An Outline of the Present Situation on Bulk Chemical Transportation in the Domestic Waters of Japan and the Implementation of MARPOL 73/78 Annex II†

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This paper discovers the peculiar chemical tanker fleet engaged in domestic water of Japan which is least familiar with internationally and introduces the efforts being made to solve the problems caused by the impact of the amended Annex II to MARPOL 73/78 and the Standards for the Procedures and Arrangements applicable to chemical tankers engaged even in domestic voyages only.

1. Introduction

Following the progress of petrochemical industries, the demands for the marine transportation of chemicals in the world have been increasing and chemical tankers have begun to play an important role in this area. Under such circumstances, Standards and Codes for chemical tankers have been considered in IMO both from the safety aspects and from the pollution prevention aspects.

According to the Lloyds' Statistics Tables (1984), the number of ships carrying bulk chemical cargoes in the world was 1,206, and the fleet totalled 6,474,089 G/T (the average gross tonnage = 5,400 G/T). Among them the number of ships carrying bulk chemicals in Japan was 400 and the fleet totalled 522,338 G/T (the average gross tonnage = 1,300 G/T). As can be seen from these figures, the main feature of Japanese chemical tankers is that their size is comparatively small. Most of them are engaged solely on domestic voyages.

In IMO, discussions have been made based mainly upon large chemical tankers that are engaged on international voyages, and the situation concerning small chemical tankers such as in operation in Japan has not been sufficiently understood in the discussion.

This paper describes the actual conditions of the domestic transportation of chemicals by chemical tankers in Japan, and explains how such small chemical tankers would cope with the requirements of MARPOL 73/78 Annex II.

2. Chemical Industry and Marine Transportation in Japan

2.1 The Current Situation of the Chemical Industry in Japan

The chemical industry is one of the largest manufacturing industries in Japan. Its total annual shipment in 1983 amounted to 19 trillion Japanese Yen or 75 billion US dollars (exchange rate: one US dollar = 255 Yen), which represents 8.2% of the total shipment of all the manufacturing industries in Japan.

The chemical industry in Japan has been ranked as one of the three major chemical industries in the world with sales amounting to US $73 billion behind the United States of America (US $169 billion) and the EEC (US $156 billion), according to a statistical survey of the CEFIC, 1982.

The petrochemical industry producing basic organic chemicals shares as much as 41% of all the chemical industry in Japan as shown in Figure 1; and it plays an important role in supplying raw materials to the other chemical industries. The reason for this is that the main feedstock for the chemical industry today is from oil rather than coal. The present total production capacity of ethylene in Japan, one of the most important raw materials for the organic chemical industry, is as much as 6.2 million tons a year.

We cannot ignore the inorganic chemical industry. The current total production capacity of caustic soda (sodium hydroxide) in Japan is 3.8 million tons a year and it is consumed by the chemical industry, the paper and pulp industry, the chemical fibre industry, etc. as one of the basic materials.

Table 1 shows the quantity of production, and the import and export of the main basic chemicals in the chemical industry in Japan in 1983.

The chemical factories and petrochemical complexes

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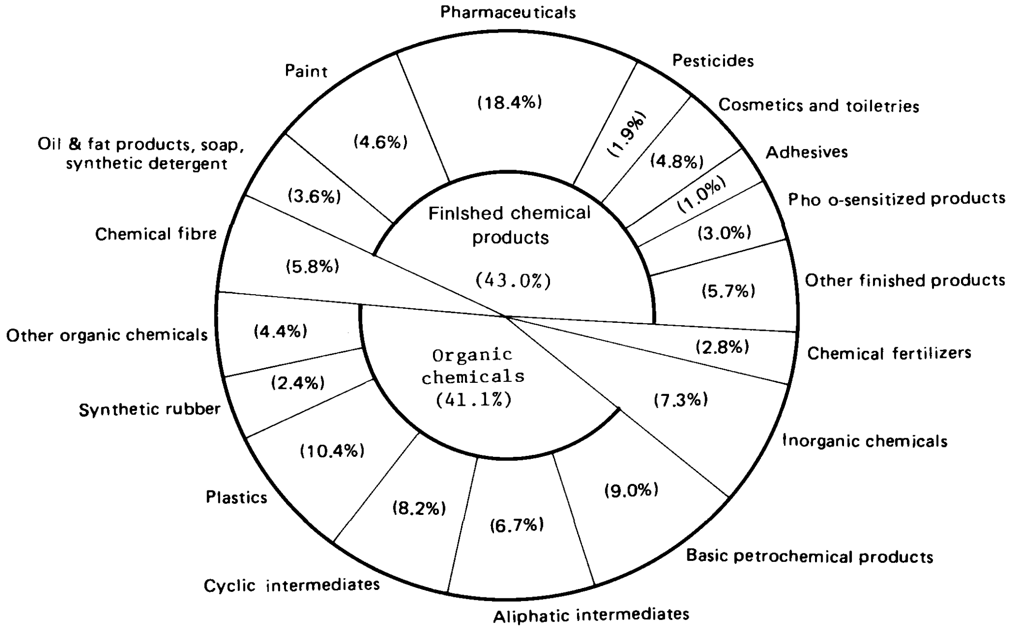
producing the raw materials, and using these raw materials to produce second or third chemical products, are mostly allocated on the sea side. Figure 2 shows the locations of 15 petrochemical complexes which are grouped into three areas, i.e. Tokyo Bay, Ise-Bey and Seto Inland Sea. Final chemical product industries are allocated in the Pacific Ocean Belt Zone, i.e. on the sea side zone between Tokyo and Osaka.



(Source: Ministry of International Trade and Industry of Japan)

Fig. 1. Composition of various chemical products in total shipment (1982)

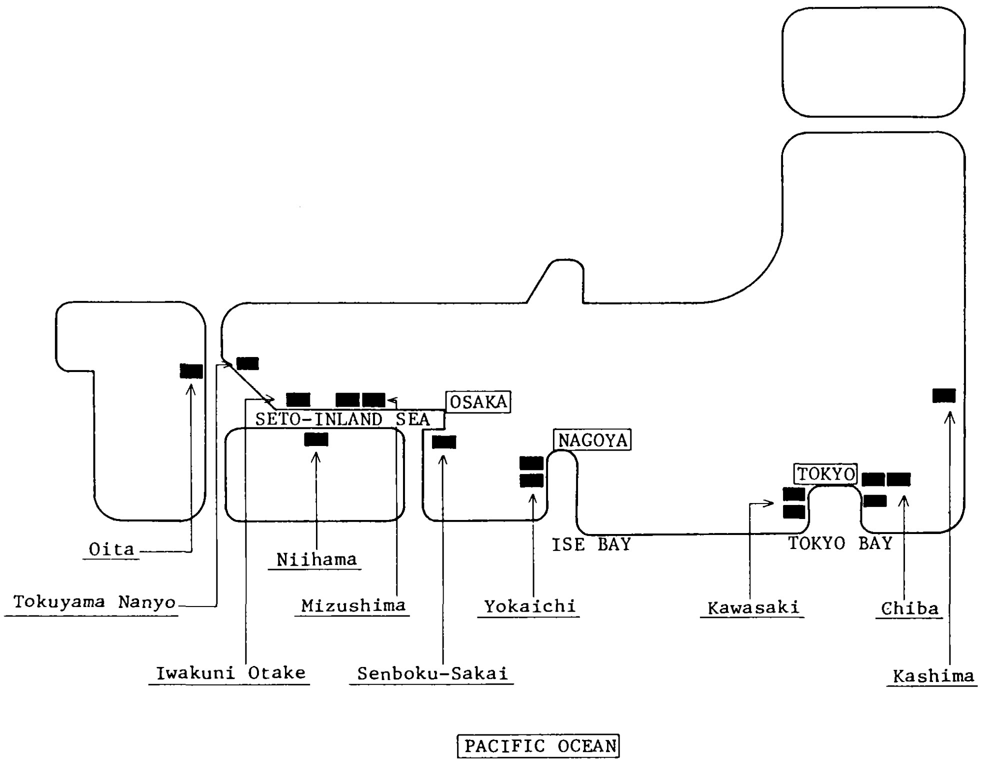


Fig. 2. The location of the 15 petrochemical complexes in Japan

Table 1 The main basis chemical production, import and export in Japan (1983)(unit: ton)

(a) Inorganic Chemicals

Chemical Name	Production	Import	Export
Ammonia aqueous	70 028 (100%, calculated)	—	12 95
Carbon disulphide	91 266	—	—
Sodium hydroxide	2 863 291 (97%, calculated)	10 225	129 488
Hydrochloric acid	1 600 302 (35%, calculated)	9 610	256
Hydrofluoric acid	157 283 (50%, calculated)	—	—
Hydrogen peroxide solution	85 072 (100%, calculated)	—	6 795
Nitric acid	550 887 (98%, calculated)	—	4 933
Sodium hypochlorite solution	882 489 (127%, calculated)	—	—
Sulphuric acid	6 661 754 (100%, calculated)	2 077	723 323

(b) Organic Chemicals

Chemical Name	Production	Import	Export
Acetic acid	325 208 (99%, calculated)	19 770	12 168
Acetone	247 445	21 873	21 686
Acrylonitrile	459 083	121 509	11 632
Alkylbenzene	180 333	—	—
Aniline	97 473	—	—
Benzene (pure)	1 938 004	Pure 384 Crude 15 296	96 351
Creosote oil	525 423	—	41 222
Cyclohexane	454 025	1 522	15
Ethylene dichloride	1 735 800	457 065	—
Ethylene glycol	357 471	158 691	21 779
Naphthalene (refined)	133 710	1 238	1 537
Phenol (synthetic)	271 279	—	—
Phthalic anhydride	742 025	4 313	21 738
Styrene monomer	1 167 198	118 725	2 024
Terephthalic acid	702 134	450	136 559
Toluene (pure)	855 958	10 959	89 554
Vinyl chloride monomer	1 572 877	—	72
Xylenes	1 270 433	108 728 Crude 36 833	29 848

2.2 The Transportation of Chemicals by Sea

Almost all the chemicals are transported in Japan by chemical tankers in bulk from manufacturers or stock points to consuming factories which are located on the sea side. Marine transportation of chemicals is preferable to rail/road transportation, not only due to the location of the chemical industry, but also due to the efficiency and cost of the transportation of a large quantity of chemicals.

Small size chemical tankers of less than 500 gross tonnage are engaged in chemical transportation in Japan. The chemical factories and stock points in Japan located on the sea side, required a limited quantity of chemical transportation at first, and pier facilities were constructed to meet the demand. In spite of the later expansion of the chemical industry, the capacities of the pier facilities have remained unchanged, and the transportaion of chemicals in lots of 500 tons has continued and become the commercial practice.

Table 2 shows the list and the quantity of chemical products transported in bulk by chemical tankers engaged in domestic services in Japan.

3. Chemical Tankers Engaged in Domestic Services in Japan

3.1 Sizes of Chemical Tankers Engaged in Domestic Services in Japan

As shown in Table 3 there are 509 chemical tankers engaged in domestic services and 90% of them have a gross tonnage of less than 500 and even 57% of them have a gross tonnage of less than 200. Figure 3 shows that these small chemical tankers are the main feature of chemical transportation in Japan.

3.2 Kinds of Chemical Tankers

The chemical tankers engaged in domestic service in Japan are grouped into two kinds, i.e. general chemical tankers and dedicated chemical tankers.

3.2.1 General chemical tankers

A general chemical tanker means a chemical tanker designed for the carriage of any liquid chemical cargo in bulk. It can carry various cargoes but on one voyage the simultaneous carriage is limited to one or two kinds of substance because for a small chemical tanker the carrying capacity is limited and parcel carriage is not economical. Mini size tankers of less than 200

Table 2 The quantities of bulk chemicals transported by chemical tankers engaged in domestic services in Japan, 1983

No.	Substance	Pollution category	Quantity of transportation (tons)
1	Sulphuric acid	C	3 360 753
2	Sodium hydroxide solution	C	3 007 442
3	Xylenes	C	784 894
4	Coal tar	—	676 987
5	Styrene monomer	B	675 790
6	Benzene	C	648 042
7	Methyl alcohol	Ⅲ	588 746
8	Ethylene glycol	Ⅲ	588 103
9	Sulphur liquid	Ⅲ	569 473
10	Toluene	C	444 700
11	Paraxylene	C	262 691
12	Acetic acid	C	224 044
13	Acrylonitrile	B	206 762
14	Hydrochloric acid	D	198 810
15	Ethylene dichloride	B	196 474
16	Creosote (Coal tar)	C	178 352
17	Cumene	B	139 537
18	Cyclohexane	C	137 350
19	Alkylbenzene	D	129 028
20	Ethyl alcohol	Ⅲ	117 275
21	2-Ethyl hexanol	C	115 724
22	Acetone	Ⅲ	104 867
23	Others		8 097 027
	Total		21 452 871

Source: Results of researches carried out by the All Japan Domestic Tanker Owners Association and the Japan Association for Preventing Marine Accidents

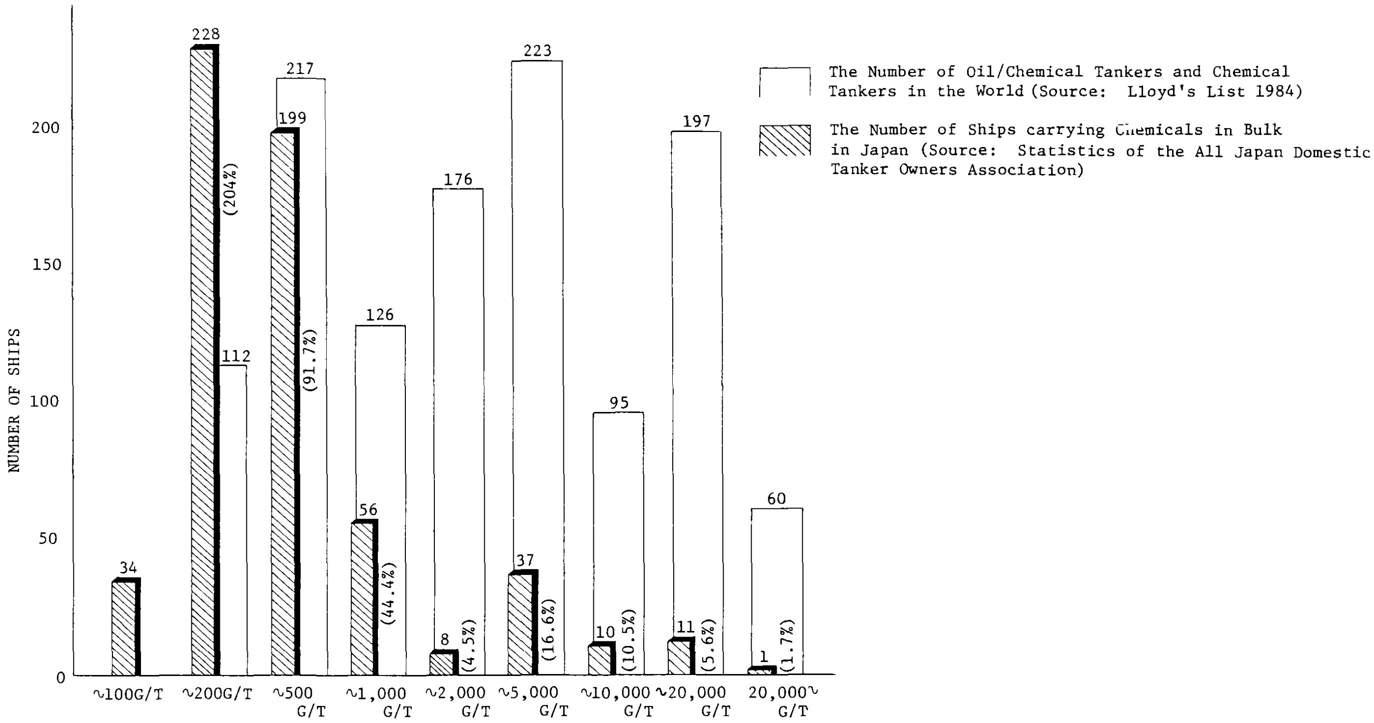


Fig. 3. The comparison between the number of chemical tankers in the world and that of Japan

Table 3 The list of registered chemical tankers engaged in domestic services in Japan

Kind / Gross Tonnage	General Chemical Tanker			Dedicated Chemical Tanker					Total	
	Coastal service	Limited coastal	Sub-total	Pressure tank	Molten	Corrosive	High qual.	Sub-total		
~ 100		1	44			30	3	218	34	262
~ 200	35	8	(8.6)	1	2	167	15	(42.8)	228	(51.5)
~ 300	18				1	11	4		34	
~ 400	18		104			15	3	95	36	199
~ 500	68		(20.4)	3	15	26	17	(18.7)	129	(39.1)
~ 600	2		16	2		1		22	5	38
~ 700	14		(3.1)	1	7	11		(4.3)	33	(7.5)
~ 800										
~ 900			1					5		6
~ 1 000	1		(0.2)		3	2		(1.0)	6	(1.2)
~ 1 100	1								1	
~ 1 200										
~ 1 300										
~ 1 400	1				1				2	
~ 1 500			2					2		4
~ 1 600			(0.4)			1		(0.4)	1	(0.8)
~ 1 700										
~ 1 800										
~ 1 900										
~ 2 000										
~ 3 000										
~ 5 000										
~10 000										
	158	9	167	7	29	264	42	342	509	
Total	167 (32.8%)			342 (67.2%)					(100%)	

Source: Statistics of The All Japan Domestic Tanker Owners Association

Table 4 The list of dedicated chemical tankers

Kind of cargo	Substance	Gross Tonnage					Sub-total	Total
		~200	~500	~700	~1 000	~1 000		
High press.	Acetaldehyde	1	2	1			4	7
	Propylene oxide		1	2			3	(2%)
Molten	Anthracene	1	3	1			5	
	Sulphur liquid		5	4	2		12	
	Phthalic anhydride		4				4	
	Naphthalene molten			1		1	2	29
	Caprolactam		2				2	(8.5%)
	Phenol		2	1			3	
	Coal tar pitch molten				1		1	
Corrosive	Sulphuric acid	61	11	9	1		82	
	Sodium hydroxide solution	54	14	3		1	72	
	Hydrochloric acid	24	5				29	
	Acetic acid	6	12				18	
	Nitric acid	11	5				16	
	Phosphoric acid	6	1				7	
	Acid mixture	3					3	
	Sulphuric acid spent	3					3	
	Sodium hypochlorite solution	10					10	
	Sodium hydrosulphide solution	4					4	264
	Aluminium disulphate solution	3			1		4	(77.2%)
	Hydrogen peroxide solution 60%	1	2				3	
	Ammonia aqueous	3					3	
	Bleaching liquor	2					2	
	Aluminum sulphate	2					2	
	Calcium chloride	2					2	
	Ferric chloride solution	1					1	
	Sodium hydrogensulfide		1				1	
	Chlorosulphonic acid		1				1	
High quality	Glycerine							
	Ethylene glycol		13				13	
	Carbon disulphide	5	1				6	
	Formaldehyde solution	3					3	
	Epichlorohydrin	2	1				3	
	Toluene diisocyanate							
	Diphenylmethane diisocyanate	1	2				3	
	Magnesium hydroxide	3	2				5	42
	Aniline		2				2	(12.3%)
	Acetone cyanohydrin		2				2	
	Dinitrotoluene	1					1	
	Chlorobenzene	1					1	
	Acrylamide solution		1				1	
	Fatty acids	1					1	
	Sodium dichromate	1					1	
Total (number)		218	95	22	5	2	342	
(%)		63.8	27.8	6.4	1.4	0.6	100	

Source: Statistics of The All Japan Domestic Tanker Owners Association gross tonnage are indispensable for the transportation of chemicals on a river or into a small bay.

The general chemical tankers normally carry petrochemicals and organic compounds and cargo tank washing is required before the subsequent loading of another cargo. Such chemical tankers will be mostly affected when MARPOL 73/78 Annex II and P & A Standards are implemented.

Figure 4 shows a typical example of the general chemical tanker.

3.2.2 Dedicated chemical tankers

A dedicated chemical tanker means a chemical tanker exclusively chartered by a chemical factory or a shipper to transport its particular cargo. Table 4 shows the list of dedicated chemical tankers and their cargo. The cargoes are grouped into the following four kinds:

1. Substances of high vapour pressure at ambient temperatures which are carried in pressure tanks or at low temperatures.
2. Molten substances which are carried at high temperatures.
3. Corrosive substances which require corrosion-resistant materials and devices.
4. High quality substances which are required to maintain their high quality during the voyage.

Such a dedicated chemical tanker is prohibited by national law from carrying water ballast in cargo tanks or washing the cargo tanks, except when specially permitted. Any residue in the cargo tanks after unloading is left in the tanks. Efficient stripping or extensive reduction of residues in cargo tanks which is one of the main features of MARPOL 73/78 Annex II and P & A Standards is not relevant to this operation mode.

Figures 5, 6 and 7 show examples of dedicated chemical tankers.

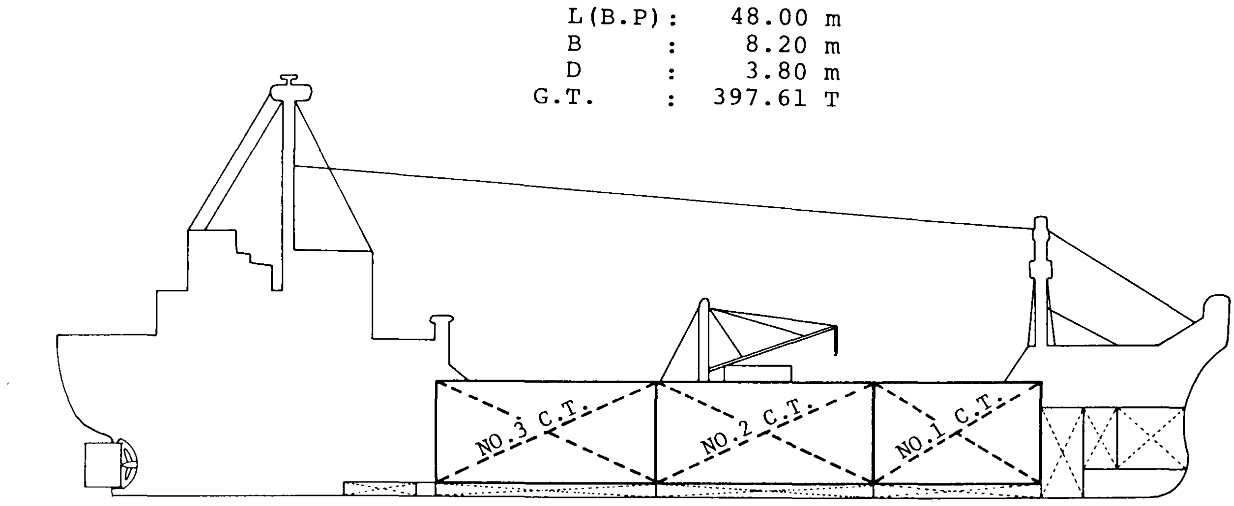


Fig. 4. Typical type of general chemical tanker

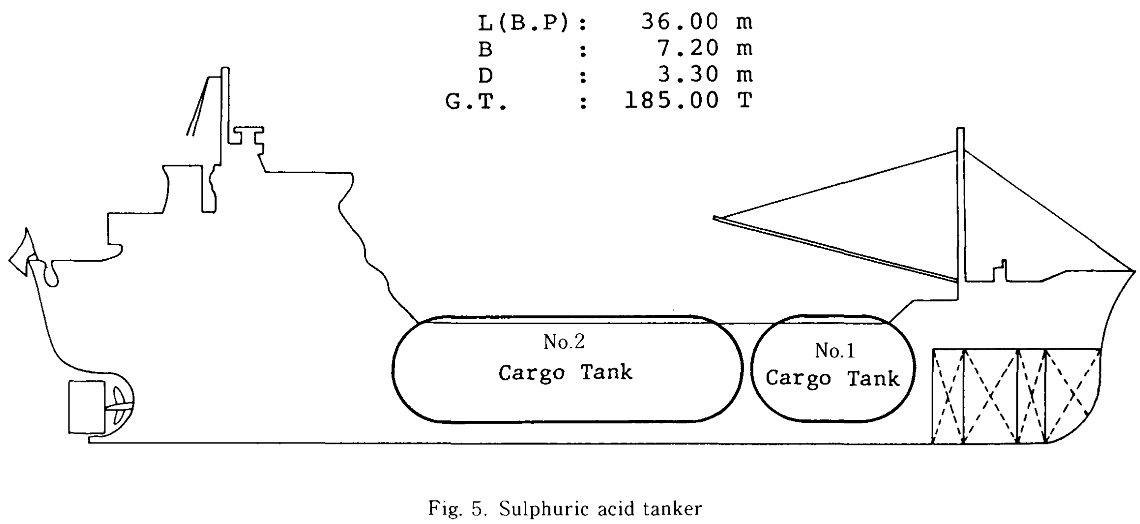


Fig. 5. Sulphuric acid tanker

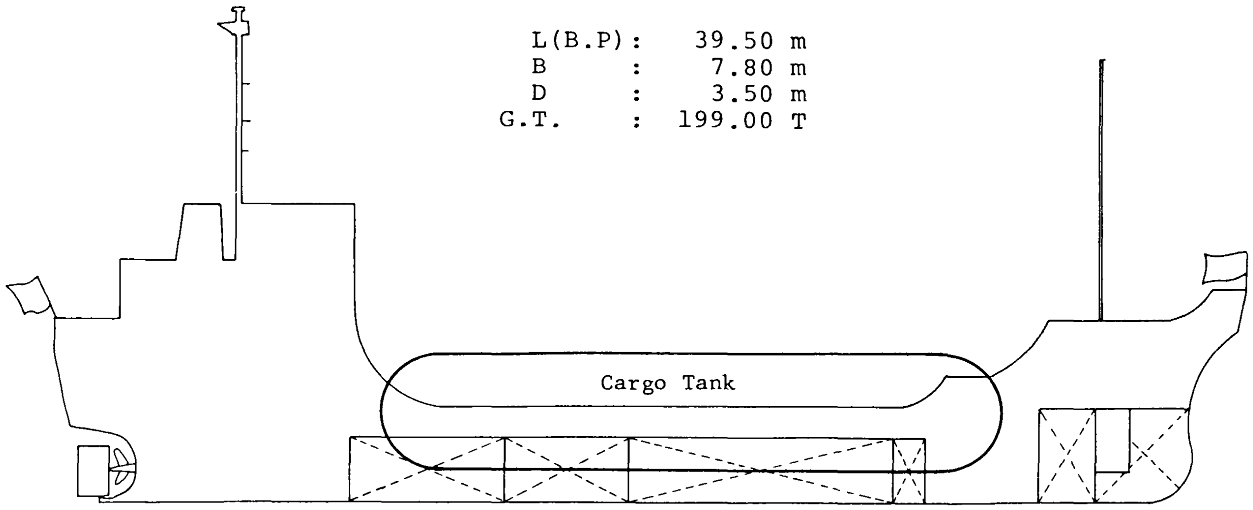


Fig. 6. Acetaldehyde tanker

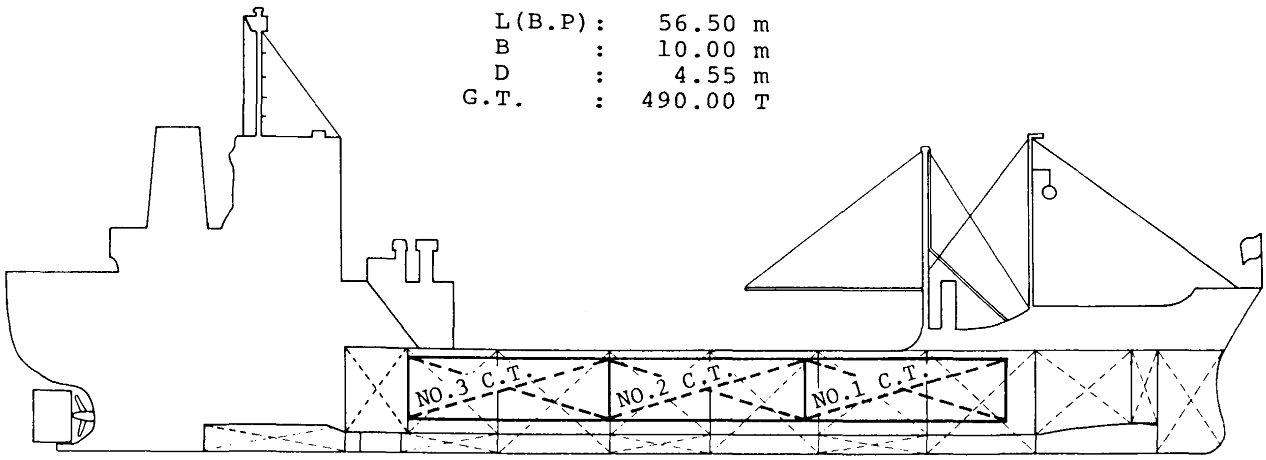


Fig. 7. Sulphur (liquid) tanker

3.3 The Navigation Area and the Impact of MARPOL 73/78 Annex II

3.3.1 The navigation area of chemical tankers for domestic services in Japan

The navigation areas of chemical tankers for domestic services in Japan are grouped into two, i.e. calm water area and coastal area. The chemical tankers of less than 200 gross tonnage are mostly engaged in calm water areas, i.e. in a bay and estuaries. Other chemical tankers of less than 500 gross tonnage are engaged in coastal areas and they normally navigate along the coastline two or three miles from the land.

Figure 8 shows the normal navigation route in the coastal areas within a 12 mile zone. In this zone it is forbidden to discharge noxious substances and water mixtures into the sea according to MARPOL 73/78 Annex II.

The coast of Japan is subject to frequent stormy weather. When MARPOL 73/78 Annex II prohibiting ships within 12 nautical miles of the nearest land from discharging waste water resulting from tank washing is implemented, it will severely affect the small chemical tankers engaged in coastal navigation off Japan.

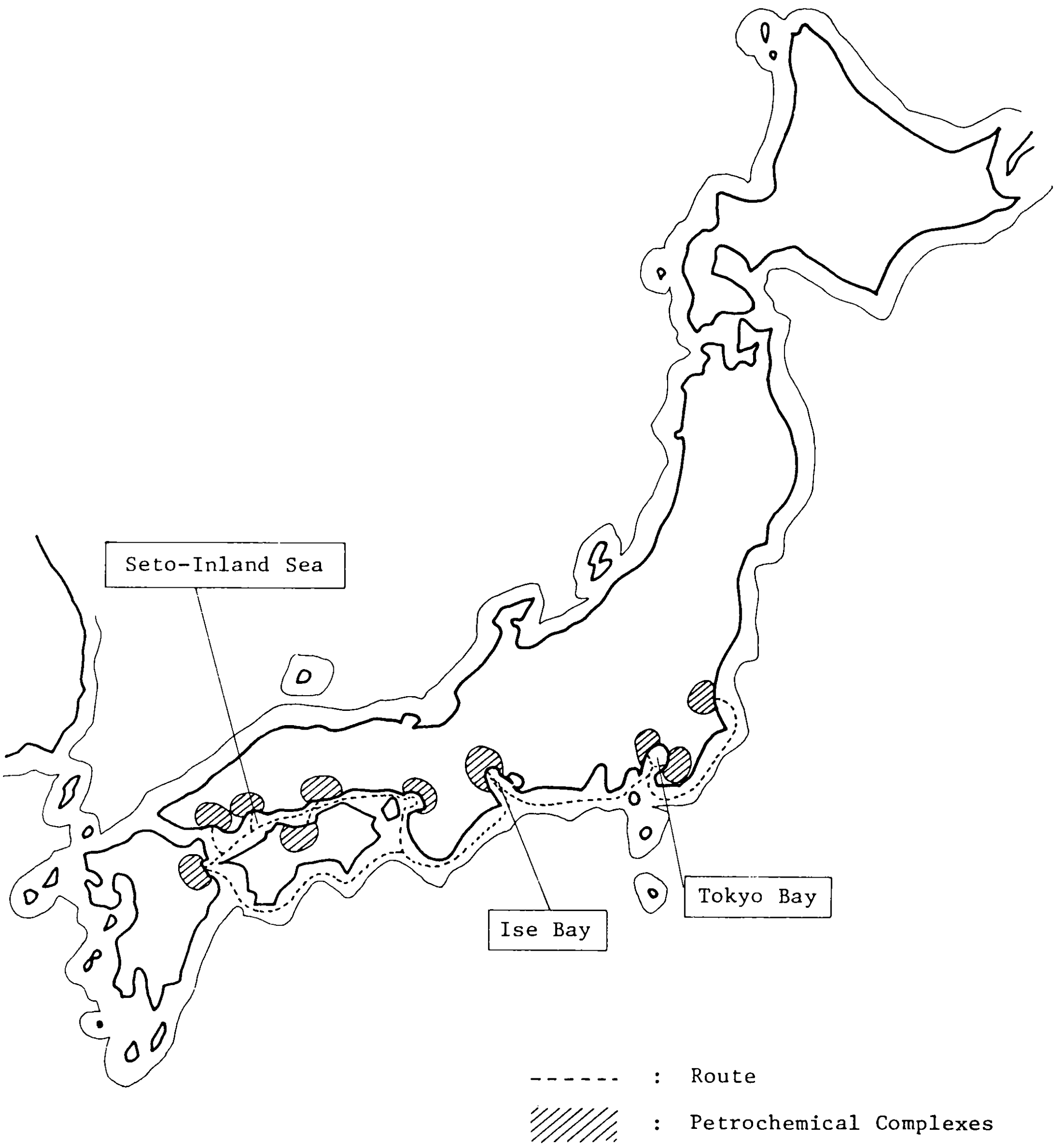


Fig. 8. The 12 mile zone and the main routes of domestic chemical tankers in Japan

3.3.2 The impact of MARPOL 73/78 annex II on small chemical tankers engaged in domestic services in Japan

All chemical tankers, regardless of their tonnage or navigating area, are regulated by MARPOL 73/78 Annex II and the BCH Code or the IBC Code as applicable. Small chemical tankers below 500 gross tonnage are treated in the Convention and the Code in the same way as larger chemical tankers. As shown in Table 3 and Figre 3 as many as 461 small chemical tankers below 500 gross tonnage are engaged in domestic services in Japan. As we can see from Figure 3 these are almost all of the chemical tankers below 500 gross tonnage currently operating in the world.

MARPOL 73/78 Annex II and P & A Standards have been amended and the concept of an efficient stripping system has been introduced to reduce the workload of seafarers in the discharge operation of noxious substances and water mixtures into the sea, and to minimise the required reception facilities which must be constructed before the implementation of MARPOL 73/78 Annex II.

The owners of small chemical tankers are making a great effort firstly to reduce the stripping quantity to 10 litres or less per tank to make tank washing easier, secondly to minimise the pollution of the marine environment, and finally to reduce the demand for shore reception facilties. However, if those seafarers refuse to navigate more than 12 nautical miles from the land, because of the safety reasons; even though the shipowners are making efforts to minimise the stripping quantity, this will not lead to a reduction in demand for shore reception facilities.

4. Preparation for the Implementation of MARPOL 73/78 Annex II from the Technical Aspects

4.1 Construction and Equipment of Chemical Tankers

4.1.1 The requirements of construction and equipment

Chemical tankers carrying noxious liquid substances of Categories A, B or C as specified by MARPOL 73/78 Annex II are required to comply with the BCH Code or the IBC Code as applicable according to Regulation 13 of MARPOL 73/78 Annex II. They are also required to satisfy the hardware requirements of MARPOL 73/78 Annex II, such as an efficient stripping system below waterline discharge arrangements, tank washing systems, etc. depending on the toxicity and viscosity of the substances carried. Existing chemical tankers carrying Category B substances not fitted with an efficient stripping system are required to be fitted with a discharge recording device and a flow meter in place of the efficient stripping system.

The constructional requirement which seriously affects the design of small chemical tankers engaged in domestic water services is the ship type requirement, i.e. the damage stability requirement specified by the BCH Code or the IBC Code. Two special arrangements are required by MARPOL 73/78 Annex II and P & A Standards; they are an efficient stripping system and a below waterline discharge arrangement.

4.1.2 Tank arrangements to comply with the damage stability requirement

Though most of the chemical tankers engaged in domestic water services in Japan are as small as 500 gross tonnage or less, new tank arrangements have been required to meet the damage stability requirement of the BCH or the IBC Code as applicable constructed on or after 1 July, 1983.

Figure 9 shows the tank arrangements and midship section of a small chemical tanker of 499 gross tonnage satisfying the ship type 2 requirements of the IBC Code. This chemical tanker mainly carries ship type 2 and/or 3 products. Smaller wing void tanks are arranged to allow sufficient carrying capacity for products of a cargo density of 800 kg/m^3 while the intended products have a cargo density ranging from 700 kg/m^3 to 1500 kg/m^3. The small wing tanks and double bottom tanks are designed so that their length is half that of the cargo tanks to minimise the loss of residual stability after sustaining assumed damage.

Figure 10 shows the tank arrangements and midship section of a small chemical tanker of 499 gross tonnage also satisfying the ship type 3 requirements of the IBC Code. This chemical tanker mainly carries ship type 3 products. Larger wing void tanks are arranged to allow carriage of heavy products of a cargo density ranging from 1200kg/m^3 to 1800kg/m^3. Non-watertight centreline girders are provided in the double bottom tanks to minimise the angle of heel due to unsymmetrical side damage.

The successful study on the tank arrangements to comply with the requirement of damage stability has enabled small chemical tankers to be designed which meet the provisions of the BCH Code or the IBC Code referred to in Regulation 13 of MARPOL 73/78 Annex II.

4.1.3 The efficient stripping system

Efficient stripping systems have been developed for small chemical tankers fitted with common cargo pumps in the cargo pump room with satisfactory operational results. As the system is simple and effective most of the existing chemical tankers engaged in domestic water services will prefer the efficient stripping system. This enables the straightforward discharge of noxious liquid substances contained in tank washings into the sea, as opposed to the mandatory prewash required for ships not fitted with the means of achieving the stripping quantity of 0.3 m^3 or 0.9 m^3 for Categories B or C substances respectively. The system is also capable of achieving the stripping quantity of 0.1 m^3 or below to meet the residue requirements for new ships.

Figure 11 shows an example of the efficient stripping system fitted onboard a small double bottom chemical tanker *Santen Maru* of 199 gross tonnage. A small diameter stripping line (25A) extending from the main suction line to the suction well of each cargo tank minimizes the cargo residues in the tank. Another small diameter discharge line fitted to the bottom of the pump strainers enables the pressure discharge of the cargo residues in the main discharge lines. This is achieved when nitrogen gas is introduced into the main discharge line near the manifolds. The actual stripping test onboard with a cargo (mixture of 60% of toluene and 40% C6-C8 saturated hydrocarbon) has proven that little cargo residue was remaining in cargo pumps, strainers, and discharge pipings.

Figure 12 shows another example of the efficient stripping system fitted onboard a small double bottom chemical tanker *Ryoka Maru No. 5* of 699 gross tonnage. Cargo residues in the tanks are collected in cargo tank No. 5(S) through stripping lines connected to the eductor on deck. The collected cargo residues are discharged ashore with a stripping pump and the associated small diameter discharged line (32A). The stripping pump also serves to discharge ashore the cargo residues in cargo pumps, strainers and main discharge lines. A water test carried out on the ship has shown that the quantity of residues in the vicinity

PRINCIPAL PARTICULARS

LENGTH	(O.A)	$64^{M}40$
"	(B.P.P)	$60^{M}00$
"	(0.96LWL)	$59^{M}14$
BREADTH	(M^{LD})	$10^{M}00$
DEPTH	(")	$4^{M}80$
DRAFT	(") (DESIGNED)	$3^{M}60$
FRAME SPACE		$0^{M}60$

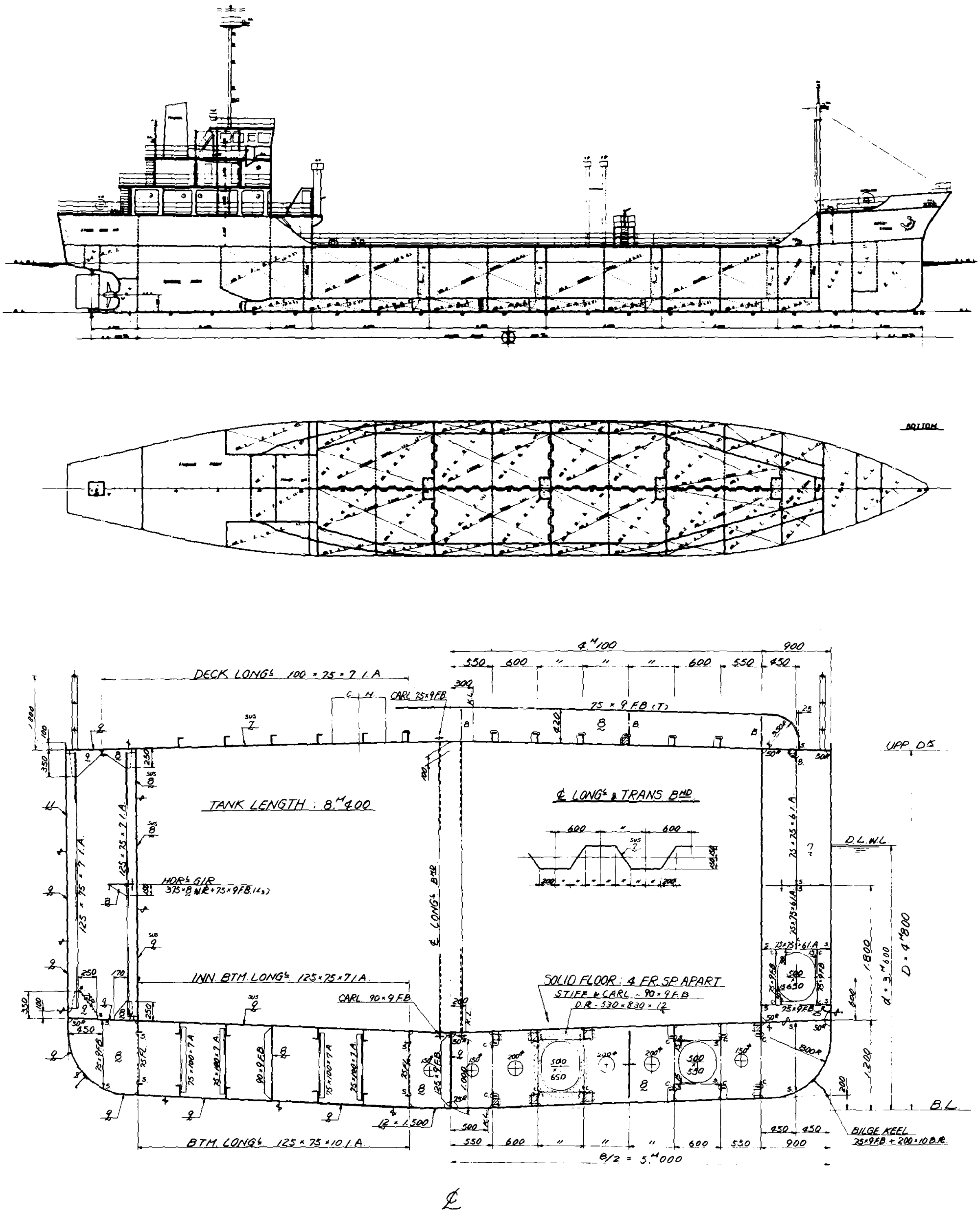


Fig. 9. 499 G/T Type 2 ship

PRINCIPAL PARTICULARS

LENGTH (O.A)	$64^{M}40$
" (B.P.P)	$60^{M}00$
" (0.96LWL)	$59^{M}40$
BREADTH (M^{LD})	$10^{M}00$
DEPTH (")	$4^{M}75$
DRAFT (") (DESIGNED)	$4^{M}00$
FRAME SPACE	$0^{M}60$

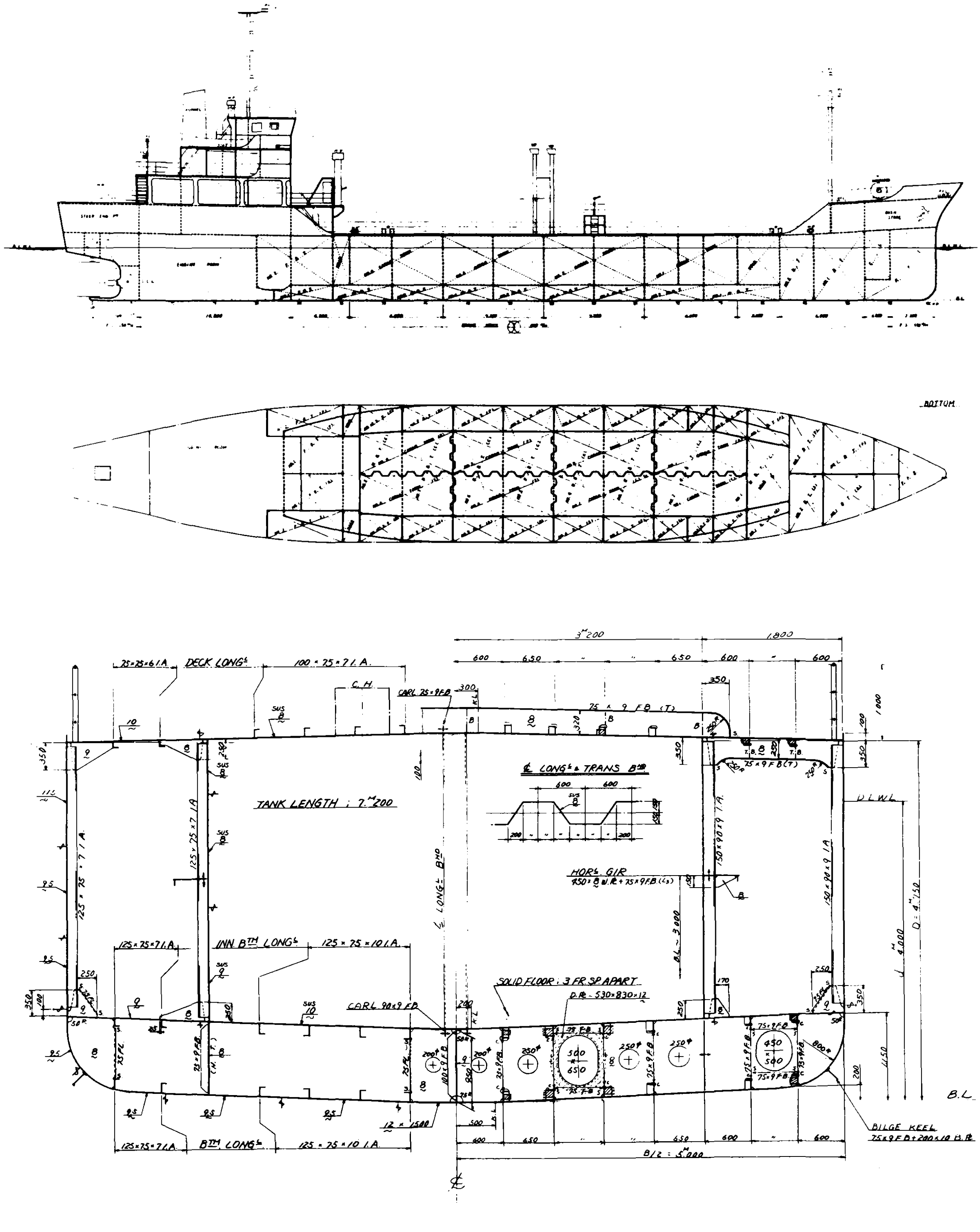


Fig. 10. 499 G/T Type 3 ship

Ship Name	Santen Maru
Year of Delivery	1977
Gross Tonnage	199.38 tons
Lpp × B × D	43.52 m × 7.50 m × 3.40 m
Carrying Capacity	641.4 m²
Bottom Construction	Double Bottom with Suction Wells
Cargo Pumps Type Capacity × Number	 Gear Pump 150 m²/ h × 7 bar × 2 scts 120 m²/ h × 7 bar × 1 set
Suction Line Diameter in Tank	Suction Main Line: 100mm
Note	Small diameter (25mm) discharge lines have been newly fitted for efficient stripping.

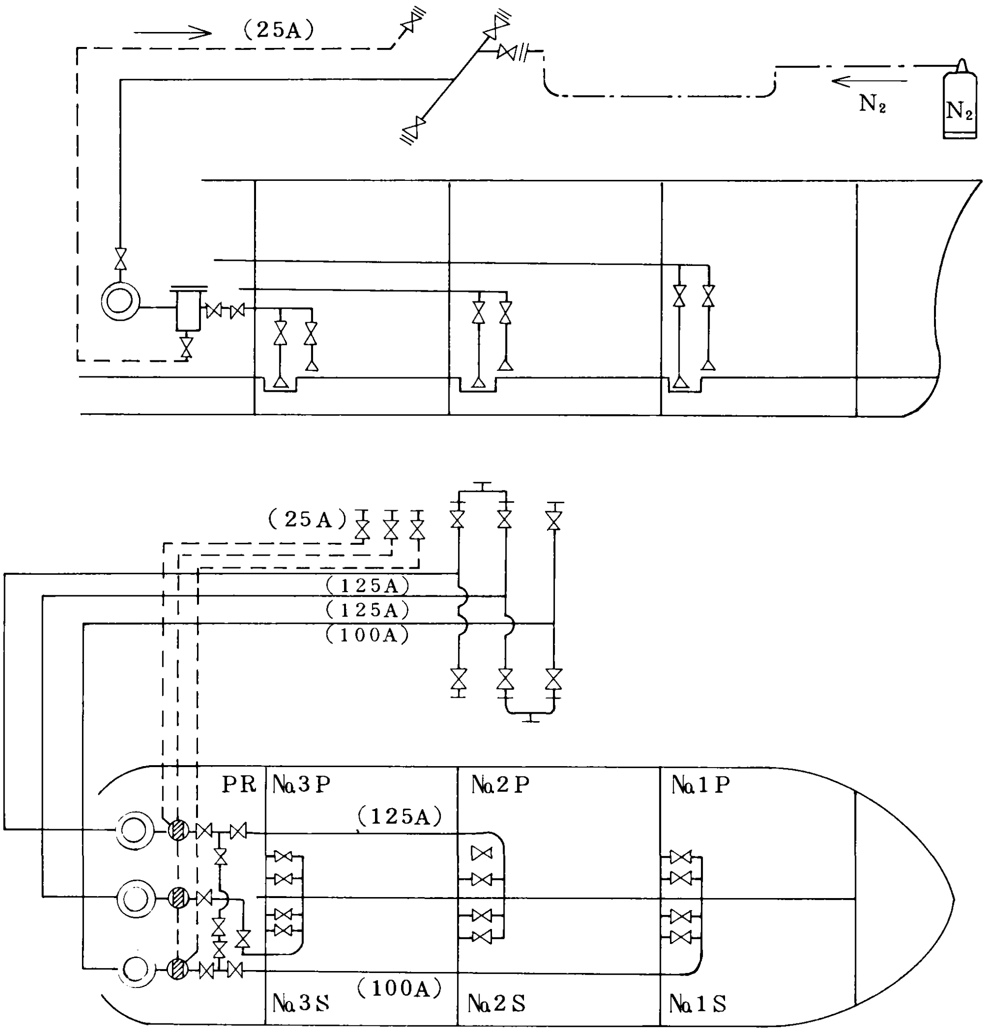


Fig. 11. Particulars and piping diagram of Santen Maru

Ship name	Ryoka Maru No. 5
Year of Delivery	1977
Gross Tonnage	697.16 tons
Lpp × B × D	69.00 m × 10.50 m × 5.00 m
Carrying Capacity	1,637.9 m²
Bottom Construction	Double Bottom with Suction Wells
Cargo Pumps Type Capacity × Number	 Screw Pump 350 m³/h × 7 bar × 2 sets
Stripping Pumps Type Capacity × Number	 Piston Pump 5 m³/h × 5 bar × 1 sets
Suction Line Diameter in Tank	Suction Main Line: 200mm Ejector Suction Line: 25mm*
Note	*Newly fitted with ejector type stripping system for cargo tanks. Cargo pumps and strainers are stripped with a separate stripping pump.

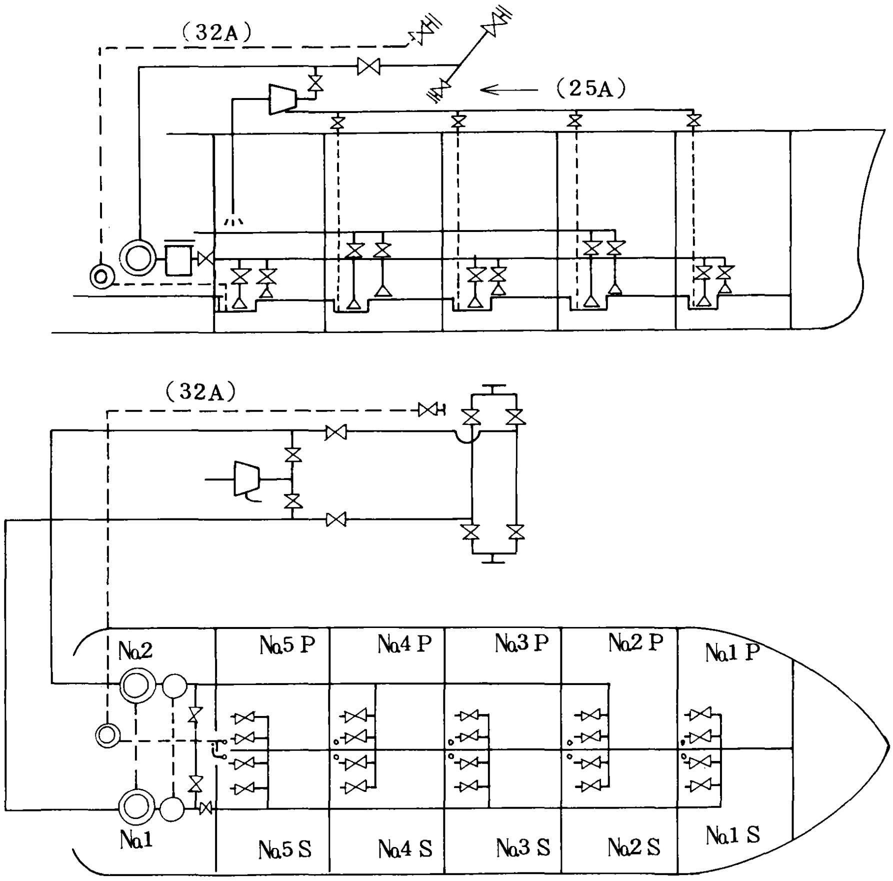


Fig. 12. Particulars and piping diagram of Ryoka Maru No. 5

of the suction wells of cargo tanks Nos. 1 to 4 was 0.3 litres in each. The total quantity of residues in the cargo pumps, strainers and main discharge lines, in addition to the residues in the vicinity of the suction wells of cargo tanks No.5 port and starboard sides, was a remarkable 10.8 litres.

These efficient stripping systems described above are proven systems applicable to the chemical tankers engaged in domestic water services in Japan. The systems are applicable not only to new ships but also to existing ships with minor modifications to the piping system.

4.1.4 Below waterline discharge outlet

The diameter of the below waterline discharge outlet for use in discharging cargo residue and water mixtures is specified by P & A Standards in order not to pass through the ship's boundary layer. The formula for calculating the diameter is as follows:

$$D = \frac{Q_D \cdot \sin\theta}{5L}$$

Where :

D =the minimum diameter of the discharge outlet, m

L =the distance from the forward perpendicular to the discharge outlet, m

Q_D =the maximum rate selected at which the ship may discharge residue/water mixture through the outlet, m^3/h

θ =the angle between the discharge direction and the vessel's hull, $0 < \theta \leqq 90$ (deg).

A small chemical tanker of 699 gross tonnage, for example, fitted with below waterline discharge arrangements of D, L and Q_D, as given below, is required to have the discharge outlet angled at about 7° to the vessel's hull, i.e. almost parallel to the hull.

$D = 0.2m$
$L = 45.0m$
$Q_D = 350m^3/h$

Baffles have been developed as shown in Figure 13 to angle the discharge direction and the effectiveness has been proven by model tests.

4.2 The Attempted Design of a Shore Reception Facility for Noxious Liquid Substances from Ships

4.2.1 Study of model plant

Basic study was carried out into the disposal method adoptable at the shore reception facility for cargo residues, tank washings, slops, and ballast water, carried in the cargo tanks of chemical tankers. A general design of a model plant was drawn as a result of the basic study.

Figure 14 shows the disposal block diagram and Figure 15 the general arrangement of the model plant.

The principal installations are as follows:

(1) Storage tanks

Four groups of storage tanks are provided to facilitate the subsequent processing, i.e. for non-chloric substances, chloric substances, substances suitable for incineration and diluted or neutralised substances.

(2) Stripping equipment

Stripping equipment with steam heating serves to separate the received substances into oily water and other substances. This reduces the demand for biochemical oxygen (BOD). The equipment is located between the storage tank and the activated sludge disposal equipment. The equipment processes non-chloric substances and chloric substances separately to avoid the difficulties of separation due to the mutual solution when processed together.

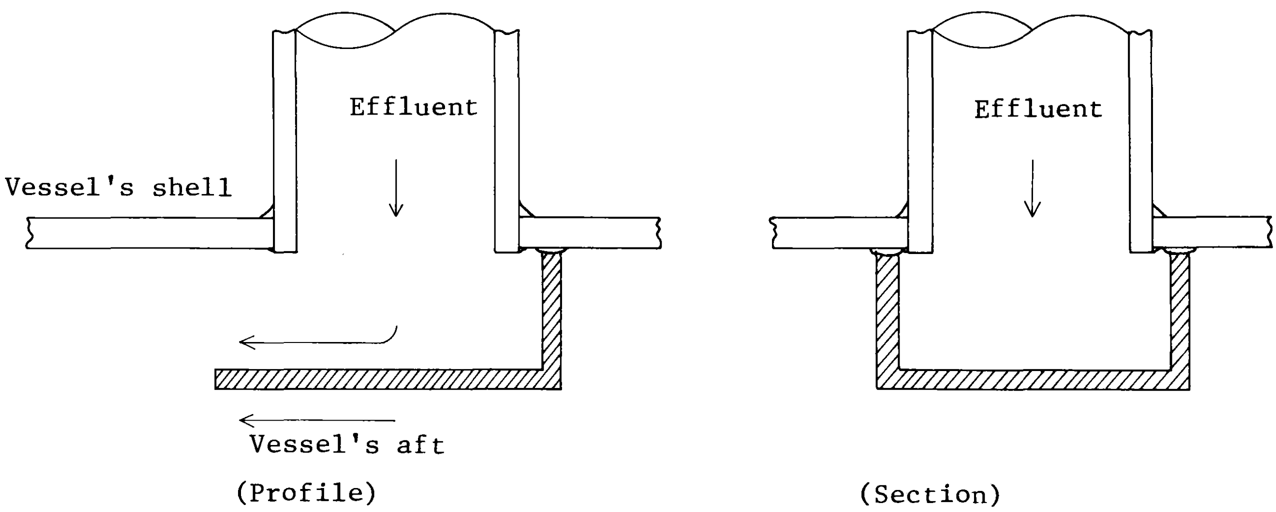


Fig. 13. Construction of a baffle

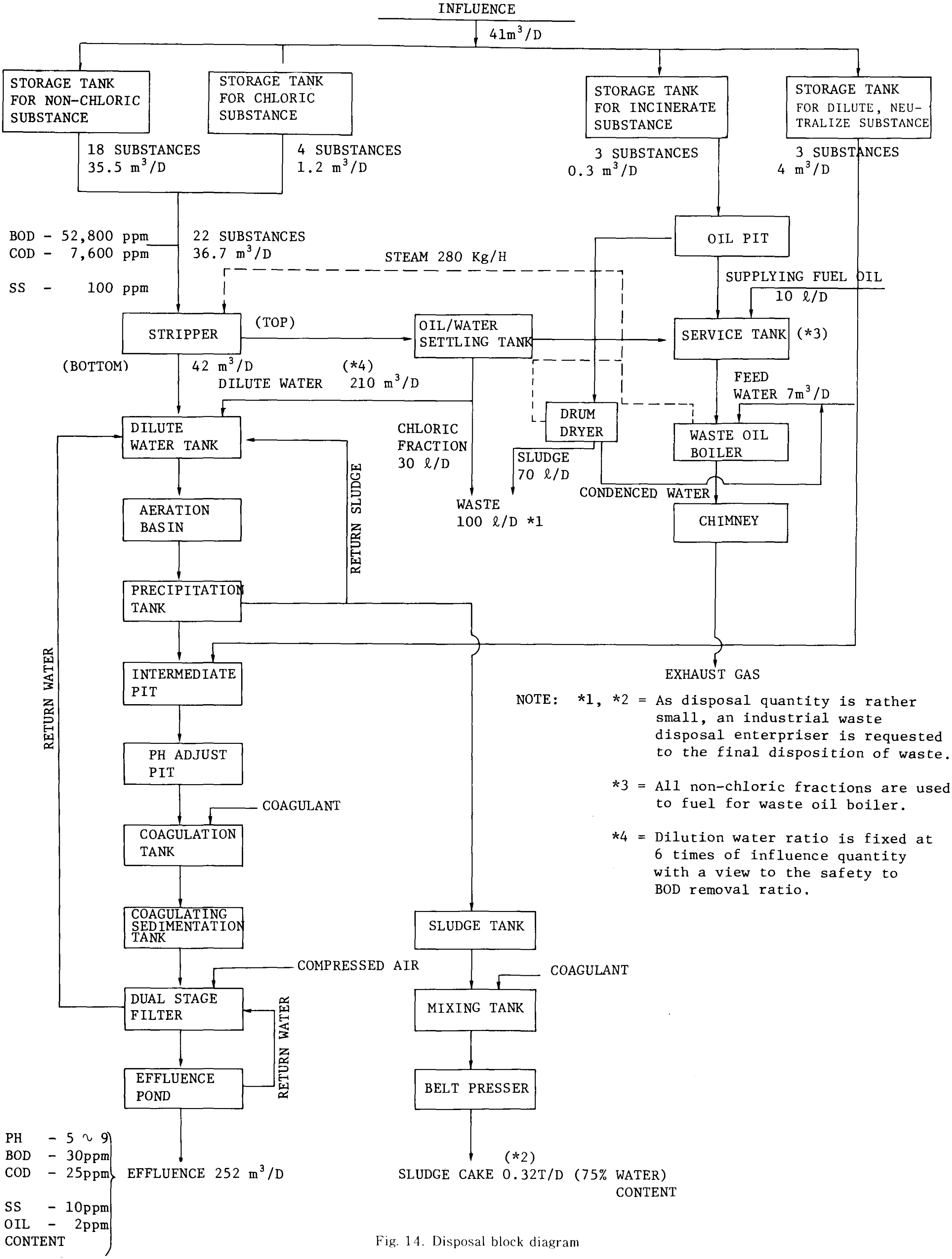
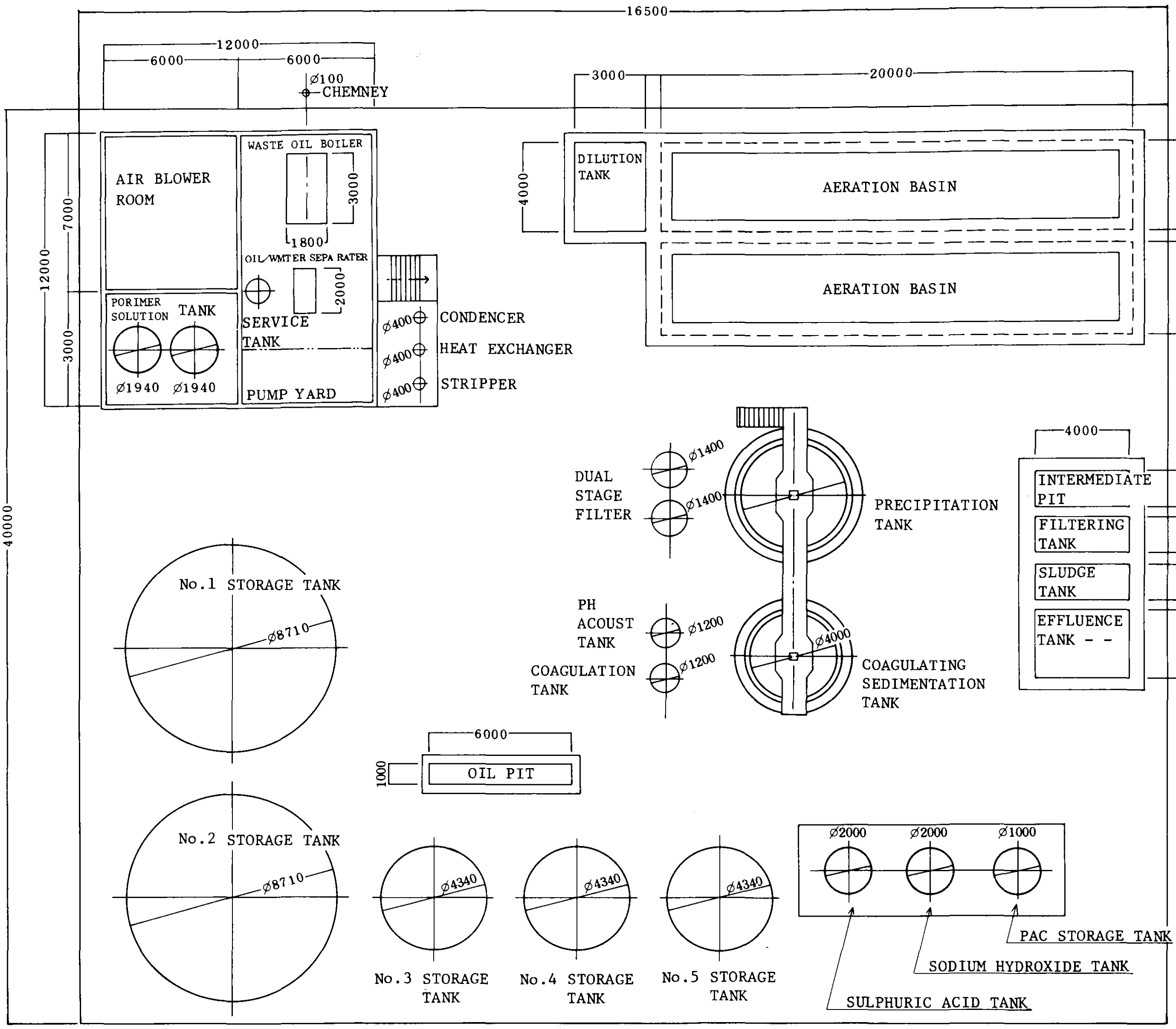


Fig. 14. Disposal block diagram



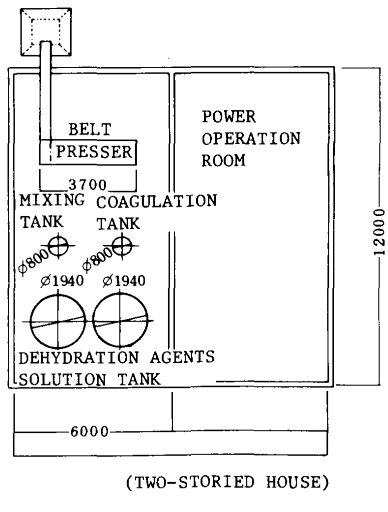


Fig. 15. General arrangement of model plant

(3) pH adjust tank

The pH adjust tank is located between the precipitation tank and the coagulation tank. This tank adjusts the pH of the substances contained in the storage tank. These substances are diluted and neutralized.

(4) Coagulating sedimentation tank and dual stage filters

The coagulating sedimentation tank and dual stage filters serve to reduce the content of suspended solids in solution to 10 ppm or less. They are used in the final stage of the disposal of the received effluents.

(5) Disposition of oil pit for incineration

Substances in slurry condition in the oil pit are led to the drum dryer where the water component is vaporised and the remaining sludge is disposed normally by incineration.

4.2.2 Capacity of mode plant

Table 5 shows the outcome of the one-year research at an actual port in Japan into the kinds and load quantities of substances which may be discharged to shore reception facilities.

Figure 14 shows the required capacity of the equipment for the system in addition to the disposal flow. The working days of the system were assumed to be 300 days a year and the load quantity 41 m^3 a day in total.

4.2.3 Conclusion

The study into the disposal method and the attempted design of a shore reception facility has indicated that a practical design is possible which receives various kinds of chemical substances and disposes of them effectively at low cost, when the substances suitable for biodegradation are received separately in two groups, i.e. chloric substances and non-chloric substances.

Table 5 Disposal system, type and load quantity of substances in model plant

Disposal Method	Substance	IMO Category	Cargo Residue Quantity (M/T)	Tank Washing Water Quantity (m^3)
Stripping + Biodegradation	Higher alcohol	NE	2.071	63.532
	C_5 Hydrocarbons faction	NE	30.545	936.892
	Safflower oil	D	0.121	3.702
	Acrylonitrile	B	3.565	148.054
	Ethylbenzene	C	3.054	126.806
	Styrene monomer	C	0.257	10.656
	Toluene	C	1.795	74.513
	Benzene	C	102.528	4 257.389
	Xylenes	C	134.455	4 345.393
	Acetic acid	C	4.124	133.278
	Acetic anhydride	C	2.473	79.917
	Cyclohexane	C	0.587	18.954
	Formaldehyde solution 45% or less	C	6.194	200.163
	Octanol	C	5.022	154.049
	Heptanol all isomers	(C)	0.702	21.521
	2-Ethyl-l-hexanol	C	0.491	15.066
	Diisobutylene	C	0.410	17.007
Stripping	Epichlorohydrin*		0.368	15.280
	Vinyl chloride monomer*	B	2.039	84.676
	Trichloroethylene*	B	0.524	21.747
	1.1-Dichloroethanc*	B	5.132	213.082
Incineration	Aromatic hydrocarbon (petroleum resin)	NE	0.544	17.582
	Para-Xylenes	C	0.256	10.639
	Coal tar	NE	0.471	14.439
Dilution and Neutralisation	Sodium hydroxide solution	C	23.653	372.162
	Sulphuric acid	C	36.379	554.000
	Hydrochloric acid	D	1.351	43.665

Note : * : Chloric substance
NE : Not yet evaluated

5. Conclusions

Studies have been successfully completed concerning the hardware of small chemical tankers engaged in domestic water services in Japan, and into the attempted design of shore reception facilities.

It can be said no technical problem remains for implementation of MARPOL 73/78 Annex II. The chemical tankers engaged in domestic services in Japan, however, face some operational problems. The main problem concerns where the tank washing water should be discharged, if tank cleaning is carried out, i.e. to the shore reception facilities which may not be sufficient, or into the sea at a distance of not less than 12 nautical miles from the nearest land. Beyond this distance navigation is unfamiliar to seafarers on such chemical tankers. Therefore, they are very concerned about the problems of navigating outside this boundary. This very difficult problem needs to be solved before the implementation of MARPOL 73/78 Annex II.

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