PREVENTION OF AIR POLLUTION FROM SHIPS
A point of view toward GHG emission reduction:
Preliminary study on estimation and future trend of GHG emissions from all marine vessels

1 Efforts to estimate GHG emission from ocean-going vessels

As for the GHG emission from ocean-going vessels, UNFCCC has requested IMO to estimate the emissions quantitatively and study available options for its reduction. The Government of Japan previously reported CO_2 emission from tankers, which was taken from the results of research by Ship & Ocean Foundation started in 1999, referred to in MEPC44/INF10. In MEPC44, several countries also requested that study be undertaken on CO_2 emission from bulk carriers and container vessels. CO_2 emission for each vessel type, prediction of its future emission with reduced technologies, and additional studies on GHGs other than CO_2, are reported in this Information Paper.

2 Contribution of each vessel type to CO_2 emission

Fuel-oil consumption suggests CO_2 emission of 360×10^6 t/y from international navigation. This figure was calculated from bunker fuel consumption published in Energy Statistics of OECD Countries 1994-1995 (OECD/IEA, 1997) and Energy Statistics and Balances of Non-OECD Countries 1994-1995 (OECD/IEA, 1997). However, in order to consider measures to reduce CO_2 emission from ocean-going vessels and to assess its effectiveness, it is essential to precisely estimate CO_2 emission for every vessel type.

In the present study, annual fuel consumption is estimated separately for tanker, bulkers and container vessels from the amount of cargo transport expressed in ton-mile, based on operation patterns, and the fuel consumption table for each vessel size, type and age. The method to assign cargo transport on a ton-mile basis for each vessel size, type and age has been already reported in MEPC44/INF10 and it is not presented here.

Fuel consumption rates in ton-mile for category ij, or Cij (Table. 1), are calculated from technical specifications in Japanese ship registers over the past 10 years, the average cruising speed and the age-deterioration rate. Annual fuel consumption for category ij, or Pij, and total fuel use P are calculated by the following equation. Table 2 shows estimations for crude-oil tankers. Since CO_2 emission from unit fuel is thought to be constant (2,999 g-CO_2/kg-Fuel on average), fuel consumption in Table 2 suggests the relative contribution of each category to CO_2 emission.

$$P = \sum_i \sum_j p_{ij} = \sum_i \sum_j C_{ij} \times tr_{ij}$$

where, p_{ij} = fuel consumption in ton-fuel/year by tankers of category *i, j*
C_{ij} = fuel consumption in ton-fuel/cargo-ton-mile by vessels of category *i, j*
tr_{ij} = cargo transportation in ton-mile /year by vessels of category *i, j*

Table 1 Estimated fuel consumption per ton-mile (Cij) of crude-oil tankers in 1997

(Unit; t-Fuel/10^6ton-mile)

DWT(10^3ton)	-1978	1979-83	1984-88	1989-93	1994-98
10 -25	12.86	12.10	10.05	7.50	5.27
25 -50	8.21	7.39	6.17	4.18	3.41
50 -80	5.75	5.58	4.84	3.37	2.90
80 -100	4.07	3.95	3.69	2.67	2.45
100 -120	3.76	3.54	3.48	2.61	2.40
120 -200	3.96	3.33	3.25	2.44	2.31
200 -320	3.21	2.98	2.93	2.23	2.17
320 +	2.96	2.84	-	-	-

The above average fuel consumption assumes a fixed service speed and takes into account age-deterioration of parts such as engines.

Table 2 Estimated fuel consumption of each vessel type and age (Pij) for crude-oil tankers in 1997

(Unit; 10^3t/year)

DWT(10^3ton)	-1977	1978-82	1983-87	1988-92	1993-97	TOTAL
10 -25	900	375	201	60	79	1,614
25 -50	1,799	850	821	552	642	4,665
50 -80	489	909	440	246	61	2,144
80 -100	1,017	833	605	771	411	3,637
100 -120	154	85	181	219	428	1,066
120 -200	1,741	240	179	902	650	3,712
200 -320	3,105	191	581	2,142	1,931	7,950
320 +	1,372	264	0	0	0	1,636
TOTAL	10,578	3,745	3,007	4,891	4,201	26,423

Consequently, it is suggested that tankers, bulkers and container vessels have contributed 31%, 30% and 32% respectively, of the total fuel consumption.

However, it should be noticed that there are many unknown factors involved in the complicated operations of container vessels and that the above contribution of container vessels may be more apart from its reality than in the case of the other vessel types (Fig. 1).

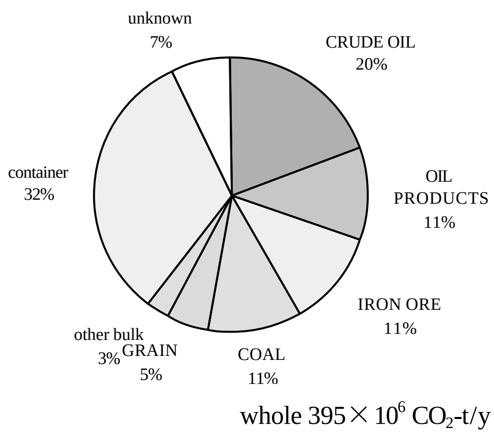


Fig. 1 Composition of fuel consumption by vessel types in 1997.

3 Technical assessment of previous improvements of transportation efficiency and the promising technologies in the short term

As shown in Table 1, transportation efficiency per ton-mile has improved by approximately 40% in the 1990s. Since age deterioration is reflected in this figure, actual improvement of transportation efficiency at the time of present shipbuilding is presumed to be around 20%. Improvement of thermal efficiency in main engines has made a great contribution to this increase.

Thermal efficiency in the main engines themselves had improved by about 20% up until the 1990s, but it has not improved noticeably in the past several years. While electrification of fuel injection may lead to additional improvement of several percent, improvement of thermal efficiency may be suppressed due to future restrictions on NOx emissions. Although better vessel designs have improved the ton-mile energy consumption in the past 20 years or so, increased service speed may have offset this improvement.

Among the promising technologies in the short term are modification of propeller boss cap, contra-rotating propellers, and hull surface paints that don't contain organotin. Although some of them are already available, cost reduction is required for their wider use.

Among the measures for reduction of CO_2 emissions in operation, are reduced cruising speed and operation under weather routing. Reduction of cruising speed will reduce fuel consumption significantly, and few technical problems are associated with its application. Economic loss due to increased service time, however, requires the overall socio-economic system to be taken into account. On the other hand, effectiveness of weather routing has not yet been sufficiently demonstrated in a quantitative manner, but both quantitative and qualitative improvements of marine observation data on weather routing are expected in the future.

Table 3 Characteristics of promising short-term technologies

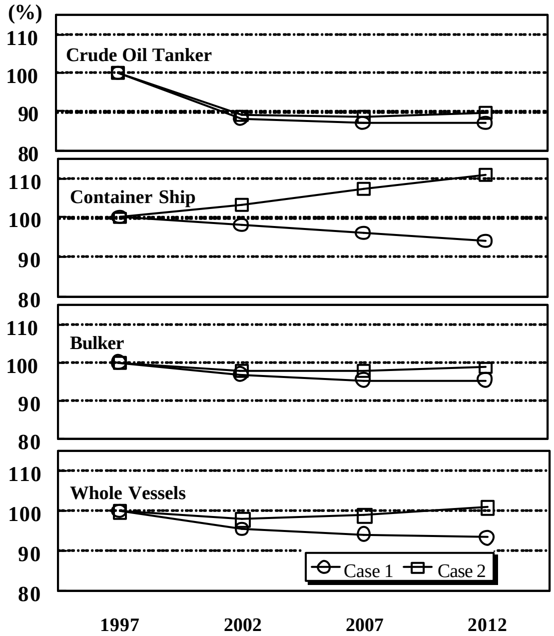
Technology	Merit	Demerit	Note
Modification of propeller boss cap	Modification of existing vessels possible.	Increase of initial cost.	Already more than 100 examples. Propulsion ability improvement of about 4% expected.
Contra-rotating propeller	Effective also for vibration and cavity prevention.	Initial cost for propeller and gearbox high. Increase in fuel price may facilitate the use.	Maximum of 5 ～ 10% improvement in propulsion efficiency expected.
Anti-fouling paint for ship-bottom	Development already underway overall to cope with the complete prohibition of organotin.	So far, no paint with cost performance better than organotin has been developed.	High cost expected to be offset by mass production.

4 Future trend of CO_2 emission from vessels

Total annual fuel consumption has been predicted for each vessel type, based on estimates of future operation, which were taken from chronological changes in past operations. It is assumed that vessels built in the future will retain the same performance as of 1997.

If there were to be no increase in operation, annual fuel consumption will be reduced by around 7%, due to the replacement of vessels over 20 years old. If the trend of the last 5 years is to continue and operation increases, annual fuel consumption will remain at the same level or it may even increase slightly, in spite of fuel consumption reducing due to the replacement of vessels over 20 years old.

CO_2 emissions from container vessels are expected to continue to increase significantly due to their increased operations at high speed. It is suggested that fuel saving technologies, as shown in previous section, should be introduced to container vessels in the near future.



Scenario No.	Replacement of Vessels	Change in Cargo Transportation
Case 1	30 years	Remain at the 1997 level (Only replacement of old vessels will affect CO_2 emission)
Case 2	30 years	Assumed to continue its previous increase. Tanker : approx.1%/yr., container : approx.6%/yr., bulker : approx.2%/yr.

Fig.2 Prediction of future CO_2 emission (1997=100)

5 Problems to be solved and actions to be taken

(a) At present, there is not sufficient information on actual operations, such as actual service speed, actual fuel consumption, and operations by small or aged vessels. For more precise prediction of future fuel consumption, more detailed information and analyzing of that data is required. As for container vessels with significant ocean-going operations, there remains much information to be known on their actual operations, and exchange of information between countries is essential.

(b) Emission reduction technologies, which are presently promising in the short term, can't be widely used immediately. Fuel consumption will be reduced significantly though reduced cruising speed, but economic loss due to increased service time needs to be addressed and overall socio-economic consideration is recommended.

(c) For more precise prediction of CO_2 emission, future reduction of fuel consumption should be evaluated quantitatively on the basis of more concrete and realistic CO_2 reduction scenarios. It will be required to incorporate economic implications in these scenarios.

(d) It is required to estimate the use and emission for GHGs other than CO_2 (CH_4, N_2O, HFCs, PFCs, SF_6). Their emissions from vessels are further less known than the case of CO_2. Their release from the heat insulating material of refrigerated carriers and their actual supply to, and recovery from, refrigerant for refer containers are not sufficiently known. As for N_2O and CH_4, even their emission mechanisms are not clarified enough. Ship & Ocean Foundation is now studying actual emission of these substances.