additional facilities required on account of longer duration alongside pier
- reception of effluents and inert gas supply correspond to additional services rendered by the shore
- total average is calculated by assuming that the percentage of inerted tankers in 1975 and beyond is 30 % for ships of class 60, 40 % for class 100, 50 % for class 210 and 60 % for class 260 and 320.

9.5.3. Cost per ship per voyage for procedure B

Immobilization of ship and additional harbour charges no longer apply, but a yearly equivalent related to additional equipment aboard the ship has to be taken into account.

US dollars	Class of ship				
	60	100	210	260	320
Add. stripping system	3,700	5,400	10,300	10,800	14,000
Reception of effluents	1,500	2,000	2,800	3,200	4,000
Total inerted tanker	5,200	7,400	13,100	14,000	18,000
Supply of inert gas	1,000	1,300	1,600	2,000	2,500
Total non inerted tanker	6,200	8,700	14,700	16,000	20,500
Total average	5,900	8,200	13,900	14,800	19,000

9.5.4. Other results related to costs

	procedure A	procedure B
Total annual cost worldwide (Million dollars)		
1975	190.2	130.8
1980	282.3	164.7
Cost per ton of transported tons of crude oil (US cents)		
1975	11.2	7.7
1980	11.3	6.6
Cost per ton of pollution prevention (US dollars)	3,170	2,180
Additional tanker fleet needed (percentage of fleet)	2 %	-

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9.6. MISCELLANEOUS CONSEQUENCES

a) Control and measurement appears to be difficult to implement. The only workable procedure would be to verify that washing operations are undertaken. Control of cleanliness of ballast would be unreliable.

b) The prevention of dirty ballasting would not prevent the polluting consequences of washing at sea tanks which do not contain dirty ballast or which are not intended for ballast. This problem is independant of ballasting procedures and would also apply to tankers equipped with an independant permanent ballast system. The prevention of washing cargo tanks at sea has to be examined.

c) Prevention of sea pollution would lead to harbour pollution. At least 5 % of oil not rejected at sea will be rejected in harbour waters. Harbour pollution may appear more damaging than sea pollution.

9.7. CONCLUSIONS

1. If interdiction of dirty ballasting upon leaving discharging port has to be adopted, the best and less costly procedure would be to equip ships, or at least ships above 150,000 tdw, with a new stripping system.
2. The cost of pollution prevention appears to be high.
3. The problem of washing cargo tanks at sea would remain.
4. Harbour pollution would increase.