ANNEX 7 COST EFFECTIVENESS ANALYSIS

1. Method

According to FSA Guidelines adopted by IMO/MSC which is being discussed in the correspondence group in respect with revisions of it, the purpose of Step 4 in FSA is made to evaluate the cost effectiveness with regard to the application of each RCO that was selected in Step 3 by Cost Benefit Assessment (CBA) or Cost Effectiveness Analysis (CEA) and compare. Also, "Cost per Unit of Risk Reduction" (CURR) and "Implied Cost of Averting a Fatality" (ICAF) are given in the guideline as an index that shows cost effectiveness of the RCO.

In this study, the Cost Effectiveness Analysis (CEA) has been tried by referring the index called Gross Cost of Averting a Fatality (GrossCAF or GCAF) and Net Cost of Averting a Fatality (NetCAF or NCAF). Definition of these indexes are as given:

$$GrossCAF = \frac{\Delta C}{\Delta R}$$

$$NetCAF = \frac{\Delta C - \Delta B}{\Delta R}$$

where ΔC is the cost of the Risk Control Option
ΔB is the cost benefit resulting from the implementation of the Risk Control Option
ΔR is the risk reduction implied by the Risk Control Option

2. Cost Estimation for implementation of RCO

Data on the cost that accompanies the application of RCO and information are investigated widely by the collaboration with the project team of "IACS Bulk Carrier FSA study - Fore end watertight integrity" (IACS, 2001). As for the details, it is as it is shown in Appendix A. Table 2.1 shows the summary of unit cost used in this study. In addition, a monetary loss due to cargo hold volume loss is included in the cost of RCO about double side skin construction. Because decrease of cargo hold volume allotted for double side skin spaces that cannot be ignored even if ships are designed newly, means a monetary loss through ships' life. On the other hand, as for this research, this was ignored though the deadweight loss occurred due to the increase in the steel weight in most of RCO. Furthermore, demurrage along with the retrofitting work is also ignored. These matters will be discussed later.

Table 2.1 Unit Cost for up-grading/conversion works

	For New Building	For W.T. Bhd Replace, Double side skin & Hold frame Replace	For Reinforcement of W.T. Bhd	For Hold frame Repaint
Material	600 [US$/ton]	800 [US$/ton]	1,170 [US$/ton]	---
Work	300 [US$/ton]	1,850 [US$/ton]	3,690 [US$/ton]	---
Paint	2.883 $[\text{US\$/m}^2]$*	(included in "Material")	(included in "Material")	2.883 $[\text{US\$/m}^2]$
Blast	---			9.900 $[\text{US\$/m}^2]$
Paint work	4.272 $[\text{US\$/m}^2]$*	(included in "Work")	(included in "Work")	4.272 $[\text{US\$/m}^2]$
Incidental work	1.961 $[\text{US\$/m}^2]$*			1.961 $[\text{US\$/m}^2]$
Facilities	---	19 [US$/day/1,000GT]		

* To be applied only for increased paint area for a double side skin construction.

2.1 Cost Estimation of RCOs for new building BC

As described in the definition of CEA, ICAF refers not price but cost. So, in this rough estimation, increased cost should be focused. In order to estimate increased cost, change of price of the bulk carriers after implementation of RCOs might be used as reference. But in reality, it is difficult to estimate rise of the prices in new-building bulk carriers caused by the application of new requirements because prices of new-building ships would be changed in the market. In this context, it is difficult to catch a precise influence on the prices of new building bulk carriers caused by the new requirements such as SOLAS Chapter XII. So cost should be estimated directly by increase of steel weight, work fee, etc. along with the application of the new requirements. Such increased costs should be calculated by considering so many factors such as increased steel weight, personnel expenses by the design change, period of construction, etc. Although their influence to the total cost must be different case by case, it is believed that cost increase by strengthening conventional ship structure is in proportion to increased steel weight. As for this estimation, it is assumed that increased cost could be estimated by increase of steel weight of the structure of bulk carriers.

Table 2.1.2 shows an actual example of increase of steel weight by the requirements related to the SOLAS Chapter XII (RCO10) and estimated cost using the unit cost shown in Table 2.1.

Table 2.1.2 Increase of Steel Weight in New Bulk Carriers (Chapter XII application)

	Cape		Panamax		Handy		Small-Handy	
UR S21	Applied	N.A.	Applied	N.A.	Applied	N.A.	Applied	N.A.
Increased steel weight [ton]	374	340	137	120	53	34	24	14
Material [$]	224,400	204,000	82,200	72,000	31,800	20,400	14,400	8,400
Work [$]	112,200	102,000	41,100	36,000	15,900	10,200	7,200	4,200
Facilities [$]	0	0	0	0	0	0	0	0
Total	336,600	306,000	123,300	108,000	47,700	30,600	21,600	12,600

Table 2.1.3 shows the increased steel weight due to the application of double side skin construction (RCO15) and estimated cost. As described before, these costs include monetary loss due to cargo hold volume loss. (See A1.3 and A2.2.1 of appendix A in detail.)

Table 2.1.3 Increase of Steel Weight and Cost for Double Side Skin Construction (RCO15)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	805	379	244	109
Paint area [m^2]	15,854	9,093	7,797	4,641
Material [$]	483,000	227,220	146,160	65,110
Work [$]	241,500	113,610	73,080	32,550
Paint [$]	45,707	26,215	22,479	13,380
Paint work [$]	98,818	56,677	48,599	28,927
Facilities [$]	0	0	0	0
Sub-total [$]	869,025	423,722	290,317	139,957
Hold volume loss [m^3]	1,806	972	833	458*
Monetary loss by hold volume loss [$]	496,500	542,200	251,542	157,032*
Total [$]	1,365,525	965,922	541,859	296,989

* Where the hold volume loss is considered 3/4 of that for existing vessels instead of 1/3 used in this examination, monetary loss will be estimated of 353,323 $ for hold volume loss of 1,031 m^3.

2.2 Cost Estimation of RCOs for existing bulk carriers relating to the application of SOLAS Chapter XII (RCO20, 21, 22)

In retroactive applying the RCOs relating to the SOLAS Chapter XII to existing ships, strengthening aft watertight bulkhead of foremost cargo hold can be conceivable two kinds of conversion of the reinforcement of the existent one by the doubling plates and of replacement of the existent with newly constructed one in accordance with the requirements. Though a material cost, personnel expenses, the cost for facilities, etc. should be contained in such retrofitting work, these costs could be estimated in the manner of parameterization by steel weight and days for retrofitting work according to modeling a practical plan. For this purpose, trial designing and planning such works were conducted in collaboration with IACS Bulk Carrier FSA study (IACS, 2001).

Table 2.2.1 shows the results of cost estimation for retrofitting work by the implementation of RCO related to the SOLAS Chapter XII in the existing ship in case of the replacement of watertight bulkhead.

Table 2.2.1 Cost Estimation of the application of SOLAS Chapter XII (BHD Replacement)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton] (Increased weight)	111 (22)	56 (11)	31 (6)	11 (2)
Material [$]	88,800	44,480	24,936	8,840
Work [$]	205,350	102,860	57,665	20,433
Facilities [$]	70,072	21,375	15,276	6,384
Total	364,222	168,715	97,877	35,667

2.3 Cost Estimation of RCO relating to Hatch Covers on existing ships (RCO23)

Table 2.3.1 shows the results of cost estimation for the implementation of RCO23. The estimated cost shown in the table in case of replacement which is deemed more realistic way than reinforcement, was used in the calculation of GrossCAF of the later description.

Table 2.3.1 Steel weight and Cost for Reinforcement of Hatch Cover

	Cpae (0.087Lf)		Panamax (0.101Lf)		Handy (0.139Lf)		Small-Handy (0.164Lf)	
	59.9 kN/m^2		52.8 kN/m^2		46.1 kN/m^2		44.5 kN/m^2	
	Replace	Reinforce	Replace	Reinforce	Replace	Reinforce	Replace	Reinforce
Steel weight [ton] (Increased weight)	102 (34)	48	66 (17)	24	67 (19)	27	38 (10)	14
Material [$]	81,600	56,160	52,800	28,080	53,600	31,590	30,400	16,380
Work [$]	94,350	177,120	61,050	88,560	61,975	99,630	35,150	51,660
Facilities [$]	5,255	8,759	2,138	3,563	1,528	2,546	638	1,064
Total [$]	181,205	242,039	115,988	120,203	117,103	133,766	66,188	69,104

2.4 Cost Estimation of RCO relating to application of double side skin to existing ships (RCO25)

Table 2.4.1 shows the results of cost estimation for the implementation of RCO25. As described before, these costs include monetary loss due to cargo hold volume loss. (See A1.3 and A2.2.2 of Appendix A in detail.)

Table 2.4.1 Steel weight and Conversion cost for Double Side Skin Construction

		Cape	Panamax	Handy	Small-Handy
All cargo holds	Steel weight [ton]	1,150	541	348	155
	Material [$]	920,000	432,800	278,400	124,000
	Work [$]	2,127,500	1,000,850	643,800	286,750
	Facilities [$]	70,0720	21,375	15,276	6,384
	Sub-total [$]	3,117,572	1,455,025	937,476	417,134
	Hold volume loss [m^3]	5,419	2,915	2,498	1,374
	Monetary loss by hold volume loss [$]	595,800	650,640	301,850	188,439
	Total [$]	3,713,372	2,105,665	1,239,281	605,573
No.1 Cargo hold only	Steel weight [ton]	156	93	81	44
	Material [$]	124,583	74,032	64,629	35,043
	Work [$]	288,099	171,198	149,454	81,038
	Facilities [$]	52,554	19,950	14,258	5,958
	Sub-total [$]	465,236	265,180	228,340	122,040
	Hold volume loss [m^3]	734	499	580	388
	Monetary loss by hold volume loss [$]	80,681	111,294	70,072	53,254
	Total [$]	545,917	376,474	298,412	175,294
Nos.1 & 2 Cargo holds	Steel weight [ton]	276	164	143	78
	Material [$]	220,417	130,979	114,343	62,000
	Work [$]	509,714	302,889	264,418	143,375
	Facilities [$]	52,554	19,950	14,258	5,958
	Sub-total [$]	782,684	453,818	393,018	211,333
	Hold volume loss [m^3]	1,298	882	1,026	687
	Monetary loss by hold volume loss [$]	142,744	196,904	123,974	94,219
	Total [$]	925,428	650,722	516,992	305,552

2.5 Cost Estimation of RCOs applied to single side skin (RCO51 & 52)

Table 2.5.1 shows the results of cost estimation for the implementation of RCO51 and RCO52. Reference is made to A2.3 of appendix A and D3 of Appendix D in Detail of these RCOs.

Table 2.5.1 Steel weight and cost for replacement or repaint of Hold Frames

Repaint every 10 years (The following cost accounts 2 times paint works.)				
	Cape Size	Panamax	Handy	Small-Handy
Paint area [m^2]	7,567	4,466	3,498	2,521
Paint [$]	193,458	114,178	89,430	64,452
Paint work [$]	94,330	55,673	43,606	31,427
Facilities [$]	31,532	9,975	5,092	1,702
Total [$]	319,321	179,826	138,128	97,581
Partially replace after 20 years operation				
	Cape Size	Panamax	Handy	Small-Handy
Steel weight [ton]	104	52	43	28
Material [$]	83,200	41,600	34,400	22,400
Work [$]	192,400	96,200	79,550	51,800
Facilities [$]	35,063	10,688	7,638	3,192
Total [$]	310,636	148,488	121,588	77,392

3. Economic benefits by Implementation of RCO

Although it is a moot point what is deemed as economic benefits for the estimation of NetCAF, in this study, the implementation benefits were evaluated by results such that RCO could suppress casualty of total loss as shown in detail:

Economic Benefits from the Implementation of RCOs: $\Delta B = \int_{y_a}^{25} (R_f - R_a) dy$

Probable loss per ship-year before RCO implemented: $R_f = f_T \times C_T + f_S \times C_S$

Probable loss per ship-year after RCO implemented: $R_a = (1 - r_{RCO}) \times f_T \times C_T + (r_{RCO} \times f_T + f_S) \times C_S$

f_T: Rate of incidence of serious casualties from the historical data (1.24×10^{-3})*

f_S: Rate of incidence of total loss casualties from the historical data (7.68×10^{-4})*

C_T: Economical loss by a serious casualty

C_S: Economical loss by a total loss casualty

y_a: Ship age when a RCO is implemented

r_{RCO}: Risk Reduction Rate of a RCO

Note*: These values are corrected considering the effect of ESP implementation.

The decrease of serious casualties were not considering it, in consideration of that even RCO includes those different from a preventive measures such like SOLAS Chapter XII, although it is considered to be able to reduce occurrence itself of an serious casualty to some degree by introducing RCO in fact. Also, considering the difference by the size of a ship by referring to standard ship price, although it shall depend on the report of IACS in MSC74 fundamentally about the economic loss by a casualty of total loss, it is doing like Table 3.1. Also in consideration of the cost depreciation by a passing year, after construction according to the progress years an economic loss is assuming that it depends in the next ceremony and also Table 3.1.

Economical loss by a serious casualty on a ship of n years in age: $C_T = C_{T0} / (1 + a / 100)^n$

Economical loss by a total loss casualty on a ship of n years in age: $C_S = C_{S0} / (1 + a / 100)^n$

C_{T0}: Economical loss by a serious casualty on a new building ship (refer to Table 3.1)

C_{S0}: Economical loss by a total loss casualty on a new building ship (refer to Table 3.1)

a: Constant (10 applied in this study)

n: Ship's age

Table 3.1 Economical cost by Serious Casualty and Total Loss

	Average	Cape Size	Panamax	Handy	Small-Handy
Ship price [$]	22,700,000	40,200,000	26,200,000	22,500,000	13,600,000
Population ratio	---	8.8 %	16.8 %	52.7 %	21.7 %
Monetary loss by serious casualty [$]	5,608,000	9,930,000	6,470,000	5,560,000	3,360,000
Monetary loss by total loss [$]	24,808,000	43,900,000	28,600,000	24,600,000	14,900,000

4. Estimation of Risk Reduction by the implementation of RCO

The risk reduction by the application of each RCO is estimated by the study of historical data and expert judgment. This is the reason why various damage scenarios are included in the historical data and it is easy to catch the effect of RCOs as probability. Effects of the application of each RCO to the case in the historical data are estimated by the delicate examination of historical data by experts and are, for simplifying, classifying into 3 groups of "effective", "may be effective" and "not effective". (Reference is made to Appendix B in detail results.) The effect of the RCO application is assumed that it is given by the following equation, by setting up each these effects with 100%, 50% and also 0%.

$$r_{Risk\_Reduction} = \frac{N_{probable\_mitigated} + N_{possible\_mitigated} \times 0.5}{N_{total\_loss}}$$

where $r_{Risk\_Reduction}$: Risk Reduction Rate of RCO

$N_{probably\_mitigated}$: Number of probably mitigated or prevented cases

$N_{posssibley\_mitigated}$: Number of possibly mitigated or prevented cases

Furthermore, the effect of the implementation of RCO to the event in the historical data was estimated in the following manner assumption, considering that the effect should be measured on the event after the ESP application to the ships which have been changed in the structural design, subdivision design and so on.

1. Multi Hold Flooding

   These events are conceivable to be decreased by the implementation of ESP and are treated as single hold flooding in this survey.

2. Effect of Number of Cargo Holds

   It makes to be not particular with the individual case of historical data. Accordingly the effect of the SOLAS Chapter XII application judges the following.

   2.1 No.1 C/H Flooding

   For bulk carriers other than Small-Handy bulk carriers, this event is presumed to be probably mitigated by the application of the Chapter XII.

   For new building Small-Handy bulk carriers, this event is presumed to be probably mitigated by the application of the Chapter XII. For existing Small-Handy bulk carriers, this event is presumed to be possibly mitigated in only the case of light cargo laden voyage.

   2.2 Cargo holds other than No.1

   For new building bulk carriers other than Small-Handy Bulk carriers, this event is presumed to be probably mitigated by the application of the Chapter XII. For existing bulk carriers other than Small-Handy bulk carriers, this event is presumed to be possibly mitigated.

   For new building Small-Handy bulk carriers, this event is presumed to be probably mitigated by the application of the Chapter XII. For existing Small-Handy bulk carriers, this event is presumed to be unable mitigated.

   2.3 Unknown cargo hold

   For new-building bulk carriers other than Small-Handy Bulk carriers, this event is presumed to be probably mitigated by the application of the Chapter XII. For existing bulk carriers other than

Small-Handy Bulk carriers, this event is presumed to be possibly mitigated.

For new building Small-Handy Bulk carriers, this event is presumed to be probably mitigated by the application of the Chapter XII. For existing Small-Handy Bulk carriers, this event is presumed to be unable mitigated.

2.4 Unknown compartment / Detail unknown

For Bulk carriers other than Small-Handy Bulk carriers, this event is presumed to be possibly mitigated by the application of the Chapter XII.

For new building Small-Handy Bulk carriers, this event is presumed to be possibly mitigated by the application of the Chapter XII. For existing Small-Handy Bulk carriers, this event is presumed to be unable mitigated.

* The application of the SOLAS Chapter XII to new building Small-Handy Bulk carriers is judged effective to mitigate casualties of hold flooding, because the application means that these Bulk carriers complying with the requirements of damage stability which require Bulk carriers to have enough stability after any one hold flooding. Actually, this application requires supplementary cost such as one for increase of subdivision that is out of scope in this study.

3. Flooding through hatch openings

For flooding by No.1 hatch cover damage, the application of IACS UR S21 is presumed to probably mitigate the casualty. For flooding by No.2 hatch cover damage, the application is presumed to possibly mitigate. In other cases such as flooding by other hatch cover damage or hatch cover washed away, the application is unable to mitigate.

4. Collapse of Hull Girder

Only for new building Bulk carriers, the application of the SOLAS XII is presumed to possibly mitigate this casualty.

The results of the above are shown in Appendix C except that the reduction rate of the destruction probability by the method of the simple structural reliability evaluation that is carried out particularly is used for the evaluation of RCOs (RCO16, 51 and 52) that said the increase of corrosion margin, stricter control of paint condition and application of enhanced corrosion allowance for single side skin structure. (The reference of Appendix D)

Accordingly, the risk reduction of RCOs was estimated as products of risk reduction rate estimated above, survival life after the implementation of RCO (assumed life of ship is 25 years) and fatality rate per ship year that is obtained in the examination of historical data and corrected about the effect of ESP.

For main RCO, estimated risk reduction is shown in Figures 4.1 and 4.2, furthermore, estimated risk reduction is shown in Figures 4.3 and 4.4.

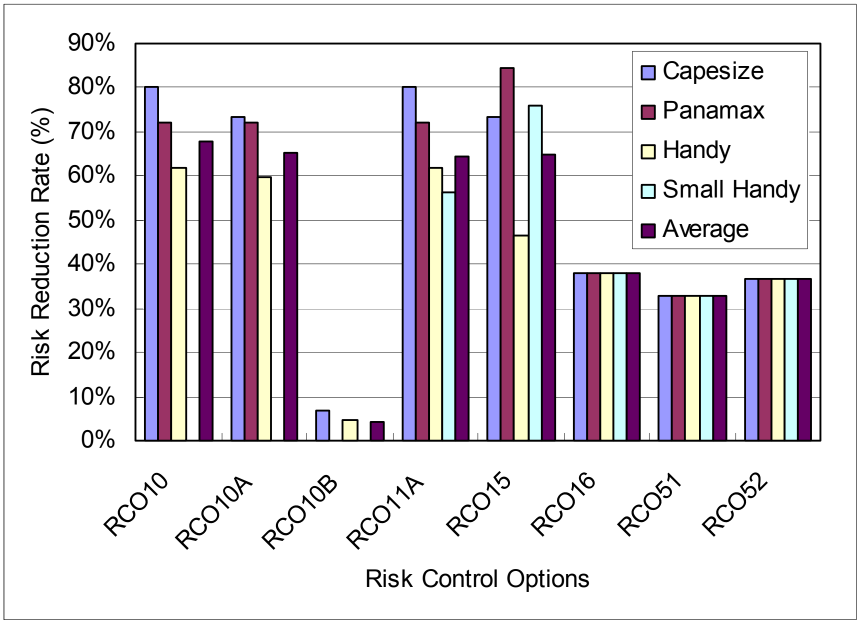

Figure 4.1 Risk Reduction Rates of RCO's for New Building Ships

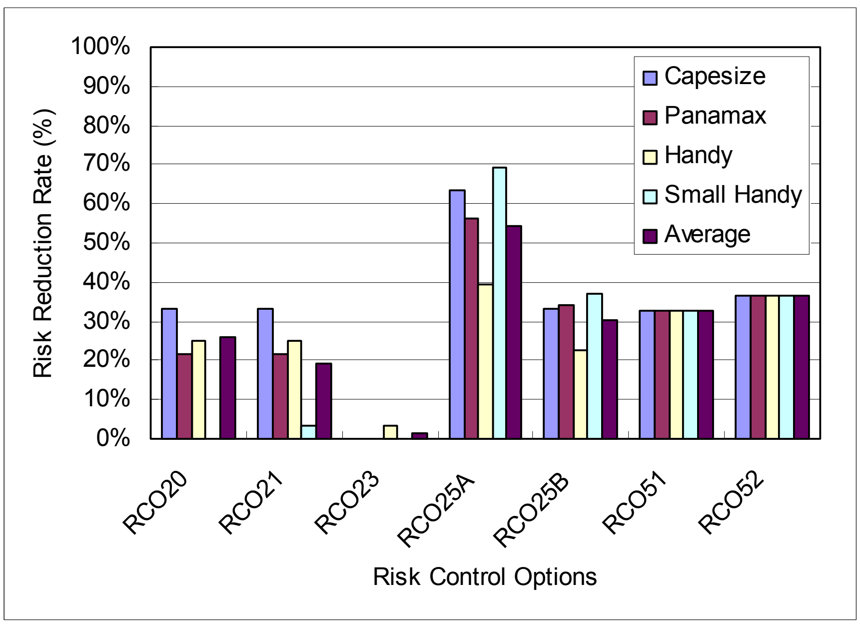

Figure 4.2 Risk Reduction Rates of RCO's for Existing Ships

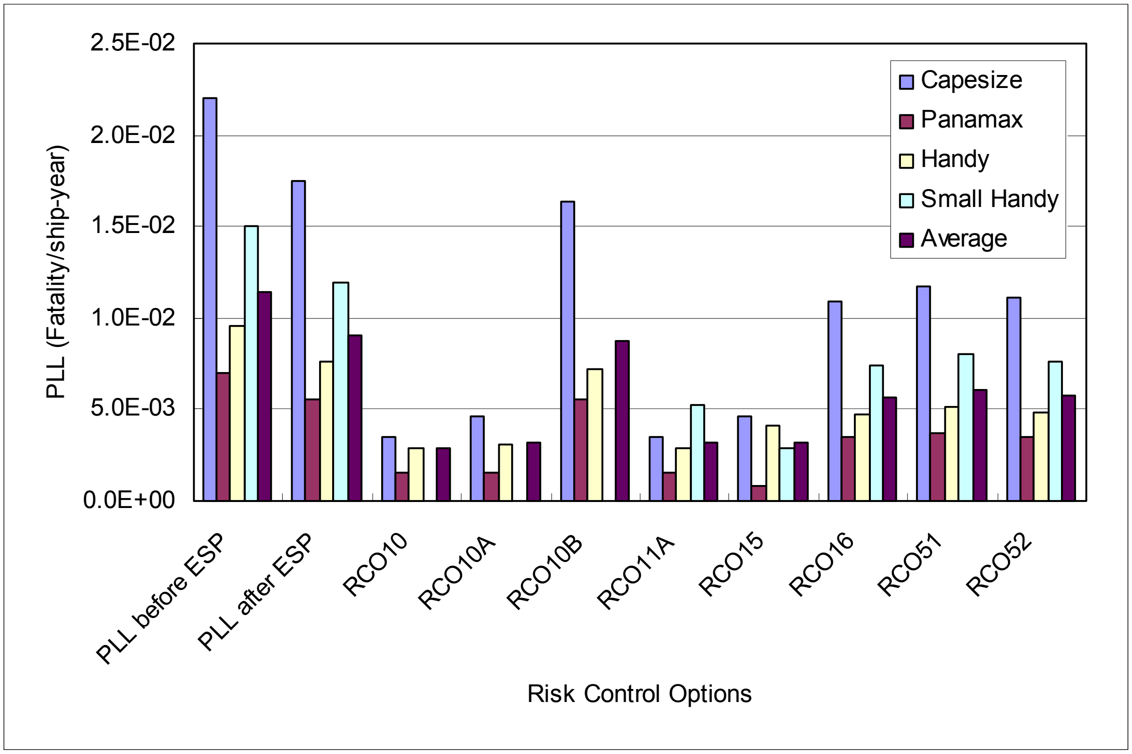

Figure 4.3 Risk Reductions of RCO's for New Building Ships

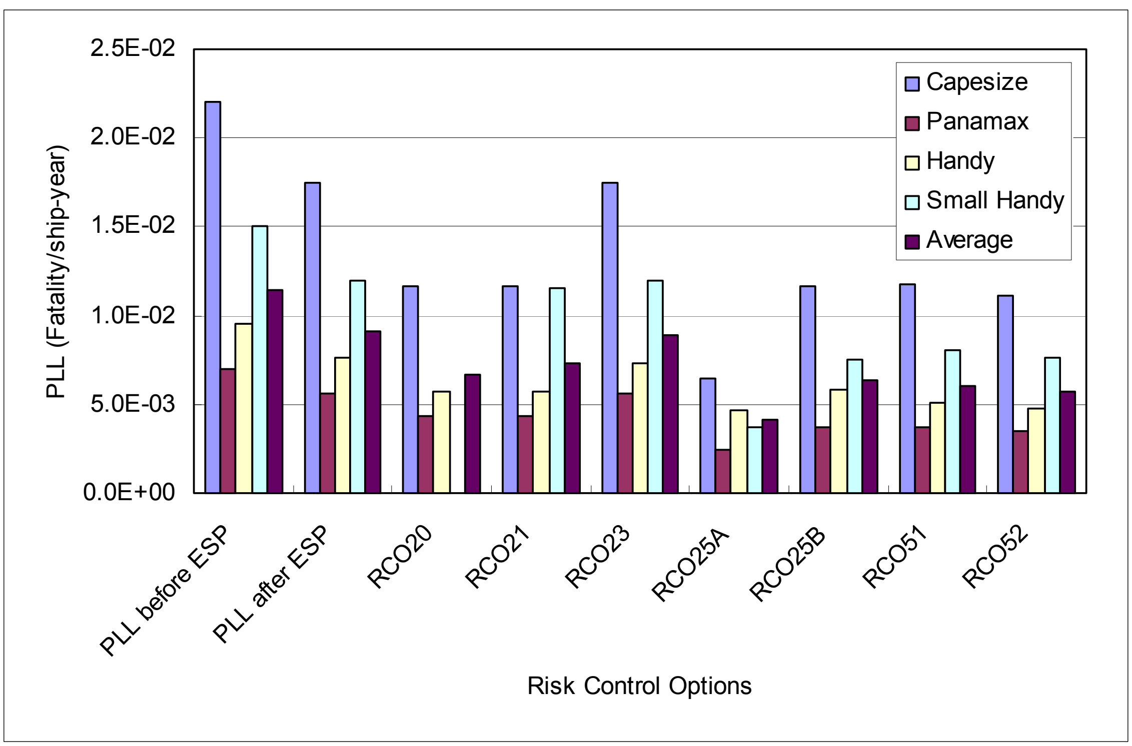

Figure 4.4 Risk Reductions of RCO's for Existing Ships

The risk reduction rate that estimated it here could apply it regarding in the case that be it examines such a measure furthermore after a certain RCO application. For example, in the case that new RCO is implemented after the SOLAS Chapter XII application, it is conceivable that the risk reduction of the RCO implemented additionally is measured in effect on the risk, which is not reduced by the application of the SOLAS Chapter XII. Accordingly, the risk reduction can be expressed as the following manner by using the risk reduction rate of the RCO itself which is estimated by the effect to the historical data as shown in Figures 4.1 and 4.2.

$$\Delta R_{additional\ RCO} = r_{additional\ RCO} \times (1 - r_{Ch.XII}) \times R_0 \times Y$$

$r_{additional\ RCO}$: Risk Reduction Rate of RCO implemented additionally

$r_{Ch.XII}$: Risk Reduction Rate of RCO relating to the SOLAS Chapter XII

R_0: Annual Fatality Rate after ESP

Y: Ship's survival life after the application of RCO

5. Estimation of GrossCAF and NetCAF

The results of the estimation of GrossCAF and NetCAF are shown in appendix E in detail. Figures 5.1 and 5.2 show GrossCAF of main RCOs based on the risk level after the ESP application.

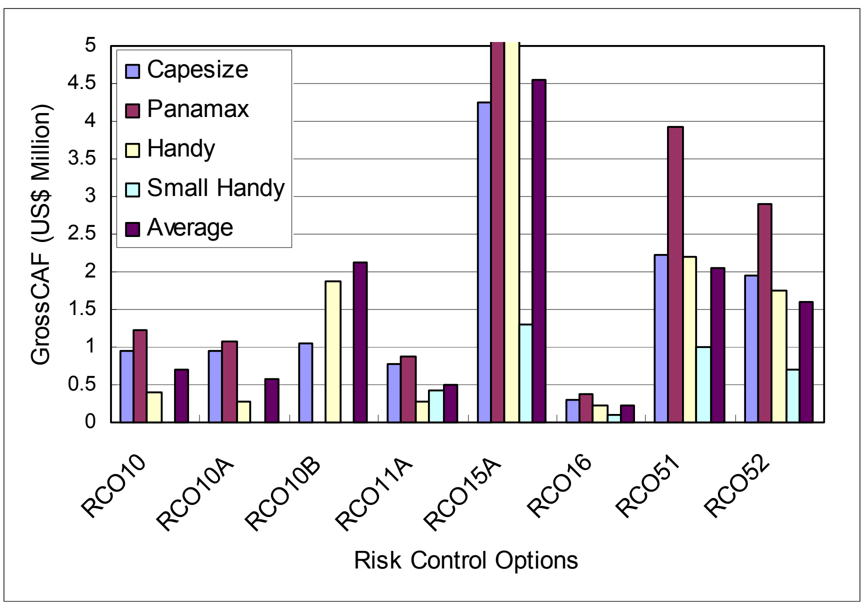

Table 5.1 Gross CAF of RCO's for New Building Ships

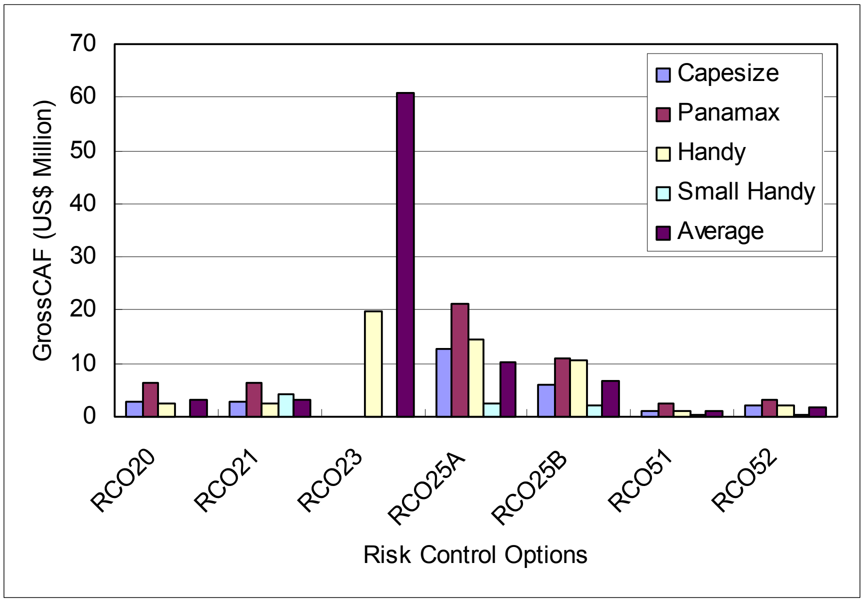

Table 5.2 Gross CAF of RCO's for Existing Ships

6. Ranking of RCO

The RCOs are ranked as GrossCAF estimated in paragraph 5 above and classified in accordance with the index for evaluation propose by Norway (MSC72/16).

<u>6.1 GrossCAF based on the risk revel after the application of ESP</u>

The main purpose of this 6.1 is an evaluation of the effect of RCOs relating to the SOLAS Chapter XII application and alternative RCOs.

6.1.1 RCO applicable to new building ships

<u>*GrossCAF of less than US□1 million*</u>

RCO16: Increase of corrosion margin (US$ 0.2 million per averted fatality)

RCO10: The application of the SOLAS Chapter XII (the Requirements of Damage Stability (Reg.4) and Structural Strength (Reg.5) for new building ships) (US$ 0.7 million per averted fatality)

RCO11: The application of the SOLAS Chapter XII to Bulk Carriers of less than 150 m in length (US$ 0.1 million per averted fatality)*

* Cost for necessary means for complying with the damage stability requirements.

<u>*GrossCAF of not less than US□1 million but less than US□3 million*</u>

RCO10B: The application of the IACS UR S21 (the Requirements of Hatch Cover Strength) (US$ 2.1 million per averted fatality)

<u>*GrossCAF of not less than US□3 million but less than US□10 million*</u>

RCO15: The application of double side skin construction (US$ 4.5 million per averted fatality)

6.1.2 RCO applicable to existing ships

GrossCAF of not less than US□1 million but less than US□3 million

RCO52: Corrosion controls of hold frames (The application of enhanced corrosion allowance) (US$ 1.6 million per averted fatality)

RCO51: Corrosion controls of hold frames (Stricter control of paint condition) (US$ 2.0 million per averted fatality)

GrossCAF of not less than US□3 million but less than US□10 million

RCO20: The application of the SOLAS Chapter XII (the Requirements of Damage Stability (Reg.4) and Structural Strength (Reg.6) for existing ships) (US$ 3.0 million per averted fatality)

RCO21: The application of the SOLAS Chapter XII to Bulk Carriers of less than 150 m in length (US$ 4.2 million per averted fatality)

RCO25B: The application of double side skin construction to Nos. 1 and 2 cargo holds (US$ 9.2 million per averted fatality)

GrossCAF not less than US□10 million

RCO25A: The application of double side skin construction to all cargo holds (US$ 14.4 million per averted fatality)

RCO23: The retroactive application of the IACS UR S21 (the Requirements of Hatch Cover Strength) (US$ 19.7 million per averted fatality)**

** value for Handy BC

6.2 GrossCAF based on the risk revel after the application of SOLAS Chapter XII

The main purpose of this 6.2 is an evaluation of the effect of applicable RCOs if required as further safety measures after the application of SOLAS Chapter XII, which may include the application of IACS UR S21 for new-building ships. The results of applicable RCOs are as follows.

6.2.1 RCO applicable to new building ships

GrossCAF of less than US$ 1 million

RCO16: Increase of corrosion margin (US$ 0.7 million per averted fatality)

GrossCAF of not less than US$ 3 million but less than US$ 10 million

RCO52: Corrosion controls of hold frames (The application of enhanced corrosion allowance) (US$ 5.4 million per averted fatality)

RCO51: Corrosion controls of hold frames (Stricter control of paint condition) (US$ 6.8 million per averted fatality)

GrossCAF of not less than US$ 10 million

RCO15: The application of double side skin construction (US$ 15.9 million per averted fatality)

6.2.2 RCO applicable to existing ships complying with the requirements for new-building ships of SOLAS Chapter XII

GrossCAF of not less than US$ 3 million but less than US$ 10 million

RCO52: Corrosion controls of hold frames (The application of enhanced corrosion allowance) (US$ 5.4 million per averted fatality)

RCO51: Corrosion controls of hold frames (Stricter control of paint condition) (US$ 6.8 million per averted fatality)

GrossCAF of not less than US$ 10 million

RCO25A: The application of double side skin construction to all cargo holds (US$ 53.1 million per averted fatality)

6.2.3 RCO applicable to existing ships not complying with the requirements for new-building ships of SOLAS Chapter XII

GrossCAF of not less than US$ 1 million but less than US$ 3 million

RCO52: Corrosion controls of hold frames (The application of enhanced corrosion allowance) (US$ 2.3 million per averted fatality)

RCO51: Corrosion controls of hold frames (Stricter control of paint condition) (US$ 2.9 million per averted fatality)

GrossCAF of not less than US$ 10 million

RCO25A: The application of double side skin construction to all cargo holds (US$ 22.8 million per averted fatality)

RCO23: The retroactive application of the IACS UR S21 (the Requirements of Hatch Cover Strength) (US$ 26.3 million per averted fatality)**

** value for Handy BC

6.3 GrossCAF of RCOs applicable to ships of less than 150 m in length

The main purpose of this 6.3 is an evaluation of the effect of applicable RCOs if required as safety measures for bulk carriers of less than 150 m on length that have been exempted to apply the requirements of SOLAS Chapter XII.

6.3.1 RCO applicable to new building ships

GrossCAF of less than US$ 1 million

RCO16: Increase of corrosion margin (US$ 0.1 million per averted fatality)

RCO11: The application of the SOLAS Chapter XII to Bulk Carriers of less than 150 m in length (US$ 0.1 million per averted fatality)*

* Cost for necessary means for complying with the damage stability requirements.

RCO52: Corrosion controls of hold frames (The application of enhanced corrosion allowance) (US$ 0.7 million per averted fatality)

RCO51: Corrosion controls of hold frames (Stricter control of paint condition) (US$ 1.0 million per averted fatality)

GrossCAF of not less than US$ 1 million but less than USR$ 3 million

RCO15: The application of double side skin construction (US$ 1.3 million per averted fatality)

6.3.2 RCO applicable to existing ships

GrossCAF of less than US$ 1

RCO52: Corrosion controls of hold frames (The application of enhanced corrosion allowance) (US$ 0.7 million per averted fatality)

RCO51: Corrosion controls of hold frames (Stricter control of paint condition) (US$ 1.0 million per averted fatality)

GrossCAF of not less than US$ 3 million but less than US$ 10 million

RCO25A: The application of double side skin construction to all cargo holds (US$ 3.3 million per averted fatality)

RCO21: The application of the SOLAS Chapter XII to Bulk Carriers of less than 150 m in length (US$ 4.2 million per averted fatality)

GrossCAF not less than US$ 10 million

RCO23: The retroactive application of the IACS UR S21 (the Requirements of Hatch Cover Strength) (US$ --- million per averted fatality)

6.4 GrossCAF of RCOs applicable to ships of double side skin construction

The main purpose of this 6.4 is an evaluation of the effect of applicable RCOs if required as further safety measures for bulk carriers of double side skin construction that have been exempted to apply the requirements of SOLAS Chapter XII. The followings show the results of estimation in the same manner as paragraph 6.2 above. However, it should be considered that the significant GrossCAF is much greater in actual sense, because the cost for double side skin construction at new-building is considerably high in comparison with that of single side skin.

6.4.1 RCO applicable to new building ships

GrossCAF of not less than US$ 1 million but less than US$ 3 million

RCO10: The application of SOLAS Chapter XII (US$ 2.2 million per averted fatality)

6.4.2 RCO applicable to existing ships

GrossCAF of not less than US$ 10 million

RCO20: The application of SOLAS Chapter XII (US$ 14.0 million per averted fatality)

RCO23: The retroactive application of the IACS UR S21 (the Requirements of Hatch Cover Strength) (US$ 36.9 million per averted fatality)**

** value for Handy BC

6.5 NetCAF

As described before that it is a moot point what is deemed as economic benefits for the estimation of NetCAF and also how evaluate results of such estimation, NetCAF was calculated for each RCO only for reference in this study. However, the results of the following RCOs should be notable. Because these results show NetCAF having significant large positive values, it means that implementation of these RCOs are conceivable a monetary loss in total of ships' life.

RCO15: The application of double side skin construction (US$ 4.5 million per averted fatality)

RCO25A: The application of double side skin construction to all cargo holds (US$ 7.8 million per averted fatality)

RCO23: The retroactive application of the IACS UR S21 (the Requirements of Hatch Cover Strength) (US$ 9.0 million per averted fatality)**

** value for Handy BC

7. Discussion on Cost Effectiveness Analysis

7.1 Cost Estimation for Implementation of RCO

In this study, demurrage and influence of deadweight loss due to increase of lightweight for retrofitting work were ignored. However, these losses are a fairly important problem on an actual operation. Table 7.1.1 shows the survey result regarding the demurrage and cost with regard to the retrofitting of double side skin construction. It shows that demurrage is the amount as much as the cost only for retrofitting works of RCO.

For new-building ships, influence of increase of lightweight and influence of making ships larger in order to keep the volume of cargo space considering the volume of double side skin construction were also ignored. In actually, these influences cannot be ignored especially for ships engaged on services with restriction of draught, breadth, gross tonnage, etc.

Table 7.1.1 An example of estimated demurrage by double side skin requirements

		Number of Sh	Initial Cost (US$)	Initial Demurrage by retrofitting work (assuming 40 days)	Demurrage per year by decrease of DWT	Demurrage per Year by decrease of Cargo Volume (US$/year)	Cost including Demurrage caused by Volume loss	Cost including Demurrage caused by DWT increase & Volume loss	Ratio between DWT & Vol Volume
RCO25A (ALL)	Cape	6,742	3,117,572	781,488	18,469	59,580	3,713,372	3,898,062	105.0%
	Panamax	14,393	1,455,025	343,116	18,167	65,064	2,105,665	2,287,333	108.6%
	Handy	42,764	937,476	316,483	24,159	30,185	1,239,326	1,480,918	119.5%
	Small-han	9,716	417,134	238,820	17,584	18,844	605,573	781,408	129.0%
	ALL	73,616	1,169,653	354,027	21,599	38,200	1,551,651	1,767,636	113.9%
RCO25B (n1&n2)	Cape	6,742	782,684	586,116	4,425	14,274	925,428	969,677	104.8%
	Panamax	14,393	453,818	320,242	5,498	19,690	650,722	705,701	108.4%
	Handy	42,764	393,018	295,384	9,923	12,397	516,992	616,218	119.2%
	Small-han	9,716	211,333	222,899	8,792	9,422	305,553	393,470	128.8%
	ALL	73,616	416,613	317,304	8,405	13,603	552,639	636,685	115.2%
RCO15A (ALL)	Cape	6,742	869,025	0	32,321	49,650	1,365,525	1,688,733	123.7%
	Panamax	14,393	423,722	0	31,792	54,220	965,922	1,283,841	132.9%
	Handy	42,764	290,317	0	42,279	25,154	541,859	964,645	178.0%
	Small-han	9,716	139,957	0	30,771	15,703	296,990	604,701	203.6%
	ALL	73,616	349,556	0	37,797	31,833	667,888	1,045,862	156.6%
RCO15B (n1&n2)	Cape	6,742	208,204	0	7,744	11,895	327,157	404,592	123.7%
	Panamax	14,393	128,232	0	9,621	16,409	292,319	388,531	132.9%
	Handy	42,764	119,238	0	17,364	10,331	222,549	396,194	178.0%
	Small-han	9,716	69,979	0	15,386	7,852	148,495	302,351	203.6%
	ALL	73,616	122,64	0	14,708	11,335	235,997	383,0793	162.3%

7.2 RCOs relating to corrosion control of hold frames (RCO51, 52)

GrossCAF of RCO51 and RCO52 are showing a lower value in comparison with other RCOs. However, the following restriction about this result should be noted.

RCO51 requires two times re-paint work of hold frames every 10 years after entry in service and RCO52 requires replacement of hold frames for ships of 20 years in age. It means that these RCOs cannot apply to ships over 10 or 20 years in age at this moment. On the other hand, risk reduction of the implementation of these RCOs was evaluated on the basis that these RCOs apply to all ships which are supposed to have 25 years of life in order to simplifying the evaluation. Therefore, this result is not applicable to the existing aged ships and the risk reduction may be overestimated.

Accordingly, GrossCAF of these RCOs calculated here should be considered as minimum values and as values of the first next approximation persistently. Although these results still show that these RCOs conceivable as effective risk control measures applicable to existing ships after the application of SOLAS Chapter XII, further precise examination may be requested for actual implementation.

List of Appendixes

Appendix A Cost Evaluation for Implementation of RCOs

A1 Conditions of Cost Evaluation

A1.1 Principle

In this study, the following two groups of economical factors are considered as costs for the implementation of RCOs, which are summarized in Table A1.1.1.

(1) Cost for RCO implementation work itself

(2) Monetary loss caused by the implementation of RCOs

Table A1.1.1 Cost for the Implementation of RCO

	For new-building ships	For existing ships
1-1 Material Cost	Cost for steel needed additionally (including welding material) Cost for paint applied additionally*	Cost for steel needed additionally (including welding material) Cost for paint applied additionally (including sand blast)
1-2 Work Cost	Cost for additional steel work Cost for additional paint work*	Cost for steel work (including incidental work such as scaffolding) Cost for paint work Cost for cleaning Cost for design
1-3 Cost for facilities		Fee for dockage and/or use of berth Cost for testing
2 Monetary loss	Monetary loss due to deadweight loss Monetary loss due to cargo hold volume loss*	Monetary loss due to deadweight loss Monetary loss due to cargo hold volume loss Demurrage

* These items may apply only to costs for the application of double side skin construction.

A1.2 Cost for RCO implementation work

A1.2.1 For new-building ships

It is conceivable that the increase of the cost for the implementation of RCO in new-building ship is the cost for increase of the additional material for the implementation and of the work associated with. Where these costs are in proportion to the increase of steel weight, these costs may be expressed by using unit costs, which are calculated values of actual costs per steel weight. In this study, actual cost for material and work are estimated by a survey of standard ships' price based on historical data in these ten years and cost for steel and steel works summarized in Table A1.2.1 for each type of bulk carriers on the basis of the following assumption.

Ratio of cost for steel: 20-25%
Ratio of cost for equipments: 40-35%
Ratio of cost for work: 30%

Table A1.2.1 Standard Price and Costs for new-building ships

	DWT (ton)	Prices (US$)	Steel (US$)	Steel work (US$)
Handy	50,000	22,500,000	4,500,000	2,250,000
Panamax	74,000	26,200,000	6,550,000	3,280,000
Cape Size	170,000	40,200,000	10,050,000	5,030,000

Unit costs for the implementation works of RCO are estimated as follows, which are simplified values, calculate by dividing the above costs by steel weight of each type of bulk carriers.

Unit cost for increased steel weight: 600 US$/ton
Unit cost for additional steel work: 300 US$/ton

For the application of double side skin construction, unit costs for paintwork are used in addition to the above, in the same manner as existing ships considering the increase of compartment required to be painted.

A1.2.2 For existing ships

For existing ships, unit costs for the implementation of RCO are estimated as unit costs for material and works which are based on steel weight and a unit cost for facilities which is based on ships' size (gross tonnage), by using the results of trial design of the implementation work of SOLAS Chapter XII for existing ships mentioned later. In cases of paint work not associated with steel works such as re-paint of hold frames, separate unit cost is estimated based on paint area. Tables A1.2.2 and A1.2.3 shows the unit costs in detail.

Table A1.2.2 Unit Costs for Retrofitting Work for Existing Ships

Application of SOLAS Ch.XII (Retrofitting work to which this unit cost may be applicable.)	Replacement of W.T. BHD (Double side skin application) (Replacement of hold frames)	Reinforcement of W.T. BHD
Weight of steel works for up-grading of W.T. BHD in Panamax BC	55.6 [ton]	23.2 [ton]
Cost for material required for up-grading of W.T. BHD in Panamax BC	44,400 [US$]	27,100 [US$]
Cost for up-grading work of W.T. BHD in Panamax BC	103,000 [US$]	85,600 [US$]
Unit cost for material	800 [US$/ton]	1,170 [US$/ton]
Unit cost for work	1,850 [US$/ton]	3,690 [US$/ton]
Unit cost for facilities	19 [US$/day/1,000GT]	

Table A1.2.3 Unit Costs for Paint Works

	Panamax BC (In case of W.T. BHD replacement)	Unit Cost
Paint	2,970 / 1,030 [US$/m^2]	2.883 [US$/m^2]
Sand blast*	990 / 100 [US$/m^2]	9.900 [US$/m^2]
Paint works	4,400 / 1,030 [US$/m^2]	4.272 [US$/m^2]
Incidental	2,020 / 1,030 [US$/m^2]	1.961 [US$/m^2]
Facilities	---	19 [US$/day/1,000GT]

* This unit cost is not applicable for new-building ships.

A.1.3 Monetary Loss caused by the Implementation of RCO

The following factors should be considered as monetary loss caused by the implementation of RCO.

(1) Loss of expected economical benefits due to deadweight loss corresponding to increased steel

weight caused by the implementation of RCO

(2) Loss of expected economical benefits due to cargo hold volume loss corresponding to double side skin structures

(3) Demurrage during retrofitting works

It is conceivable that item (1) may occur in the case of laden voyage with full draught (heavy cargoes loaded) and item (2) may occur in the case of laden voyage with full capacity cargoes (light cargoes loaded). For evaluation of these influences of items (1) and (2), ratio of voyage type for each types of bulk carriers should be considered. Also influence of item (3), which is considered as operational cost of ships being assumed as 90 % of incomes of laden voyage, can be estimated by considering ratio of voyage type. For this purpose, the voyage rates of typical services for each type of bulk carriers are estimated as shown in Table A1.3.1 on the basis of published data, and the ratio of voyage types for each type of bulk carriers are assumed as shown in Table A1.3.2 on the basis of hearing to ship operators.

Table A1.3.1 Average Voyage Rates

	Cape Size	Panamax	Handy	Small-Handy
Deadweight [ton]	181,000	70,600	44,400	23,400
Hold volume [m^3]	209,000	74,800	60,600	22,500
Voyage Rates with heavy cargoes (such as ore) [US$/day]	36,200	14,120	13,320	9,360
Voyage Rates with light cargoes (such as grain) [US$/day]	72,400	28,240	22,200	14,040

Table A1.3.2 Ratio of Voyage Type

				Cape Size	Panamax	Handy	Small-Handy
Laden voyage	Heavy cargo	Full draft		16.00 %	6.00 %	14.40 %	18.90 %
		Not full	Full capacity	4.80 %	0.40 %	0.36 %	0.21 %
			Not full	19.20 %	3.60 %	3.24 %	1.89 %
			(sub total)	(24.00 %)	(4.00 %)	(3.60 %)	(2.10 %)
		(Sub total)		(40.00 %)	(10.00 %)	(18.00 %)	(21.00 %)
	Light cargo	Full draft		3.00 %	20.00 %	29.40 %	39.20 %
		Not full	Full capacity	6.30 %	16.00 %	8.82 %	5.88 %
			Not full	0.70 %	4.00 %	3.78 %	3.92 %
			(sub total)	(7.00 %)	(20.00 %)	(12.60 %)	(9.80 %)
		(Sub total)		(10.00 %)	(40.00 %)	(42.00 %)	(49.00 %)
	(Sub total)			(50.00 %)	(50.00 %)	(60.00 %)	(70.00 %)
Ballast voyage				50.00 %	50.00 %	40.00 %	30.00 %

On the basis of table A1.3.1 and table A1.3.2, items (1) to (3) are estimated as follows;

(1) Loss of expected economical benefits due to deadweight loss per year [US$/year/ton] is expressed as (Laden voyage days per year with full draught) x (voyage rate per day) / (deadweight).

In case of Cape Size:

365 days x (16.00 % x 36,200 US$/day + 3.00 % x 72,400 US$/day) / 181,000 ton

= 16.060 [US$/year/ton]

(2) Loss of expected economical benefits due to cargo hold volume loss per year [US$/year/$m^3$] is expressed as (Laden voyage days per year with cargoes of full capacity) x (voyage rate per day) / (cargo hold volume).

In case of Panamax BC:

365 days x (0.40 % x 14,120 US$/day + 16.00 % x 28,240 US$/day) / 74,800 m^3

= 22.324 [US$/year/$m^3$]

(3) Demurrage [US$/day] is estimated as (Voyage incomes per year) x 90 %.

In case of Handy BC:

(18.00 % x 13,320 US$/day + 42.00 % x 22,200 US$/day) x 90 %

= 10,549 [US$/day]

Accordingly, monetary loss per unit caused by the implementation of RCO can be estimated as shown in Table A1.3.3.

Table A1.3.3 Monetary Loss per Unit caused by the Implementation of RCO

	Cape Size	Panamax	Handy	Small-Handy
Monetary Loss due to Deadweight Loss [US$/year/ton]	16.060	33.580	69.423	113.723
Monetary Loss due to Cargo Hold Volume Loss [US$/year/$m^3$]	10.994	22.324	12.082	13.711
Demurrage [US$/day]	19,537	11,437	10,549	7,961

A2 Cost for the Implementation of each RCO

A2.1 Application of SOLAS Chapter XII

A2.1.1 For new-building ships

Table A2.1.1 shows cost for the application of SOLAS Chapter XII to new-building ships estimated on the basis of actual results of the application. This table also shows cost for the application of IACS UR S21 of the requirements relating to the hatch cover that has been implemented at the same time.

Table A2.1.1 Cost for the application of SOLAS Chapter XII for new-building ships

		Cape		Panamax		Handy		Small-Handy	
Deadweight [ton]		170,000	172,000	72,000	73,500	33,500	36,000	---	---
Actual Increased Steel Weight [ton]	Hull	358	322	103	137	27	41	---	---
	Hatch Cover*	34	29	15	16	16	18	---	---
	Total	392	351	118	153	43	59	---	---
Average		372 (340)		136 (120)		51 (34)		---	
UR S21		Applied	N.A.	Applied	N.A.	Applied	N.A.	Applied	N.A.
Estimated Increased Weight [ton]**		374	340	137	120	53	34	24	14***
Material [$]		224,400	204,000	82,200	72,000	31,800	20,400	14,400	8,400
Work [$]		112,200	102,000	41,100	36,000	15,900	10,200	7,200	4,200
Facility [$]		0	0	0	0	0	0	0	0
Sub-total		336,600	306,000	123,300	108,000	47,700	30,600	21,600	12,600
Monetary Loss [$]		150,161	136,510	115,012	100,740	91,985	59,010	68,065	39,705
Total		486,761	442,510	238,312	208,740	139,685	89,610	89,665	52,305

* These hatch covers are initially designed in the condition of design load of 2.08 ton/m^2.

** Details relating to hatch covers are referred to A2.4.

*** Increased weight for small handy bulk carriers is estimated by extrapolation of one for handy bulk carriers based on bending capacity of W.T. bulkhead.

A2.1.2 For existing ships

It is difficult to estimate a cost for the application of SOLAS Chapter XII to existing ships on the basis of actual results, because these actual results have diverseness in extent of retrofitting work. Therefore, in this study, the cost is diverted from the results of trial design and cost estimation of the retrofitting work in "IACS Bulk Career FSA study – Fore end watertight integrity" (IACS, 2001), an outline of which is given as follows.

Tables A2.1.2 to A2.1.5 show the results of trial design and cost estimation of the retrofitting work for the application of SOLAS Chapter XII to existing Cape Size bulk carrier and Panamax bulk carrier. In these trial designs, up-grading of aft bulkhead and double bottom of foremost cargo hold for Cape Size bulk carrier and up-grading of aft bulkhead of foremost hold for Panamax bulk carrier was examined. For up-grading of bulkhead, two methods of reinforcement by doubling plates and replacement with newly constructed one are examined. These extents of retrofitting works are in accordance with the actual results of ships registered in ClassNK such that up-grading of double bottom was not needed in almost Panamax bulk carriers.

The above-examined costs show rather higher value because these costs are calculated on the basis of standard fee of Japanese middle class shipyard. Therefore, unit costs referred in Tables A1.2.2 and A1.2.3 are estimated by coordination with actual material unit cost referring to MSC68/4/9, etc. Tables A2.1.6 and A2.1.7 show the results of cost estimation for the application of SOLAS Chapter XII that is developed for smaller ships. These tables also include monetary losses evaluated on the basis of values referred in Table A1.3.3.

Table A2.1.2 Cost for the application of SOLAS Chapter XII (BHD replacement of Cape Size BC)

Item	(Cape size BC / BHD replace)			Cost
Material	Main material	Steel plate	110.9 ton	63,550 [$]
		Paint	1,800 m^2	5,760 [$]
		Other		0 [$]
	Sub material	Welding bar	3.7 ton	6,370 [$]
		Shot blast		19,320 [$]
	Sub total			95,000 [$]
Work	Repair work	Steel work (BHD)	6,000 hrs	300,000 [$]
		Steel work (DB)	1,560 hrs	78,000 [$]
		Paint work (BHD)	270 hrs	13,500 [$]
		Paint work (DB)	220 hrs	11,000 [$]
	Incidental work		222 hrs	10,080 [$]
	Cleaning, etc.			18,300 [$]
	Design, Control, etc.		500 hrs	30,000 [$]
	Sub total			460,880 [$]
Facilities	Berth		40 days	214,170 [$]
	Test			1,600 [$]
	Sub total			215,770 [$]
Grand total				771,650 [$]

Table A2.1.3 Cost for the application of SOLAS Chapter XII (BHD reinforcement of Cape Size BC)

Item	(Cape size BC / BHD reinforce)			Cost
Material	Main material	Steel plate	45.0 ton	25,790 [$]
		Paint	660 m^2	2,940 [$]
		Other		7,260 [$]
	Sub material	Welding bar	1.5 ton	2,590 [$]
		Shot blast		15,050 [$]
	Sub total			53,630 [$]
Work	Repair work	Steel work (BHD)	3,920 hrs	196,000 [$]
		Steel work (DB)	1,560 hrs	78,000 [$]
		Paint work (BHD)	570 hrs	28,500 [$]
		Paint work (DB)	220 hrs	11,000 [$]
	Incidental work		90 hrs	4,090 [$]
	Cleaning, etc.			18,300 [$]
	Design, Control, etc.		500 hrs	30,000 [$]
	Sub total			365,890 [$]
Facilities	Berth		37 days	198,100 [$]
	Test			1,200 [$]
	Sub total			199,300 [$]
Grand total				618,820 [$]

Table A2.1.4 Cost for the application of SOLAS Chapter XII (BHD replacement of Panamax BC)

Item	(Panamax BC / BHD replace)			Cost
Material	Main material	Steel plate	55.6 ton	31,860 [$]
		Paint	1,030 m^2	3,300 [$]
		Other		1,100 [$]
	Sub material	Welding bar	1.85 ton	3,190 [$]
		Shot blast		9,940 [$]
	Sub total			49,390 [$]
Work	Repair work	Steel work (BHD)	4,000 hrs	200,000 [$]
		Paint work (BHD)	220 hrs	11,000 [$]
	Incidental work		111 hrs	5,050 [$]
	Cleaning, etc.			20,470 [$]
	Design, Control, etc.		350 hrs	21,000 [$]
	Sub total			257,520 [$]
Facilities	Berth		30 days	72,380 [$]
	Test			400 [$]
	Sub total			72,780 [$]
Grand total				379,690 [$]

Table A2.1.5 Cost for the application of SOLAS Chapter XII (BHD reinforcement of Panamax BC)

Item	(Panamax BC / BHD reinforce)			Cost
Material	Main material	Steel plate	23.2 ton	13,290 [$]
		Paint	580 m^2	1,800 [$]
		Other		5,500 [$]
	Sub material	Welding bar	0.77 ton	1,340 [$]
		Shot blast		8,180 [$]
	Sub total			30,110 [$]
Work	Repair work	Steel work (BHD)	2,950 hrs	147,500 [$]
		Paint work (BHD)	460 hrs	23,000 [$]
	Incidental work		46.4 hrs	2,110 [$]
	Cleaning, etc.			20,470 [$]
	Design, Control, etc.		350 hrs	21,000 [$]
	Sub total			214,080 [$]
Facilities	Berth		28 days	67,560 [$]
	Test			400 [$]
	Sub total			67,960 [$]
Grand total				312,150 [$]

Table A2.1.6 Estimated Cost for the application of SOLAS Chapter XII (BHD replacement)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	111	56	31	11
Work period [days]	40	30	30	30
Material [$]	88,800	44,480	24,936	8,840
Work [$]	205,350	102,860	57,665	20,433
Facility [$]	70,072	21,375	15,276	6,384
Sub-total	364,222	168,715	97,877	35,667
Increased weight [ton]	22	11	6	2
Monetary loss [$]	785,053	346,850	320,811	241,327
Total	1,149,275	515,565	418,688	276,994

Table A2.1.7 Estimated Cost for the application of SOLAS Chapter XII (BHD reinforcement)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	45	23	13	5
Work period [days]	37	28	28	28
Material [$]	52,650	26,910	15,210	5,850
Work [$]	166,050	84,870	47,970	18,450
Facility [$]	64,817	19,950	14,258	5,958
Sub-total	283,517	131,730	77,438	30,258
Increased weight [ton]	45	23	13	5
Monetary loss [$]	722,876	320,242	295,384	222,899
Total	1,006,393	451,972	372,822	253,157

A2.2 Cost for the Application of Double Side Skin Construction

A2.2.1 For new-building ships

Basic concept of the estimation of cost for the application of double side skin construction is in accordance with one for existing ships except unit costs specified in A1 above and the matters specified otherwise in the followings.

.1 Cost for additional paint works estimated on the basis of the following paint area should be included.

For mid-holds

Paint area = (Hold length) x ((Depth of D.H.) + (Breadth of D.H.) x 2) x 2

+ ((Breadth of D.H.) x (Depth of D.H.) x (Hold length) / (Floor space)) x 2

Floor space = (Breadth of D.H.) x 2

For foremost/aftermost holds

Paint area = 1.3 x (Paint area of mid-hold)

General assumption (Basic principle is as same as one for volume of double side skin structures)

Hold length = 0.8 Lf / (Number of C.H.)

Breadth of D.H. = 1.2 [m]

Depth of D.H. = 0.2 B [m]

Total paint area inside of double side skin structures

A = 1.6 Lf x (0.6 B + 4.8) x (N + 0.6) / N [m^2]

.2 Cargo hold volume loss is estimated as 1/3 of one for existing ship because this matter is conceivable to be improved by design considerably. However, it should be noted that design of small-handy bulk carriers might not so have a space for improvement. Alternative value for small-handy bulk carriers calculated so that volume loss is estimated as 3/4 of one for existing ships, is noted at the foot of Table A2.2.1 for reference.

.3 Increased steel weight is conceivable to be also improved by design considerably. In this study, it is estimated as 70% of one for existing ship considering the actual results.

Table A2.2.1 shows the results of this cost estimation.

Table A2.2.1 Cost for the application of double side skin construction for new-building ships

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	805	379	244	109
Paint area [m^2]	15,854	9,093	7,797	4,641
Material [$]	483,000	227,220	146,160	65,110
Work [$]	241,500	113,610	73,080	32,550
Paint [$]	45,707	26,215	22,479	13,380
Paint work [$]	98,818	56,677	48,599	28,927
Facilities [$]	0	0	0	0
Sub-total [$]	869,025	423,722	290,317	139,957
Deadweight loss [ton]	805	379	244	109
Cargo hold volume loss [m^3]	1,806	972	833	458*
Monetary loss due to cargo hold volume loss [$]	819,708 (496,500)	860,119 (542,200)	674,328 (251,542)	464,744* (157,032)
Total [$]	1,688,733	1,283,841	964,645	604,701

* Where the hold volume loss is considered 3/4 of that for existing vessels instead of 1/3 used in this examination, monetary loss will be estimated of 353,323 $ for hold volume loss of 1,031 m^3.

A2.2.2 For existing ships

For the estimation of steel weight for the retrofitting works of double side skin structures, steel weight per unit area of double side skin is estimated by conducting simple design trial in the midship sections of Cape Size bulk carrier and Panamax bulk carrier as shown in Table A2.2.2. These results are developed to fore part and aft part in accordance with the following conditions.

(a) Double side spaces are used as void spaces and structural scantlings depend on depth of ship (*D*) corresponding to cargo height that may be representative design factor of inner structure of double side skin.

(b) Area in profile of double side skin is in proportion to the product of length of ship and depth of ship (*Lf* x *D*).

(c) Steel weight needed for retrofitting works of foremost hold and aftermost hold are 130% of one of mid-hold.

Accordingly, steel weight for the retrofitting works is expressed as follows.

$W = 0.00665 \times Lf \times D^2 \times (N + 0.6) / N$ [ton]

N: Numbers of cargo holds

Volume of double side skin spaces is estimated on the assumption of the following conditions.

(a) Transverse section of mid-hold is assumed as shown in Figure A2.2.1.

(b) Length of cargo hold is 0.8 x *Lf* / *N* [m], where "*N*" is number of cargo holds.

(c) Volume of foremost cargo hold is 90% of one of mid-hold.

(d) Volume of aftermost cargo hold is 70% of one of mid-hold.

(e) Breadth of double side skin space in mid-hold is 1.2 [m].

(f) Volume of double side skin spaces in foremost/aftermost cargo hold are 130% of one in mid-hold.

Accordingly, the estimated costs for the retrofitting works for the application of double side skin construction are shown in Table A2.2.3.

Figure A2.2.1 Cargo Hold Model of Trans. Section of Double Side Skin Structure

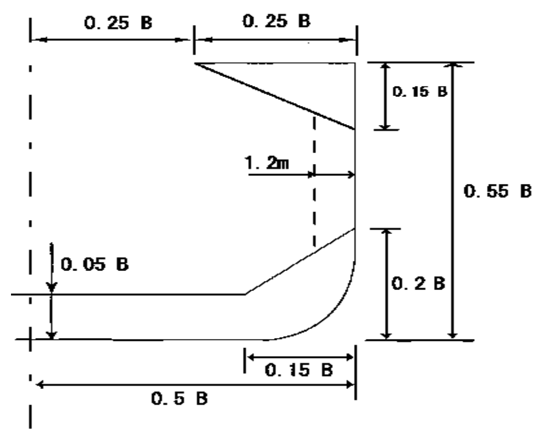

Table A2.2.2 Results of Design Trial of Double Side Skin Structures

	Plate scantling			Weight (incl. stiff.) [ton/m]	Unit weight [ton/m²]
	Thick. [mm]	Width [m]	Length [m]		
Panamax Bulk Carrier					
Side shell plating					
Plate #1	15.50	1.960	1.00	238.48	
Plate #2	15.50	4.290	1.00	521.99	
Plate #3	15.50	0.950	1.00	115.59	
Sum (Height of double side)	---	7.200	---	876.06	121.67
Hold frame					
Web plate	13.00	0.360	5.10	229.89	
Face plate	16.00	0.150	5.10	117.89	
Bkt web #1-1	13.00	0.360	1.00	45.08	
Bkt web #1-2	13.00	0.270	1.00	33.81	
Bkt face #1	16.00	0.150	1.50	34.67	
Bkt web #2-1	15.00	0.360	1.00	52.01	
Bkt web #2-2	15.00	0.270	1.00	39.01	
Bkt face #2	16.00	0.150	2.00	46.23	
Sum	---	---	---	598.60	83.14
Total weight [ton/m]				1,474.66	
Total unit weight [ton/m²] (weight / height of double side)					204.81
Cape Size Bulk Carrier					
Side shell plating					
Plate #1	17.00	1.200	1.00	160.14	
Plate #2	17.00	2.997	1.00	399.95	
Plate #3	17.00	2.853	1.00	380.73	
Plate #4	17.00	1.480	1.00	197.51	
Sum (Height of double side)	---	8.530	---	1,138.33	133.45
Hold frame					
Web plate	13.00	0.500	5.70	363.55	
Face plate	19.00	0.150	5.70	159.40	
Bkt web #1-1	13.00	0.500	1.20	76.54	
Bkt web #1-2	13.00	0.500	1.20	76.54	
Bkt face #1	19.00	0.150	2.30	64.32	
Bkt web #2-1	15.00	0.500	1.48	108.92	
Bkt web #2-2	15.00	0.400	1.48	87.14	
Bkt face #2	19.00	0.150	3.00	83.90	
Sum	---	---	---	1,020.30	1196.61
Total weight [ton/m]				2,158.63	
Total unit weight [ton/m²] (weight / height of double side)					253.06

Table A2.2.3a Cost for the application of double side skin construction for existing ships (all holds)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	1,150	541	348	155
Work period [days]	40	30	30	30
Material [$]	920,000	432,800	278,400	124,000
Work [$]	2,127,500	1,000,850	643,800	286,750
Facility [$]	70,0720	21,375	15,276	6,384
Sub-total [$]	3,117,572	1,455,025	937,476	417,134
Deadweight loss [ton]	1,150	541	348	155
Cargo hold volume loss [m^3]	5,419	2,915	2,498	1,374
Monetary loss due to cargo hold volume loss [$]	1,561,978 (595,800)	1,175,424 (650,640)	859,925 (301,850)	603,094 (188,439)
Total [$]	4,679,550	2,630,449	1,797,401	1,020,228

Table A2.2.3b Cost for the application of double side skin construction for existing ships (only no.1 hold)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	156	93	81	44
Work period [days]	30	28	28	28
Material [$]	124,583	74,032	64,629	35,043
Work [$]	288,099	171,198	149,454	81,038
Facility [$]	52,554	19,950	14,258	5,958
Sub-total [$]	465,236	265,180	228,340	122,040
Deadweight loss [ton]	156	93	81	44
Cargo hold volume loss [m^3]	734	499	580	388
Monetary loss due to cargo hold volume loss [$]	691,807 (80,681)	462,610 (111,294)	421,540 (70,072)	325,846 (53,254)
Total [$]	1,157,044	727,790	649,880	447,886

Table A2.2.3c Cost for the application of double side skin construction for existing ships (Nos.1 & 2 holds)

	Cape	Panamax	Handy	Small-Handy
Steel weight [ton]	276	164	143	78
Work period [days]	30	28	28	28
Material [$]	220,417	130,979	114,343	62,000
Work [$]	509,714	302,889	264,418	143,375
Facility [$]	52,554	19,950	14,258	5,958
Sub-total [$]	782,684	453,818	393,018	211,333
Deadweight loss [ton]	276	164	143	78
Cargo hold volume loss [m^3]	1,298	882	1,026	687
Monetary loss due to cargo hold volume loss [$]	773,108 (142,744)	572,124 (196,904)	518,584 (123,974)	405,036 (94,219)
Total [$]	1,555,793	1,025,942	911,602	616,369

A2.3 Safety measures for single side skin structures

In respect to the estimation of costs for safety measures for single side skin structures, the following concrete measures are examined for simplifying detail of which is described in Appendix D and Table A2.3.1 shows the results of this cost estimation.

(a) Corrosion margin in web and face of hold frames should be increased of 2 mm in thickness. (It is only applicable to new-building ships.)

(b) Corrosion control in early stage of corrosion by enhanced annual maintenance in service should be conducted considering that coating damage is unavoidable and cannot be covered by a periodical survey or maintenance in dry dock. In this study, the effect of such maintenance is evaluated in the model of re-paint with sand blasting every 10 years. In this model, paint area is estimated as twice of profile area of double side skin part. (Stricter control of paint condition)

(c) Corrosion allowance of hold frames should be reduced. In this study, the effect of such measure is evaluated in the model of replacement of lower one-third part of hold frames before 20 years in ship's age. (Application of enhanced corrosion allowance)

Table A2.3.1a Cost for the implementation of RCOs relating to single side skin structure (Cape Size)

Cape Size BC			
	Increase of web of hold frame in thickness (2mm up)	Re-paint of hold frames every 10 years	Replacement of lower part of hold frames in ships of 20 years
Steel weight [ton]	54	0	104
Paint area [m^2]	---	7,567	---
Work period [days]	0	9 x 2 times	20
Material cost [$]	32,400	0	83,200
Work cost [$]	16,200	0	192,400
Paint cost [$]	---	193,458	---
Paint work cost [$]	---	94,330	---
Cost for facilities [$]	0	31,532	35,063
Sub-total [$]	48,600	319,321	310,636
Deadweight loss [ton]	54	0	0
Monetary loss [$]	21,681	351,670	390,744
Total [$]	70,281	670,990	701,380

Table A2.3.1b Cost for the implementation of RCOs relating to single side skin structure (Panamax)

Panamax BC			
	Increase of web of hold frame in thickness (2mm up)	Re-paint of hold frames every 10 years	Replacement of lower part of hold frames in ships of 20 years
Steel weight [ton]	22	0	52
Paint area [m^2]	---	4,466	---
Work period [days]	0	7 x 2 times	15
Material cost [$]	13,200	0	41,600
Work cost [$]	6,600	0	96,200
Paint cost [$]	---	114,178	---
Paint work cost [$]	---	55,673	---
Cost for facilities [$]	0	9,975	10,688
Sub-total [$]	19,800	179,826	148,488
Deadweight loss [ton]	22	0	0
Monetary loss [$]	18,469	160,121	171,558
Total [$]	38,269	339,947	320,046

Table A2.3.1c Cost for the implementation of RCOs relating to single side skin structure (Handy)

Handy BC			
	Increase of web of hold frame in thickness (2mm up)	Re-paint of hold frames every 10 years	Replacement of lower part of hold frames in ships of 20 years
Steel weight [ton]	19	0	43
Paint area [m^2]	---	3,498	---
Work period [days]	0	5 x 2 times	15
Material cost [$]	11,400	0	34,400
Work cost [$]	5,700	0	79,550
Paint cost [$]	---	89,430	---
Paint work cost [$]	---	43,606	---
Cost for facilities [$]	0	5,092	7,638
Sub-total [$]	17,100	138,128	121,588
Deadweight loss [ton]	19	0	0
Monetary loss [$]	32,976	105,494	158,242
Total [$]	50,076	243,622	279,830

Table A2.3.1d Cost for the implementation of RCOs relating to single side skin structure (Small-handy)

Small-Handy BC			
	Increase of web of hold frame in thickness (2mm up)	Re-paint of hold frames every 10 years	Replacement of lower part of hold frames in ships of 20 years
Steel weight [ton]	13	0	28
Paint area [m^2]	---	2,521	---
Work period [days]	0	4 x 2 times	15
Material cost [$]	7,800	0	22,400
Work cost [$]	3,900	0	51,800
Paint cost [$]	---	64,452	---
Paint work cost [$]	---	31,427	---
Cost for facilities [$]	0	1,702	3,192
Sub-total [$]	11,700	97,581	77,392
Deadweight loss [ton]	13	0	0
Monetary loss [$]	36,869	63,685	119,410
Total [$]	48,569	161,267	196,802

A2.4 Safety measures for Hatch Covers

A2.4.1 Estimation of Steel Weight of Hatch Covers

In this study, retroactive application of IACS UR S21 to existing ships is examined as a safety measure for hatch covers. This examination targets to hatch covers for foremost cargo hold as a representative to hatch covers which may be located in the extent of the application of this requirement. For new-building ships, cost estimation of safety measures for hatch covers is referred to actual results referred in A2.1.1.

Increased steel weight of hatch covers is conceivable to be in proportion to increase of strength of hatch cover panels that can be expressed as follows:

(a) In case of side rolling type (main girders are arranged in lengthwise) (Cape Size & Panamax) (length of hatch covers)^2 x (breadth of hatch covers) x (design load of hatch covers) x α

(b) In case of folding type (main girders are arranged in breadthwise) (Handy Size)

(length of hatch covers) x (breadth of hatch covers)^2 x (design load of hatch covers) x β

where α and β are fixed values.

Accordingly, increased weight of hatch covers can be estimated by considering bending capacity in comparison between design load under ILLC and design load under S21 as shown in Table A2.4.1.

Table A2.4.1 Design Load for Hatch Covers

	Design Load [ton/m^2]	Allowable stress [kg/mm^2]*1
ILLC1966	1.75	10.553*2
IACS UR S21	6.106*4	25.688*3

*1: Value based on using high-tensile steel of 32kg/mm^2 (Yield stress: 315 kN/mm^2, Tensile strength: 440 kN/mm^2).

*2: This value is estimated as 1/4.25 of tensile strength. It is conceivable to include safety margin for corrosion.

*3: This value is estimated as 0.8 times of yield stress considering safety factor for corrosion.

*4: This value for Cape Size BC of 281.50 m in Lf and having foremost hatch covers positioned in 0.087Lf aftward of forward perpendicular.

For this purpose, equivalent design load of hatch covers under ILLC is estimated as follows:

Equivalent design load = (Design load under ILLC) / (Allowable stress under ILLC) x (Allowable stress under IACS UR S21) x Kc
= 3.408 [ton/m^2]

Kc = 0.8 (Safety factor for corrosion)

Figure A.2.4.1 shows the design load for hatch covers under S21 in comparison with equivalent design load estimated above. Table A4.2.4 shows the results of weight estimation, which is given by comparing of design load and considering the actual results in new-building ships referred in A2.1.1. For the application to existing ships, both method of up-grading by replacement of hatch covers and reinforcement of existing hatch covers should be examined. In the later case, increased weight is estimated as 140% of one by replacement referring the actual results of up-grading of bulkheads relating to the application of SOLAS Chapter XII.

Table A2.4.2 Steel Weight of Foremost Hatch Covers

	Cape	Panamax	Handy	Small-Handy
Design load under S21 [ton/m^2]	6.106	5.382	4.699	4.536
Weight of foremost hatch covers designed by ILLC [ton]	67	48	48	28
Weight of foremost hatch covers designed by S21 [ton]	102	66	67	38
Increased weight (for replacement) [ton]	34	17	19	10
Steel weight for reinforcement [ton]	48	24	27	14

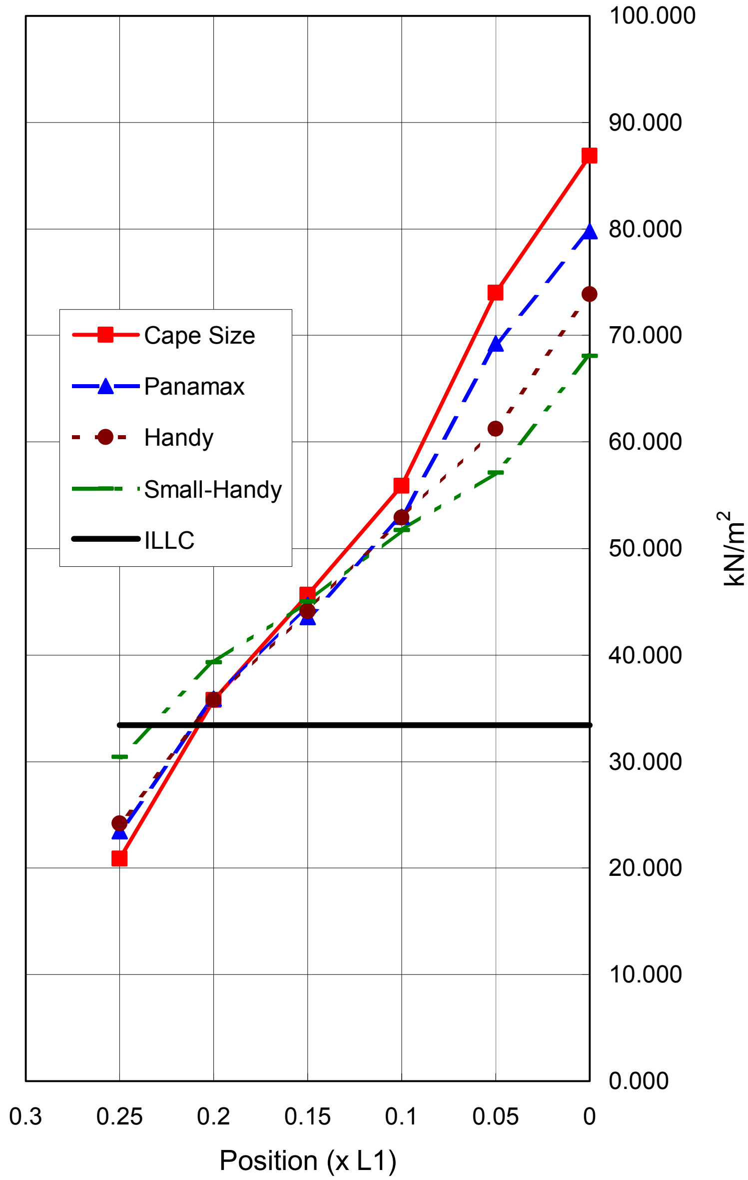

Figure A2.4.1 Design Load for Hatch Covers

A2.4.2 Cost for the Application of UR S21

Table A2.4.3 shows the results in detail that are estimated on the assumption of the following conditions.

.1 In case of replacement

Unit costs: As same as those for replacement of bulkheads except unit cost for steel work which is estimated as 50% of one of bulkhead considering that steel work outside may be limited.

Work period: 3 days

.2 In case of reinforcement

Unit costs: As same as those for reinforcement of bulkheads.

Work period: 5 days

Table A2.4.3 Cost for the Implementation of RCO relating to Hatch Covers

	Capesize		Panamax		Handy		Small-Handy	
	Replace	Reinforce	Replace	Reinforce	Replace	Reinforce	Replace	Reinforce
Steel weight [ton]	102	48	66	24	67	27	38	14
Period [days]	3	5	3	5	3	5	3	5
Material [$]	81,600	56,160	52,800	28,080	53,600	31,590	30,400	16,380
Work [$]	94,350	177,120	61,050	88,560	61,975	99,630	35,150	51,660
Facility [$]	5,255	8,759	2,138	3,563	1,528	2,546	638	1,064
Total [$]	181,205	242,039	115,988	120,203	117,103	133,766	66,188	69,104
Increase weight [ton]	34	48	17	24	19	27	10	14
Monetary loss [$]	5,460	7,709	5,709	8,059	13,190	18,744	11,345	15,882
Demurrage [$]	58,612	97,686	34,311	57,186	31,648	52,747	23,882	39,803
Total [$]	64,072	105,395	40,020	65,245	44,838	71,491	35,227	55,685
Grand total [$]	245,277	347,434	156,008	185,448	161,941	205,257	101,415	124,789

A3 Conclusion

Figures A3.1 to A3.4 show the results of cost estimation for each type of bulk carriers. As given in these figures consisting of shaded part showing the cost for the implementation of RCO and striped part showing the monetary losses caused by the implementation, it is found that such monetary losses cannot be ignored.

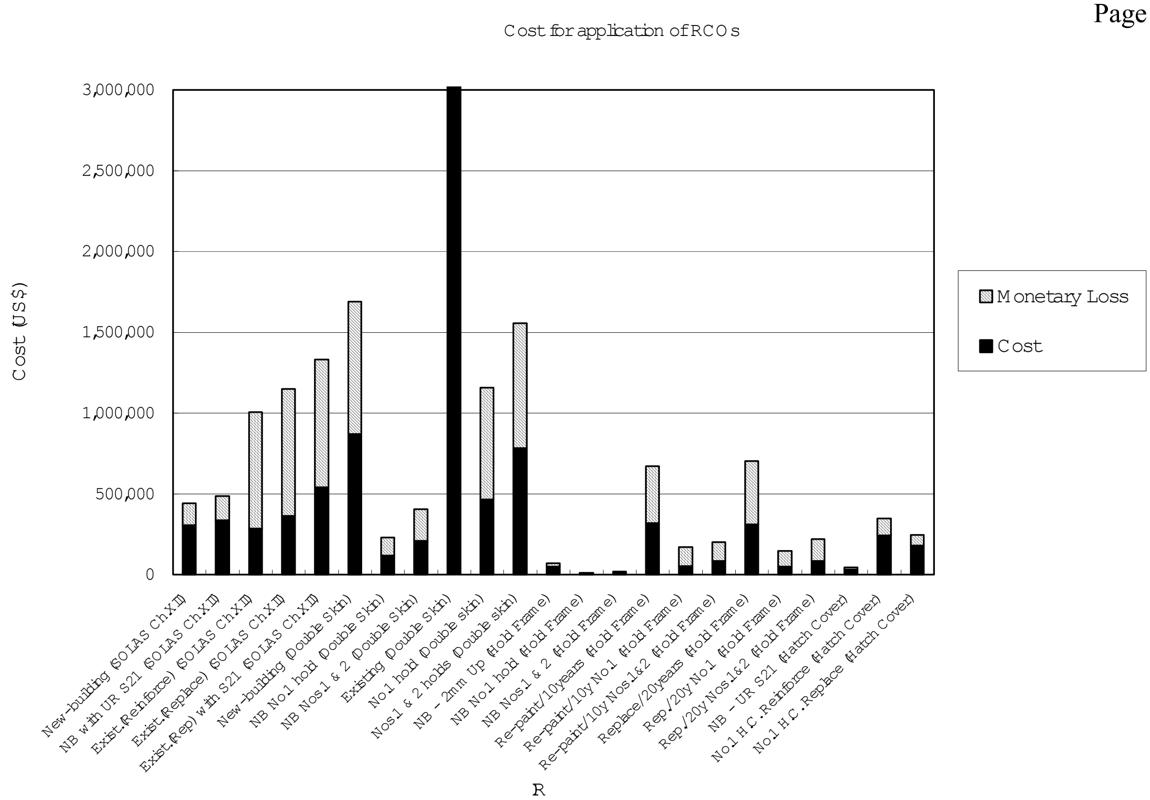

Figure A3.1 Cost for the implementation of each RCO for Cape Size BC

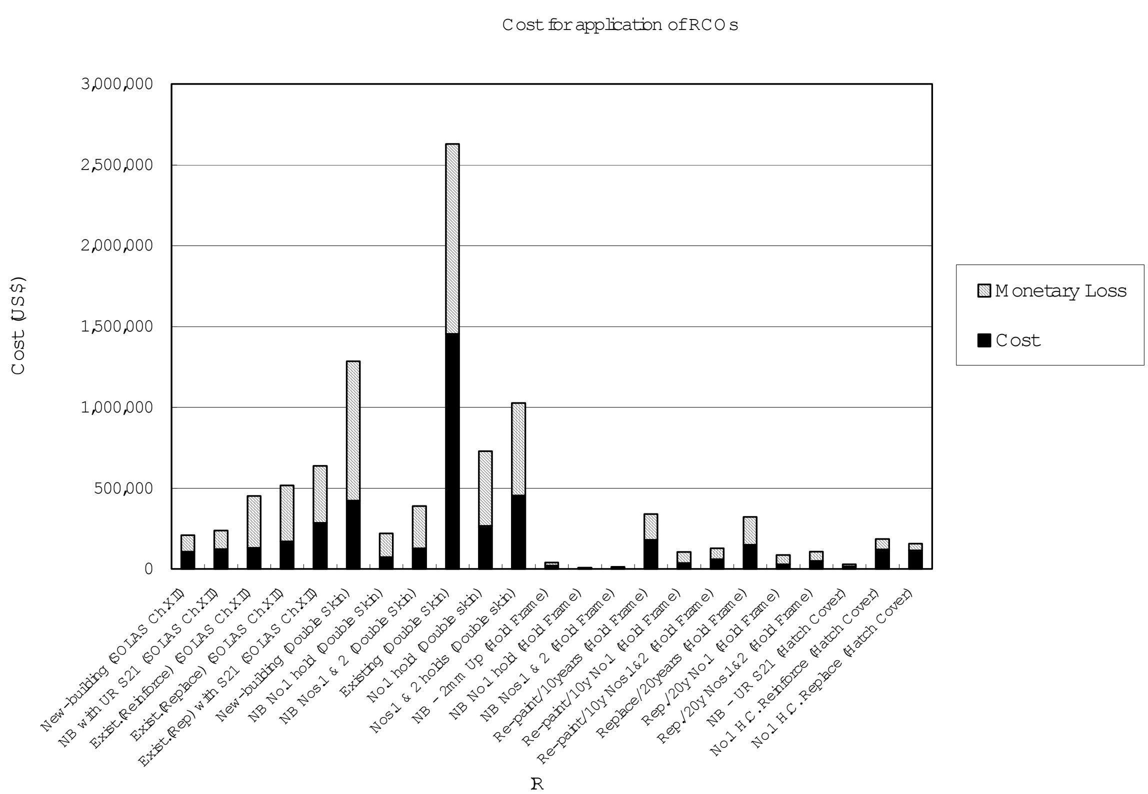

Figure A3.2 Cost for the implementation of each RCO for Panamax BC

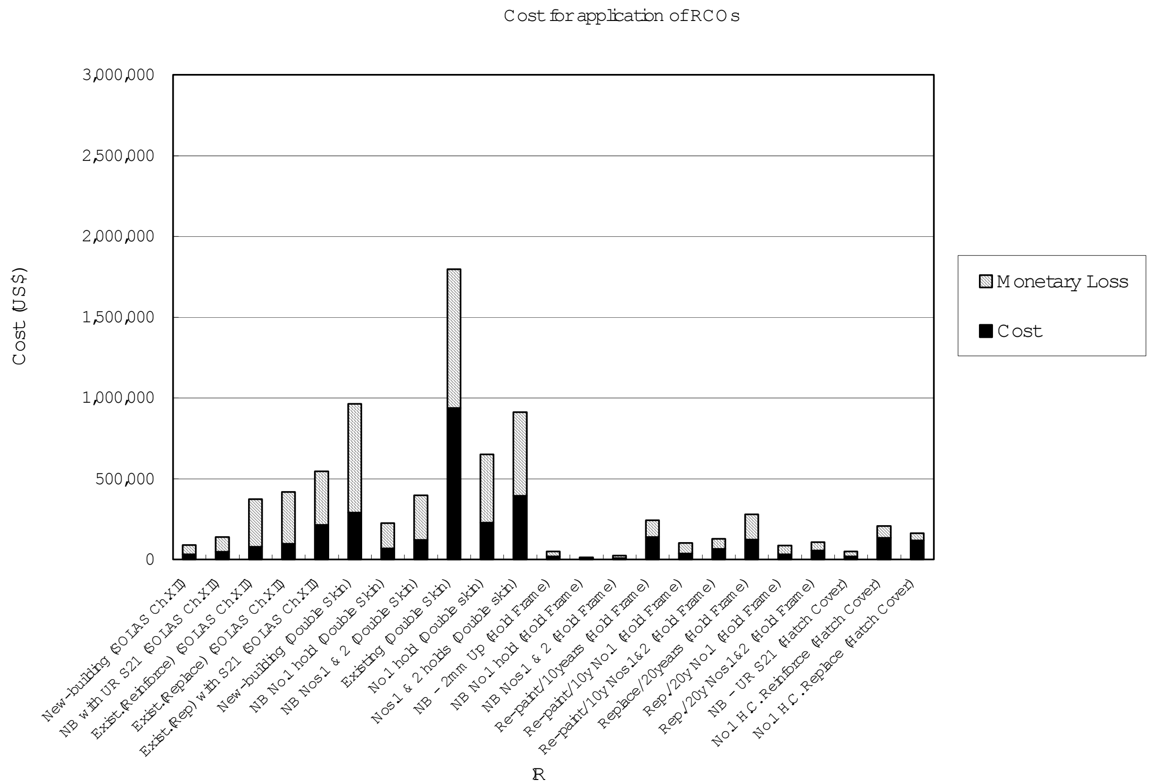

Figure A3.3 Cost for the implementation of each RCO for Handy BC

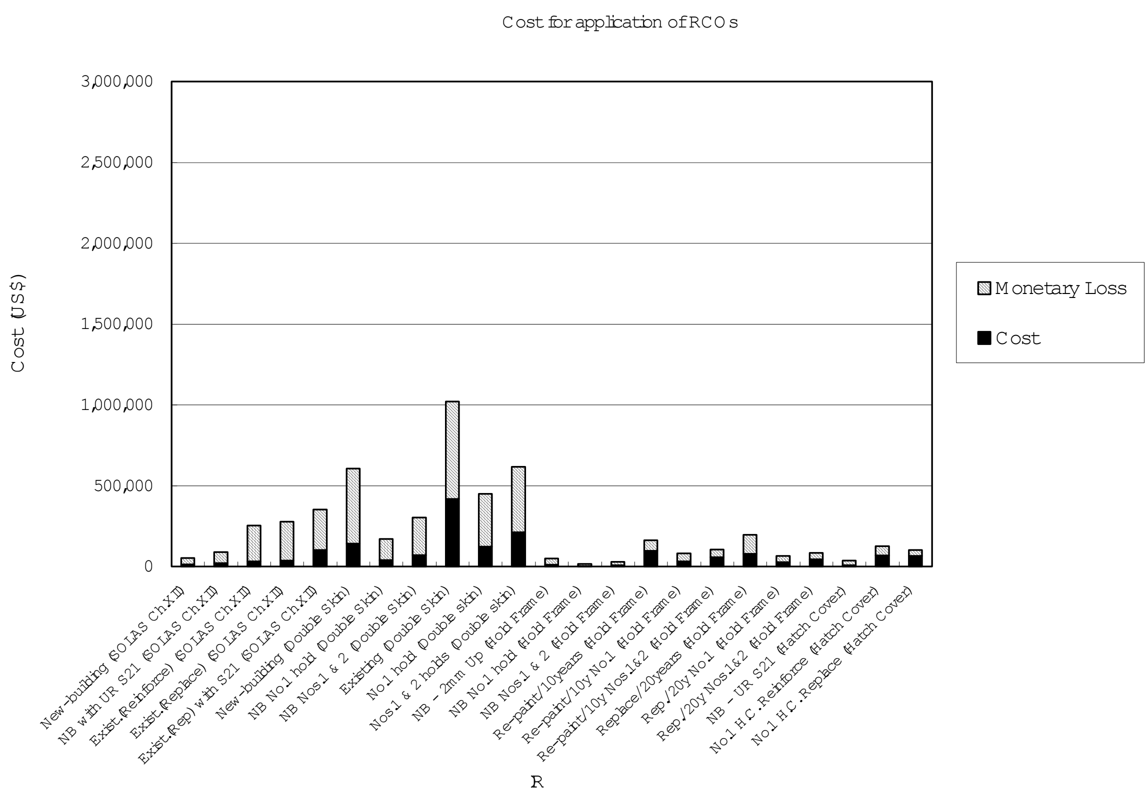

Figure A3.4 Cost for the implementation of each RCO for Small-Handy BC

Appendix B Results of Experts Judgement

Table B1a Summary of Casualties resulted in total loss due to structural failure (Part 1)

Main Cause	ID	Size	No. of Hold	Number of Fatalities	Age	RCO Case No. Possible to Prevent or Mitigate
n.1 Hold Flooding and suspected progressive flooding to adjacent Hold	2	Capesize	12	0	21	10A,20,11,21,12,22,15,25A,25B
	5	Capesize	9	5	16	10A,20,11,21,12,22,15,25A,(25B)
	9	Capesize	9	0	21	10A,20,11,21,12,22,15,25A,(25B)
	16	Capesize	9	30	17	10A,20,11,21,12,22,15,25A,25B
	24	Panamax	8	25	16	10A,20,11,21,12,22,15,25A,25B
	26	Panamax	9	19	13	(10A),(11),(12),(15)
	27	Panamax	9	0	17	15,25A,25B
	31	Panamax	7	0	18	10A,20,11,21,12,22,15,25A,25B
	33	Panamax	6	0	14	15
	35	Panamax	8	0	24	10A,20,11,21,12,22,15,25A,25B
	38	Panamax	8	0	14	(10A),(11),(12),(15)
	63	Handy	7	0	14	10A,11,12,15
	116	Handy	?	0	23	15,25A,25B,10A,11,12,(20),(21),(22)
	117	Handy	?	0	20	10A,(20),11,(21),12,(22),15,25A,25B
	95	Small-Handy	5	20	21	11A,15,25A,25B
	98	Small-Handy	?	25	13	11A,15
	(16 Cases)	Sub total		124	282	
Other Hold Flooding and suspected progressive flooding to adjacent Hold	11	Capesize	9	0	13	10A,11,12,15
	14	Capesize	9	0	15	10A,11,12,15,25A
	21	Capesize	9	0	23	10A,11,12,15,25A
	84	Capesize	9	0	21	10A,11,12,15,25A,25B
	108	Capesize	9	0	17	10A,11,12,15,25A
	25	Panamax	7	0	12	10A,11,12,15
	28	Panamax	7	0	24	10A,11,12,15,25A
	39	Panamax	7	0	21	10A,11,12,15,25A
	43	Handy	8	38	24	10A,11,12,15,25A
	46	Handy	?	0	13	10A,11,12,15
	51	Handy	8	0	24	10A,11,12,15,25A,25B
	58	Handy	?	3	17	10A,11,12,15,25A
	59	Handy	7	0	17	10A,11,12,15,25A,25B
	73	Handy	7	0	29	10A,11,12,15,25A
	76	Handy	?	29	18	10A,11,12,15,25A
	87	Handy	5	0	11	10A,11,12,15
	92	Small-Handy	5	0	13	10A,11,12,15 (Lf>150m)
	127	Small-Handy	5	0	15	11A,15,25A,25B
	133	Small-Handy	6	0	23	11A,15,25A
	144	Small-Handy	5	0	8	15,25A
	(20 Cases)	Sub total		70	358	
One Hold Flooding and suspected progressive flooding (Hold Nos.are unknown)	3	Capesize	9	26	9	(10A),(11),(12),(15)
	6	Capesize	9	36	21	(10A),(20),(11),(21),(12),(22),(15),(25A),(25B)
	17	Capesize	9	0	19	10A,(20),11,(21),12,(22)
	29	Panamax	7	27	14	(10A),(11),(12),(15)
	40	Panamax	?	0	11	10A,11,12,15
	109	Panamax	?	0	27	10A,(20),11,(21),12,(22),15,25A,(25B)
	52	Handy	7	0	22	10A,20,11,21,12,22,15,25A,25B
	60	Handy	7	0	18	10A,(20),11,(21),12,(22),15,25A,(25B)
	64	Handy	6	0	21	10A,(20),11,(21),12,(22),15,25A,(25B)
	65	Handy	7	2	24	(10A),(20),(11),(21),(12),(22),(15),(25A),(25B)
	70	Handy	?	30	25	(10A),(20),(11),(21),(12),(22),(15),(25A),(25B)
	88	Handy	5	0	23	(10A),(20),(11),(21),(12),(22),15,25A,(25B)
	90	Handy	?	31	18	(10A),(20),(11),(21),(12),(22),15,25A,(25B)
	91	Handy	?	26	18	(10A),(20),(11),(21),(12),(22),15,25A,(25B)
	101	Handy	7	21	26	-
	102	Handy	5	19	12	(10A),(11),(12)
	106	Handy	?	25	21	(10A),(11),(12)
	113	Handy	?	1	23	10A,(20),11,(21),12,(22),15,25A,(25B)
	93	Small-Handy	?	51	13	11A,15
	121	Small-Handy	7	0	23	10A,(20),11,(21),12,(22),15,25A,(25B) (Lf>150m)
	123	Small-Handy	?	0	21	11A,15,25A,(25B)
	125	Small-Handy	6	24	22	10A,(20),11,(21),12,(22),15,25A,(25B) (Lf>150m)
	137	Small-Handy	?	0	29	(11A),(11B),15,25A,(25B)
	(23 Cases)	Sub total		319	460	

Table B1b Summary of Casualties resulted in total loss due to structural failure (Part 2)

Main Cause	ID	Size	No. of Hold	Number of Fatalities	Age	RCO Case No. Possible to Prevent or Mitigate
One Hold flooding and progressive flooding to remote Hold	22	Capesize	9	33	24	15,25A,(25B)
	61	Handy	7	0	12	-
	122	Small-Handy	4	0	24	15,25A,25B,11A
	(3 Cases)	Sub total		33	60	
Single Hold flooding - broken up	34	Panamax	7	0	25	15,25A,25B
	143	Small-Handy	4	0	16	15,25A
	(2 Cases)	Sub total		0	41	
Single Hold flooding - sank	97	Small-Handy	4	8	23	10A,20,15,25A,(25B) (Lf>150m)
	119	Small-Handy	?	0	19	11A,15,25A
	124	Small-Handy	4	20	16	11A,15,25A,(25B)
	126	Small-Handy	4	30	18	11A,21,15,25A,(25B)
	131	Small-Handy	?	0	22	11A,15,25A,(25B)
	134	Small-Handy	4	24	22	(11A),15,25A,25B
	136	Small-Handy	3	13	17	11,15,25A,25B
	140	Small-Handy	?	0	28	(11A),15,25A,(25B)
	146	Small-Handy	?	0	18	(11A),15,25A
	147	Small-Handy	5	4	22	15,25A,(25B)
	148	Small-Handy	3	24	18	(11A),15,25A,(25B)
	149	Small-Handy	?	0	16	(11A),15,25A
	(12 Cases)	Sub total		123	239	
Other compartment flooding - consequently sank	O4	Capesize	9	0	23	-
	O27	Handy	?	0	24	-
	O33	Handy	7	6	18	-
	O39	Handy	7	0	22	-
	O42	Handy	6	0	20	-
	O50	Handy	?	0	24	-
	O59	Handy	7	0	25	-
	O53	Small-Handy	7	5	20	-
	O54	Small-Handy	5	0	20	-
	O55	Small-Handy	?	0	22	-
	O56	Small-Handy	4	26	20	-
	O57	Small-Handy	?	0	5	-
	(12 Cases)	Sub total		37	243	
	(88 Cases)	Total		706	1683	
		Mean		8.0	19.1	

Table B2 Summary of Casualties resulted in total loss due to hatch cover failure

Main Cause	ID	Size	No. of Hold	Number of Fatalities	Age	RCO Case No. Possible to Prevent or Mitigate
n1&n2 Flooding suspected escalated by BHD Failure	H9	Handy	?	30	9	10A,11,12,14
	H18	Handy	5	27	21	10A,20,11,21,12,22,14,24
		Sub total		57	30	
n1&n2 Flooding suspected escalated by n.2 HC Failure	H4	Panamax	8	17	24	10A,11,12,14,24
	H7	Handy	?	0	17	10B,11B,23(P,M)
	H8	Handy	?	69	15	10A,11,20,14,24
	H10	Handy	?	24	21	10A,20,11,12,14,24
	H14	Handy	5	0	14	10A,(10B),11,(11B),12
		Sub total		110	67	
FE&n1 Flooding suspected escalated by n.1 HC Failure	H21	Capesize	9	44	4	10B,11,12
	H19	Handy	6	33	39	10A,11,12,20
		Sub total		77	43	
n4 Flooding + other holds flooding	110	Panamax	7	18	23	10A,11,12,15,25A
		Sub total		18	23	
	(10 Cases)	Toal		262	140	
		Mean		26.2	14	

Table B3 Summary of Casualties resulted in total loss due to unknown structural failure

Main Cause	ID	Size	No. of Hold	Number of Fatalities	Age	RCO Case No. Possible to Prevent or Mitigate
Unknown Structural Failure and/or Hold Flooding	74	Handy	7	6	23	(10A)(10B),(20),(11),(21),(12),(22),(23),(14),(24),(15),(25A),(25B)
	94	Small-Handy	5	0	22	(11A),(11B),(15),(25A),(25B)
	99	Small-Handy	4	0	23	(11A),(11B),(15),(25A),(25B)
	107	Small-Handy	4	27	15	(11A),(11B),(15),(25A),(25B)
	138	Small-Handy	4	0	16	(11A),(11B),(15),(25A),(25B)
	139	Small-Handy	4	24	19	(11A),(11B),(15),(25A),(25B)
Total	(6 Cases)			57	118	
Mean				9.5	19.667	

Appendix C Results of Estimation of Risk Reduction

Table C1 Effectiveness of RCOs in term of Risk Reduction Rates

		Number of Total Loss Cases	Number of Probably Mitigated	Number of Possibly Mitigated	Converted Number of Cases	Risk Reduction Rate
RCO10	Capesize	15	11	2	12	80.0%
	Panamax	16	10	3	11.5	71.9%
	Handy	42	22	8	26	61.9%
	ALL	73	43	13	49.5	67.8%
RCO10A	Capesize	15	10	2	11	73.3%
	Panamax	16	10	3	11.5	71.9%
	Handy	42	21	8	25	59.5%
	ALL	73	41	13	47.5	65.1%
RCO10B	Capesize	15	1	0	1	6.7%
	Panamax	16	0	0	0	0.0%
	Handy	42	1	2	2	4.8%
	ALL	73	2	2	3	4.1%
RCO20	Capesize	15	4	2	5	33.3%
	Panamax	16	3	1	3.5	21.9%
	Handy	42	5	11	10.5	25.0%
	ALL	73	12	14	19	26.0%
RCO11	Capesize	15	11	2	12	80.0%
	Panamax	16	10	3	11.5	71.9%
	Handy	42	22	8	26	61.9%
	Small Handy	31	12	11	17.5	56.5%
	ALL (Incl. SH)	104	55	24	67	64.4%
RCO21	Capesize	15	4	2	5	33.3%
	Panamax	16	3	1	3.5	21.9%
	Handy	42	5	11	10.5	25.0%
	Small Handy	31	1	0	1	3.2%
	ALL	104	13	14	20	19.2%
RCO23	Capesize	15	0	0	0	0.0%
	Panamax	16	0	0	0	0.0%
	Handy	42	1	1	1.5	3.6%
	Small Handy	31	0	0	0	0.0%
	ALL	104	1	1	1.5	1.4%
RCO15	Capesize	15	10	2	11	73.3%
	Panamax	16	12	3	13.5	84.4%
	Handy	42	18	3	19.5	46.4%
	Small Handy	31	21	5	23.5	75.8%
	ALL	104	61	13	67.5	64.9%
RCO25A	Capesize	15	9	1	9.5	63.3%
	Panamax	16	9	0	9	56.3%
	Handy	42	15	3	16.5	39.3%
	Small Handy	31	19	5	21.5	69.4%
	ALL	104	52	9	56.5	54.3%
RCO25B	Capesize	15	3	4	5	33.3%
	Panamax	16	5	1	5.5	34.4%
	Handy	42	5	9	9.5	22.6%
	Small Handy	31	5	13	11.5	37.1%
	ALL	104	18	27	31.5	30.3%
RCO16	ALL	104	Based on the simple structural reliability analysis of single side skin structure in Appendix D.			38.0%
RCO51	ALL	104				32.9%
RCO52	ALL	104				36.6%

Appendix D Evaluation of Structural Reliability on Hold Frames

D1 Preamble

Major factor of flooding casualties from single side structures has been considered decline of strength in hold frames or drop away of hold frame webs caused by corrosion. In this study, an evaluation of some RCOs was carried out by simplified structural reliability on hold frames with respect to strength of frames considering corrosion with/without possible safety measures. This evaluation is based on the assumption that structural strength of side structures depends on decline of section modulus in hold frames after corrosion. Improvement of welding at lower end of frame webs that is also seemed as one of effective safety measures should be discussed as a part of safety measures evaluated in the followings.

D2 Model of reliability analysis

D2.1 Corrosion Model on Hold Frames

For an examination of relationship between depth of corrosion and decline of section modulus on hold frames, a corrosion model in section of hold frames can be estimated as shown in Figure D2.1.1. Because most of corrosion is conceivable to be in cargo hold side where it is easy to make start of corrosion at coating damages on hold frames by loading/unloading, and to progress under the condition of loading of iron ore and coal alternately or sea water washing after loading. Figure D2.1.2 shows the ratio of decline of section modulus of hold frames due to corrosion which is estimated that the above corrosion model apply to hold frames in the Generic Model by using the probabilistic progress model of corrosion as shown in Figure D2.1.3.

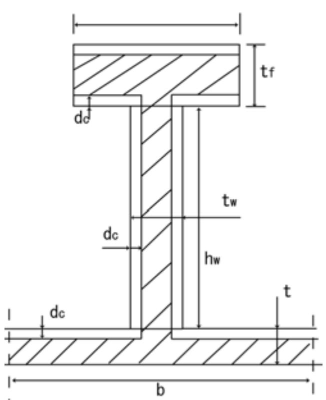

Figure D2.1.1 Corrosion Model in section of hold frame

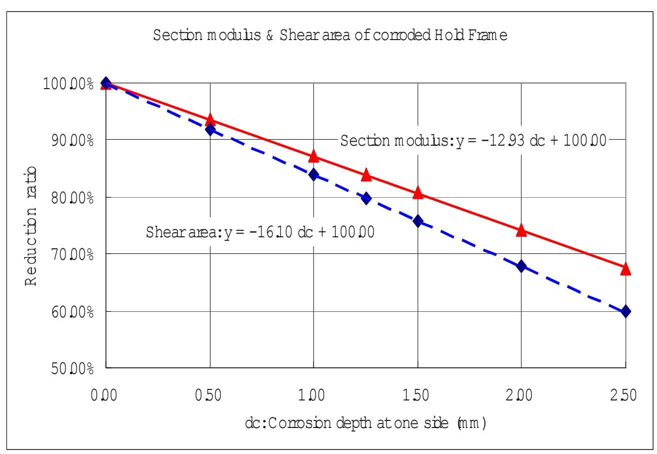

Figure D2.1.2 Reduction Ratio of section modulus and shearing area due to corrosion

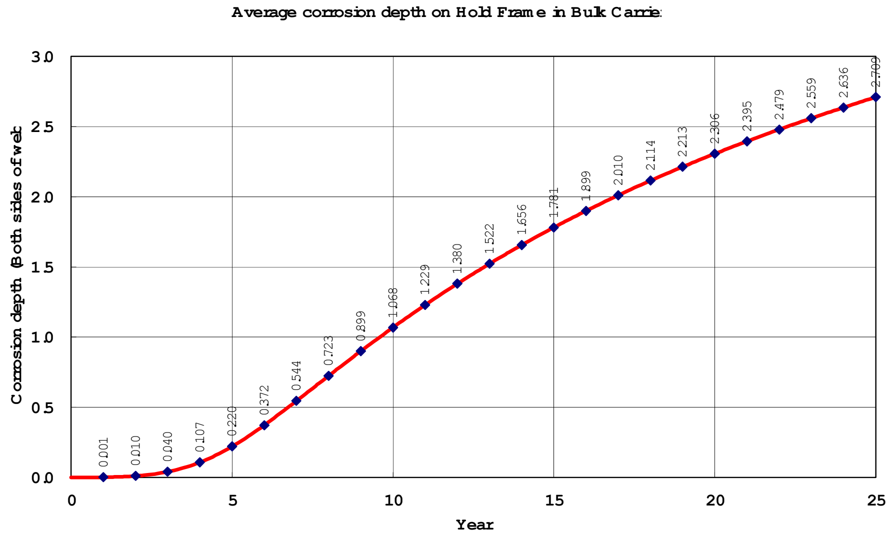

Figure D2.1.3 Average Curve of Probabilistic Progress Model of Corrosion in Lower Webs of Hold Frame on Bulk Carriers

D2.2 Simplified Model for Structural Reliability Analysis

D2.2.1 Outline of Model

The structural reliability analysis as presented here is intended to be representative for hold frames of typical bulk carriers. The failure criterion is formulated as a limit state function:

$$g = p_c - p_d$$

Where the failure domain is $g < 0$.

Failure occurs when the outer pressure load p_d on the hold frame exceeds the structural capacity p_c, which is decreasing year by year for the sake of corrosion.

The relation between extreme outer pressure loads and structural capacity against age of ships has been modelled shown in Figure D2.2.1. When hold frames are not so wasted, there is almost no overlap between distribution of extreme outer pressure loads and structural capacity of hold frames. So the failure probability may be very small. On the contrary, when hold frames are going to be heavily wasted and variety of structural capacity is becoming large, there are considerable area of overlap between loads and structural capacity.

In order to make it simple, the structural capacity is represented by section module of the hold frame, of which reduction rate of modules follows the line in Figure D2.1.2. Because it is not so easy to estimate the distribution of extreme outer pressure loads and failure probability of hold frames could be estimated from historical data and survey records, pd has been decided by matching failure probability by this model with the failure probability calculated from the data.

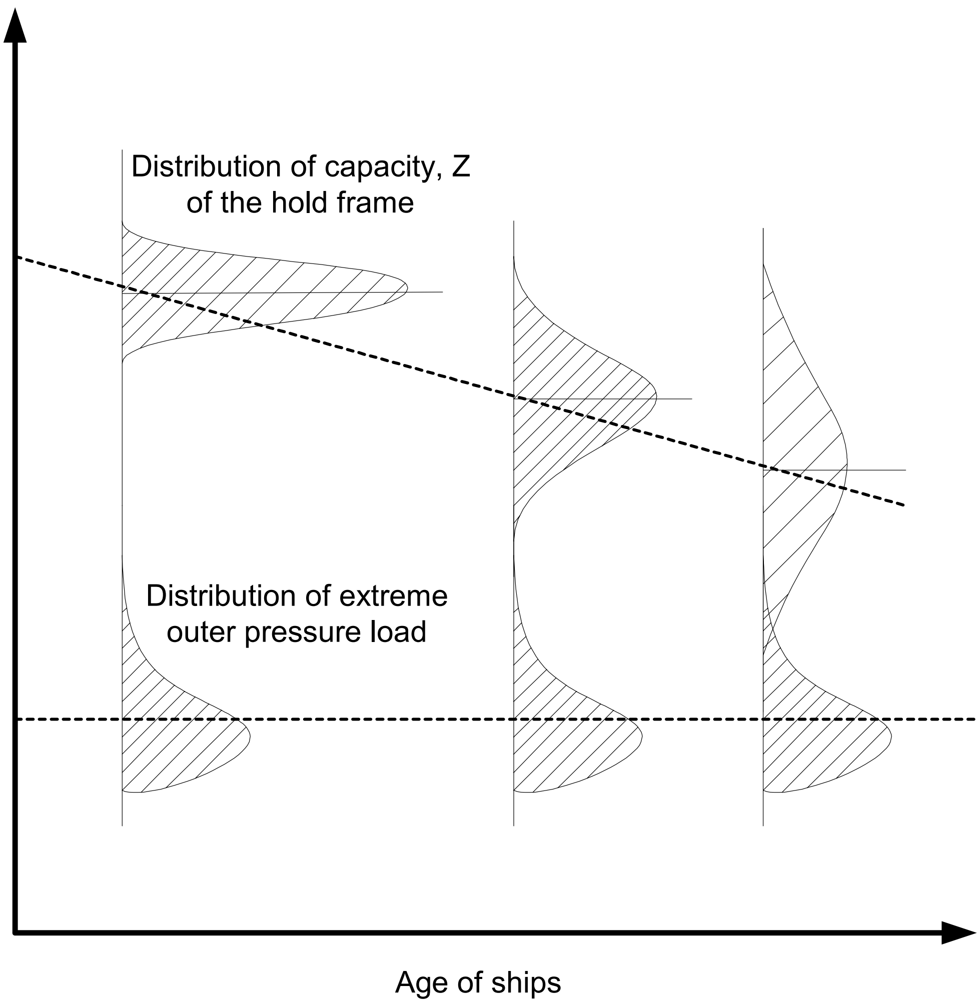

Figure D2.2.1 Simplified model for representing the relation between extreme outer pressure load and structural capacity of hold frames against age of ships

D2.2.2 Calculation of failure probability

.1 Loads

It is assumed that long-term distribution of extreme values of outer pressure loads is expressed by Reyleigh distribution. Probability density function of extreme values of outer pressure loads ξ in terms of the same dimension as section modules; Z is expressed by the following equation.

$$f_S(\xi)=\frac{\xi}{\sigma_S{}^2}\exp\left[-\left(\frac{\xi}{2\sigma_S^2}\right)^2\right]$$

where μ_S : mean of outer pressure loads, S, in terms of the same dimension as section modules

σ_S : Standard deviation of S (σ_S^2 : variance of S)

As it is known that the coefficient of variation is 0.05227 for Reyleigh distribution, following formula representing the relation between σ_S and μ_S could be obtained:

$$V_S = \frac{\sigma_S}{\mu_S} = 0.05227$$

$$\sigma_S = 0.05227\mu_S$$

.2 Distribution of section modules, z, of hold frames of 't' years old bulk carriers

It is assumed the distribution of z of hold frames for new-building bulk carriers is expressed by the normal distribution $N(\mu_0, \sigma_0^2)$, where μ_0 is mean value and σ_0^2 is variance, and that section modules z is decreasing age by age where the figure of coefficient of variation is 100% of magnitude of wastage as follows:

$$\sigma_t^2 = \sigma_0^2 + (\mu_0 - \mu_t)^2$$

where σ_t^2 : the variance of section of modules for 't' years old bulk carriers.

.3 Calculation of Failure Probability

Assuming Z is a function of 't' and S is not a function of 't' in the failure function in terms of the same dimensions as section modules, *M, the safety index* β_t for 't' years old bulk carriers could be approximately expressed by following equation:

$$\beta_t = \frac{\mu_t - \mu_S}{\sqrt{\sigma_0^2 + (\mu_0 - \mu_t)^2 + \sigma_S^2}} = \frac{\mu_t - \mu_S}{\sqrt{\sigma_0^2 + (\mu_0 - \mu_t)^2 + (0.05227\mu_S)^2}}$$

As β_t is considered to be a function of ship's age t and the service life of bulk carriers is assumed to be 25 years, failure probability P_f could be expressed by following equation:

$$P_f = \sum_{t=1}^{25} \Phi(-\beta_t)$$

where Φ is the standard normal distribution function expressed by $\Phi(-\beta) = \int_{-\infty}^{-\beta} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{t^2}{2}\right) dt$

(See Figure D2.2.2)

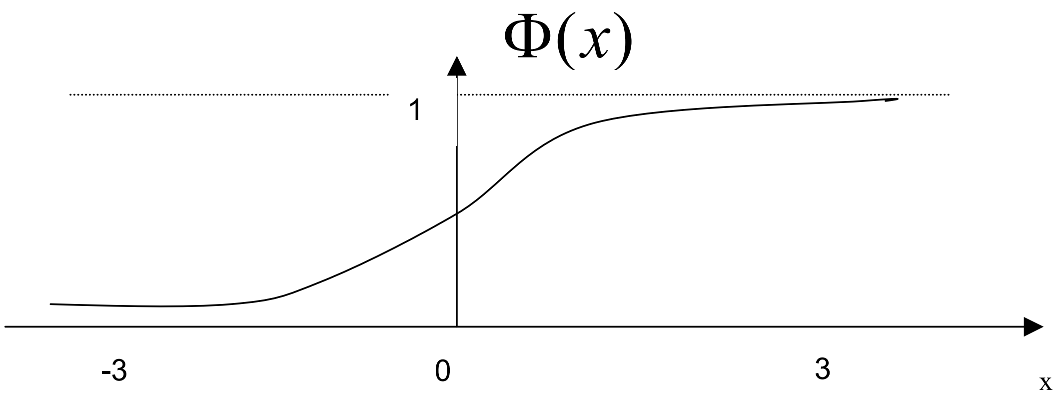

Figure D2.2.2 Standard normal distribution function, Φ

D3 Risk Control Options

The following counter measures for corrosion are examined as a risk control option (RCO) in accordance with the above mentioned evaluation relating to the structural reliability of single side structures.

Case 3: Corrosion control by enhanced annual maintenance in service. In this study, the effect of such maintenance is evaluated in the model of re-paint with sand blasting at 20 years in ship's age. (Control of paint condition)

Case 4: Corrosion control in early stage of corrosion by enhanced annual maintenance in service. In this study, the effect of such maintenance is evaluated in the model of re-paint with sand blasting every 10 years. (Stricter control of paint condition)

Case 5: Corrosion allowance of hold frames is reduced. In this study, the effect of such measure is evaluated in the model of replacement of lower one-third part of hold frames at 20 years in ship's age. (Application of enhanced corrosion allowance)

Case 9: Corrosion margin in web and face of hold frames is increased of 1 mm in thickness at new building.

Case 10: Corrosion margin in web and face of hold frames is increased of 2 mm in thickness at new building.

Figure D3.1 gives a progress of corrosion after the application of the each of above RCO on the basis of the following assumption.

(a) Progress of corrosion after re-paint is same level as one for new-building condition.

(b) Structural strength of hold frames after partial replacement is same level as one at the time of new building.

As the results, probability of destruction can be calculated as shown in Figure D3.2. These results suppose that counter measures after the corrosion have progressed significant level cannot achieve the effects, except where drastic counter measures apply to such as replacement of hold frames shown as case 3 in the figure.

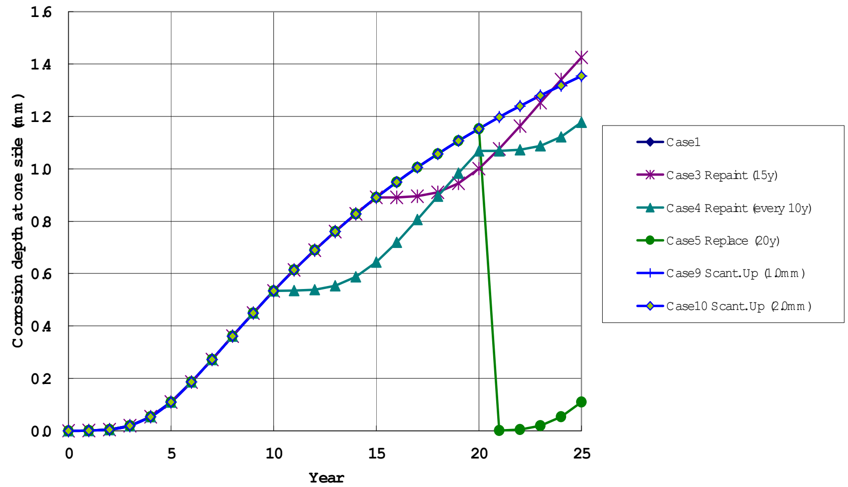

Table D3.1 Depth of Corrosion in Web and Face of Hold Frame at one side

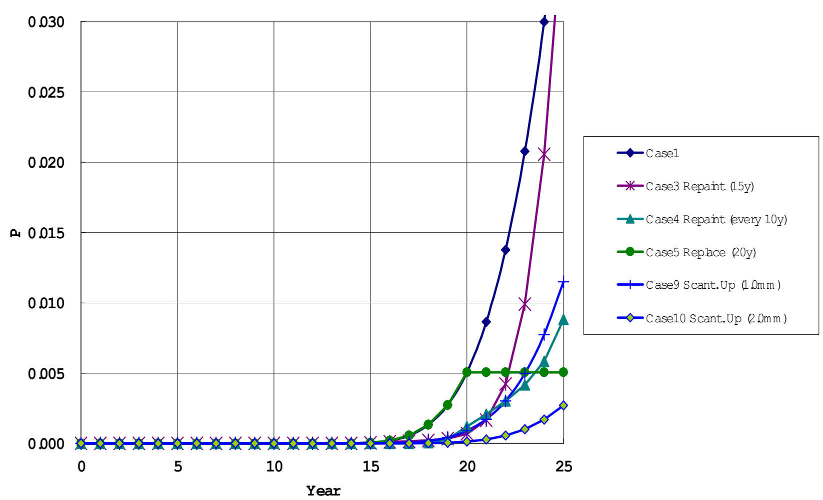

Figure D3.2 Probability of Destruction (Accumulated)

Accordingly, corrosion control by stricter control of paint condition such that re-paint with sand blasting is carried out every 10 years (case 4) or by application of enhanced corrosion allowance (case 5) and increase of corrosion margin (2.0 mm / case 10) are adopted as RCOs in this study. Furthermore, other safety measures such as improvement of welding at lower end of hold frames as mentioned in D1, application of enhanced scantling of hold frames at replacement, etc. should be examined in coordinate with the above RCOs in an examination of actual implementation of those.

REFERENCES:

(1) N. YAMAMOTO: Reliability Based Criteria For Measures Against Corrosion, ClassNK Technical Bulletin Vol.18, 2000

(2) ALAA E. MANSOUR: An Introduction to Structural Reliability Theory, SSC-351, 1990

Appendix E Results of ICAF Estimation

Table E1 Detail of Gross CAF of RCOs

		Total Number of Fatalities	Estimated Population of BC by size	Annual Fatalities Rate before ESP	Annual Fatalities Rate after ESP (Base Risk Level)	Risk Reduction Rate	Expected Life Time (year)	Cost, ΔC	ΔPLL	ΔR	GrossCAF (USD / Averted Fatality)
RCO10	Capesize	174	7,898	2.20E-02	1.75E-02	80.0%	25	337,000	1.40E-02	3.51E-01	***961,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	71.9%	25	123,000	4.01E-03	1.00E-01	***1,228,000***
	Handy	452	47,367	9.54E-03	7.59E-03	61.9%	25	48,000	4.70E-03	1.18E-01	***409,000***
	Total	732	70,400	1.04E-02	8.27E-03	67.8%	25	97,000	5.61E-03	1.40E-01	692,000
RCO10A	Capesize	174	7,898	2.20E-02	1.75E-02	73.3%	25	306,000	1.29E-02	3.21E-01	***952,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	71.9%	25	108,000	4.01E-03	1.00E-01	***1,079,000***
	Handy	452	47,367	9.54E-03	7.59E-03	59.5%	25	31,000	4.52E-03	1.13E-01	***274,000***
	Total	732	70,400	1.04E-02	8.27E-03	65.1%	25	78,000	5.38E-03	1.35E-01	580,000
RCO10B	Capesize	174	7,898	2.20E-02	1.75E-02	6.7%	25	31,000	1.17E-03	2.92E-02	1,061,000
	Panamax	106	15,134	7.00E-03	5.57E-03	0.0%	25	15,000	0.00E+00	0.00E+00	---
	Handy	452	47,367	9.54E-03	7.59E-03	4.8%	25	17,000	3.62E-04	9.04E-03	1,881,000
	Total	732	70,400	1.04E-02	8.27E-03	4.1%	25	18,000	3.40E-04	8.50E-03	2,118,000
RCO20	Capesize	174	7,898	2.20E-02	1.75E-02	33.3%	10	364,000	5.84E-03	1.28E-01	2,855,000
	Panamax	106	15,134	7.00E-03	5.57E-03	21.9%	10	170,000	1.22E-03	2.66E-02	6,390,000
	Handy	452	47,367	9.54E-03	7.59E-03	25.0%	10	97,000	1.90E-03	4.14E-02	2,342,000
	Total	732	70,400	1.04E-02	8.27E-03	26.0%	10	143,000	2.15E-03	4.70E-02	3,043,000
RCO11	Capesize	174	7,898	2.20E-02	1.75E-02	80.0%	25	337,000	1.40E-02	3.51E-01	961,000
	Panamax	106	15,134	7.00E-03	5.57E-03	71.9%	25	123,000	4.01E-03	1.00E-01	1,228,000
	Handy	452	47,367	9.54E-03	7.59E-03	61.9%	25	48,000	4.70E-03	1.18E-01	409,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	56.5%	25	22,000	6.76E-03	1.69E-01	***130,000***
	Total	1025	89,876	1.14E-02	9.07E-03	64.4%	25	80,000	5.85E-03	1.46E-01	547,000
RCO21	Capesize	174	7,898	2.20E-02	1.75E-02	33.3%	10	364,000	5.84E-03	1.28E-01	***2,855,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	21.9%	10	170,000	1.22E-03	2.66E-02	***6,390,000***
	Handy	452	47,367	9.54E-03	7.59E-03	25.0%	10	97,000	1.90E-03	4.14E-02	***2,342,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	3.2%	10	36,000	3.86E-04	8.43E-03	***4,273,000***
	Total	1025	89,876	1.14E-02	9.07E-03	19.2%	10	120,000	1.74E-03	3.81E-02	3,151,000
RCO23	Capesize	174	7,898	2.20E-02	1.75E-02	0.0%	10	181,000	0.00E+00	0.00E+00	***---***
	Panamax	106	15,134	7.00E-03	5.57E-03	0.0%	10	116,000	0.00E+00	0.00E+00	***---***
	Handy	452	47,367	9.54E-03	7.59E-03	3.6%	10	117,000	2.71E-04	5.92E-03	***19,771,000***
	Small Handy	0	19,478	0.00E+00	0.00E+00	0.0%	10	66,000	0.00E+00	0.00E+00	***---***
	ALL	732	89,876	8.14E-03	6.48E-03	1.4%	10	111,000	9.35E-05	2.04E-03	---
RCO16	Capesize	174	7,898	2.20E-02	1.75E-02	38.0%	25	49,000	6.66E-03	1.67E-01	294,000
	Panamax	106	15,134	7.00E-03	5.57E-03	38.0%	25	20,000	2.12E-03	5.30E-02	378,000
	Handy	452	47,367	9.54E-03	7.59E-03	38.0%	25	17,000	2.89E-03	7.22E-02	236,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	38.0%	25	11,700	4.55E-03	1.14E-01	***103,000***
	ALL	1025	89,876	1.14E-02	9.07E-03	38.0%	25	19,000	3.45E-03	8.62E-02	220,000
RCO51	Capesize	174	7,898	2.20E-02	1.75E-02	32.9%	25	319,000	5.76E-03	1.44E-01	2,214,000
	Panamax	106	15,134	7.00E-03	5.57E-03	32.9%	25	180,000	1.83E-03	4.58E-02	3,930,000
	Handy	452	47,367	9.54E-03	7.59E-03	32.9%	25	138,000	2.50E-03	6.24E-02	2,212,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	32.9%	25	98,000	3.93E-03	9.84E-02	***996,000***
	ALL	1025	89,876	1.14E-02	9.07E-03	32.9%	25	152,000	2.98E-03	7.46E-02	2,038,000
RCO52	Capesize	174	7,898	2.20E-02	1.75E-02	36.6%	25	311,000	6.42E-03	1.60E-01	1,938,000
	Panamax	106	15,134	7.00E-03	5.57E-03	36.6%	25	148,000	2.04E-03	5.10E-02	2,901,000
	Handy	452	47,367	9.54E-03	7.59E-03	36.6%	25	122,000	2.78E-03	6.95E-02	1,756,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	36.6%	25	77,000	4.38E-03	1.10E-01	***703,000***
	ALL	1025	89,876	1.14E-02	9.07E-03	36.6%	25	133,000	3.32E-03	8.31E-02	1,601,000
RCO15A	Capesize	174	7,898	2.20E-02	1.75E-02	73.3%	25	1,366,000	1.29E-02	3.21E-01	***4,251,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	84.4%	25	966,000	4.70E-03	1.18E-01	***8,218,000***
	Handy	452	47,367	9.54E-03	7.59E-03	46.4%	25	542,000	3.53E-03	8.81E-02	***6,150,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	75.8%	25	297,000	9.07E-03	2.27E-01	***1,309,000***
	ALL	1025	89,900	1.14E-02	9.07E-03	64.9%	25	668,000	5.89E-03	1.47E-01	4,538,000
RCO25A	Capesize	174	7,898	2.20E-02	1.75E-02	63.3%	10	3,713,000	1.11E-02	2.42E-01	15,325,000
	Panamax	106	15,134	7.00E-03	5.57E-03	56.3%	10	2,106,000	3.13E-03	6.84E-02	30,784,000
	Handy	452	47,367	9.54E-03	7.59E-03	39.3%	10	1,239,000	2.98E-03	6.51E-02	19,034,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	69.4%	10	606,000	8.30E-03	1.81E-01	3,345,000
	ALL	1025	89,900	1.14E-02	9.07E-03	54.3%	10	1,552,000	4.93E-03	1.08E-01	14,430,000
RCO25B	Capesize	174	7,898	2.20E-02	1.75E-02	33.3%	10	925,000	5.84E-03	1.28E-01	7,254,000
	Panamax	106	15,134	7.00E-03	5.57E-03	34.4%	10	651,000	1.92E-03	4.18E-02	15,571,000
	Handy	452	47,367	9.54E-03	7.59E-03	22.6%	10	517,000	1.72E-03	3.75E-02	13,794,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	37.1%	10	306,000	4.44E-03	9.69E-02	3,158,000
	ALL	1025	89,900	1.14E-02	9.07E-03	30.3%	10	553,000	2.75E-03	6.00E-02	9,222,000

Table E2 Detail of Net CAF of RCOs

		Total Number of Fatalities	Estimated Population of BC by size	Annual Fatalities Rate before ESP	Annual Fatalities Rate after ESP (Base Risk Level)	Cost, ΔC	Rf	Ra	₸ B	ΔR	NetCAF
RCO10	Capesize	174	7,898	2.20E-02	1.75E-02	337,000	62,197	28,413	322,000	3.51E-01	43,000
	Panamax	106	15,134	7.00E-03	5.57E-03	123,000	40,521	20,747	188,000	1.00E-01	¢ 649,000
	Handy	452	47,367	9.54E-03	7.59E-03	48,000	34,850	20,197	140,000	1.18E-01	¢ 783,000
	Total	732	70,400	1.04E-02	8.27E-03	97,000			171,000	1.40E-01	¢ 662,000
RCO10A	Capesize	174	7,898	2.20E-02	1.75E-02	306,000	62,197	31,228	295,000	3.21E-01	34,000
	Panamax	106	15,134	7.00E-03	5.57E-03	108,000	40,521	20,747	188,000	1.00E-01	¢ 799,000
	Handy	452	47,367	9.54E-03	7.59E-03	31,000	34,850	20,760	134,000	1.13E-01	¢ 912,000
	Total	732	70,400	1.04E-02	8.27E-03	78,000			164,000	1.35E-01	¢ 782,000
RCO10B	Capesize	174	7,898	2.20E-02	1.75E-02	31,000	62,197	59,382	27,000	2.92E-02	137,000
	Panamax	106	15,134	7.00E-03	5.57E-03	15,000	40,521	40,521	0	0.00E+00	---
	Handy	452	47,367	9.54E-03	7.59E-03	17,000	34,850	33,723	11,000	9.04E-03	664,000
	Total	732	70,400	1.04E-02	8.27E-03	18,000			10,000	8.50E-03	589,000
RCO20	Capesize	174	7,898	2.20E-02	1.75E-02	364,000	62,197	48,120	22,000	1.28E-01	1,229,000
	Panamax	106	15,134	7.00E-03	5.57E-03	170,000	40,521	34,503	9,000	2.66E-02	2,773,000
	Handy	452	47,367	9.54E-03	7.59E-03	97,000	34,850	28,932	9,000	4.14E-02	973,000
	Total	732	70,400	1.04E-02	8.27E-03	143,000			10,000	4.70E-02	1,389,000
RCO11	Capesize	174	7,898	2.20E-02	1.75E-02	337,000	62,197	28,413	322,000	3.51E-01	43,000
	Panamax	106	15,134	7.00E-03	5.57E-03	123,000	40,521	20,747	188,000	1.00E-01	¢ 649,000
	Handy	452	47,367	9.54E-03	7.59E-03	48,000	34,850	20,197	140,000	1.18E-01	¢ 783,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	22,000	21,102	13,004	77,000	1.69E-01	¢ 326,000
	Total	1025	89,876	1.14E-02	9.07E-03	80,000			150,000	1.46E-01	¢ 589,000
RCO21	Capesize	174	7,898	2.20E-02	1.75E-02	364,000	62,197	48,120	22,000	1.28E-01	1,229,000
	Panamax	106	15,134	7.00E-03	5.57E-03	170,000	40,521	34,503	9,000	2.66E-02	2,773,000
	Handy	452	47,367	9.54E-03	7.59E-03	97,000	34,850	28,932	9,000	4.14E-02	973,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	36,000	21,102	20,640	1,000	8.43E-03	1,903,000
	Total	1025	89,876	1.14E-02	9.07E-03	120,000			8,000	3.81E-02	1,500,000
RCO23	Capesize	174	7,898	2.20E-02	1.75E-02	181,000	62,197	62,197	0	0.00E+00	---
	Panamax	106	15,134	7.00E-03	5.57E-03	116,000	40,521	40,521	0	0.00E+00	---
	Handy	452	47,367	9.54E-03	7.59E-03	117,000	34,850	34,004	1,000	5.92E-03	8,982,000
	Small Handy	0	19,478	0.00E+00	0.00E+00	66,000	21,102	21,102	0	0.00E+00	---
	ALL	732	89,876	8.14E-03	6.48E-03	111,000			1,000	2.04E-03	---

RCO16	Capesize	174	7,898	2.20E-02	1.75E-02	49,000	62,197	46,143	153,000	1.67E-01	¢ 624,000
	Panamax	106	15,134	7.00E-03	5.57E-03	20,000	40,521	30,062	100,000	5.30E-02	¢ 1,510,000
	Handy	452	47,367	9.54E-03	7.59E-03	17,000	34,850	25,851	86,000	7.22E-02	¢ 956,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	11,700	21,102	15,648	52,000	1.14E-01	¢ 354,000
	ALL	1025	89,876	1.14E-02	9.07E-03	19,000			87,000	8.62E-02	¢ 890,000
RCO51	Capesize	174	7,898	2.20E-02	1.75E-02	319,000	62,197	48,314	132,000	1.44E-01	1,298,000
	Panamax	106	15,134	7.00E-03	5.57E-03	180,000	40,521	31,477	86,000	4.58E-02	2,052,000
	Handy	452	47,367	9.54E-03	7.59E-03	138,000	34,850	27,068	74,000	6.24E-02	1,026,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	98,000	21,102	16,386	45,000	9.84E-02	539,000
	ALL	1025	89,876	1.14E-02	9.07E-03	152,000			75,000	7.46E-02	1,117,000
RCO52	Capesize	174	7,898	2.20E-02	1.75E-02	311,000	62,197	46,736	147,000	1.60E-01	1,022,000
	Panamax	106	15,134	7.00E-03	5.57E-03	148,000	40,521	30,448	96,000	5.10E-02	1,019,000
	Handy	452	47,367	9.54E-03	7.59E-03	122,000	34,850	26,184	83,000	6.95E-02	561,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	77,000	21,102	15,850	50,000	1.10E-01	246,000
	ALL	1025	89,876	1.14E-02	9.07E-03	133,000			84,000	8.31E-02	610,000

RCO15A	Capesize	174	7,898	2.20E-02	1.75E-02	1,366,000	62,197	31,228	295,000	3.21E-01	3,333,000
	Panamax	106	15,134	7.00E-03	5.57E-03	966,000	40,521	17,308	221,000	1.18E-01	6,338,000
	Handy	452	47,367	9.54E-03	7.59E-03	542,000	34,850	23,860	105,000	8.81E-02	4,959,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	297,000	21,102	10,227	104,000	2.27E-01	851,000
	ALL	1025	89,900	1.14E-02	9.07E-03	668,000			141,000	1.47E-01	4,158,000

RCO25A	Capesize	174	7,898	2.20E-02	1.75E-02	3,713,000	62,197	35,451	41,000	2.42E-01	6,945,000
	Panamax	106	15,134	7.00E-03	5.57E-03	2,106,000	40,521	25,046	24,000	6.84E-02	13,945,000
	Handy	452	47,367	9.54E-03	7.59E-03	1,239,000	34,850	25,551	14,000	6.51E-02	8,623,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	606,000	21,102	11,152	15,000	1.81E-01	1,495,000
	ALL	1025	89,900	1.14E-02	9.07E-03	1,552,000			18,000	1.08E-01	7,827,000
RCO25B	Capesize	174	7,898	2.20E-02	1.75E-02	925,000	62,197	48,120	22,000	1.28E-01	3,245,000
	Panamax	106	15,134	7.00E-03	5.57E-03	651,000	40,521	31,064	15,000	4.18E-02	6,971,000
	Handy	452	47,367	9.54E-03	7.59E-03	517,000	34,850	29,496	8,000	3.75E-02	6,223,000
	Small Handy	293	19,478	1.50E-02	1.20E-02	306,000	21,102	15,780	8,000	9.69E-02	1,409,000
	ALL	1025	89,900	1.14E-02	9.07E-03	553,000			10,000	6.00E-02	5,044,000

Table E3 Detail of Corrected Gross CAF for Bulk carriers complying with Ch.XII or bulk carriers of DSS

For BCs complying with the rquirements of SOLAS Ch.XII

		Total Number of Fatalities	Estimated Population of BC by size	Annual Fatalities Rate before ESP	Annual Fatalities Rate after ESP (Base Risk Level)	Cost, ΔC	ΔR	ΔR (add) for NB (incl. S21)	Corrected GrossCAF	ΔR (add) for EX with EX-XII	Corrected GrossCAF
RCO23	Capesize	174	7,898	2.20E-02	1.75E-02	181,000	0.00E+00			0.00E+00	---
	Panamax	106	15,134	7.00E-03	5.57E-03	116,000	0.00E+00			0.00E+00	---
	Handy	452	47,367	9.54E-03	7.59E-03	117,000	5.92E-03			4.44E-03	***26,361,000***
	Small Handy	0	19,478	0.00E+00	0.00E+00	66,000	0.00E+00			0.00E+00	---
	ALL	732	89,876	8.14E-03	6.48E-03	111,000	2.04E-03			2.34E-03	---
RCO16	Capesize	174	7,898	2.20E-02	1.75E-02	49,000	1.67E-01	3.33E-02	***1,471,000***		
	Panamax	106	15,134	7.00E-03	5.57E-03	20,000	5.30E-02	1.49E-02	***1,343,000***		
	Handy	452	47,367	9.54E-03	7.59E-03	17,000	7.22E-02	2.75E-02	***618,000***		
	Small Handy	293	19,478	1.50E-02	1.20E-02	11,700	1.14E-01	4.95E-02	236,000		
	ALL	1025	89,876	1.14E-02	9.07E-03	19,000	8.62E-02	3.07E-02	732,000		
RCO51	Capesize	174	7,898	2.20E-02	1.75E-02	319,000	1.44E-01	2.88E-02	***11,072,000***	9.60E-02	***3,322,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	180,000	4.58E-02	1.29E-02	***13,974,000***	3.58E-02	***5,031,000***
	Handy	452	47,367	9.54E-03	7.59E-03	138,000	6.24E-02	2.38E-02	***5,805,000***	4.68E-02	***2,949,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	98,000	9.84E-02	4.28E-02	2,288,000	9.52E-02	1,030,000
	ALL	1025	89,876	1.14E-02	9.07E-03	152,000	7.46E-02	2.65E-02	6,881,000	5.98E-02	2,916,000
RCO52	Capesize	174	7,898	2.20E-02	1.75E-02	311,000	1.60E-01	3.21E-02	***9,692,000***	1.07E-01	***2,908,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	148,000	5.10E-02	1.43E-02	***10,316,000***	3.99E-02	***3,714,000***
	Handy	452	47,367	9.54E-03	7.59E-03	122,000	6.95E-02	2.65E-02	***4,608,000***	5.21E-02	***2,341,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	77,000	1.10E-01	4.77E-02	1,614,000	1.06E-01	726,000
	ALL	1025	89,876	1.14E-02	9.07E-03	133,000	8.31E-02	2.95E-02	5,367,000	6.66E-02	2,272,000
RCO15A	Capesize	174	7,898	2.20E-02	1.75E-02	1,366,000	3.21E-01	6.43E-02	***21,254,000***		
	Panamax	106	15,134	7.00E-03	5.57E-03	966,000	1.18E-01	3.31E-02	***29,218,000***		
	Handy	452	47,367	9.54E-03	7.59E-03	542,000	8.81E-02	3.36E-02	***16,144,000***		
	Small Handy	293	19,478	1.50E-02	1.20E-02	297,000	2.27E-01	9.88E-02	3,007,000		
	ALL	1025	89,900	1.14E-02	9.07E-03	668,000	1.47E-01	5.03E-02	15,947,000		
RCO25A	Capesize	174	7,898	2.20E-02	1.75E-02	3,713,000	2.42E-01			1.62E-01	***22,988,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	2,106,000	6.84E-02			5.34E-02	***39,404,000***
	Handy	452	47,367	9.54E-03	7.59E-03	1,239,000	6.51E-02			4.88E-02	***25,378,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	606,000	1.81E-01			1.75E-01	3,457,000
	ALL	1025	89,900	1.14E-02	9.07E-03	1,552,000	1.08E-01			8.69E-02	22,779,000
RCO25B	Capesize	174	7,898	2.20E-02	1.75E-02	925,000	1.28E-01			8.50E-02	***10,881,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	651,000	4.18E-02			3.27E-02	***19,931,000***
	Handy	452	47,367	9.54E-03	7.59E-03	517,000	3.75E-02			2.81E-02	***18,393,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	306,000	9.69E-02			9.38E-02	3,263,000
	ALL	1025	89,900	1.14E-02	9.07E-03	553,000	6.00E-02			4.81E-02	14,713,000

For BCs having double side skin construction

		Total Number of Fatalities	Estimated Population of BC by size	Annual Fatalities Rate before ESP	Annual Fatalities Rate after ESP (Base Risk Level)	Cost, ΔC	ΔR	ΔR (add) for DSS (incl. S21)	Corrected GrossCAF	ΔR (add) for EX DSS	Corrected GrossCAF
RCO11	Capesize	174	7,898	2.20E-02	1.75E-02	337,000	3.51E-01	9.35E-02	***3,605,000***		
	Panamax	106	15,134	7.00E-03	5.57E-03	123,000	1.00E-01	1.56E-02	***7,861,000***		
	Handy	452	47,367	9.54E-03	7.59E-03	48,000	1.18E-01	6.29E-02	***763,000***		
	Small Handy	293	19,478	1.50E-02	1.20E-02	22,000	1.69E-01	4.09E-02	***538,000***		
	Total	1025	89,876	1.14E-02	9.07E-03	80,000	1.46E-01	5.29E-02	2,159,000		
RCO21	Capesize	174	7,898	2.20E-02	1.75E-02	364,000	1.28E-01			3.40E-02	***10,705,000***
	Panamax	106	15,134	7.00E-03	5.57E-03	170,000	2.66E-02			4.16E-03	***40,895,000***
	Handy	452	47,367	9.54E-03	7.59E-03	97,000	4.14E-02			2.22E-02	***4,371,000***
	Small Handy	293	19,478	1.50E-02	1.20E-02	36,000	8.43E-03			2.04E-03	***17,660,000***
	Total	1025	89,876	1.14E-02	9.07E-03	120,000	3.81E-02			1.58E-02	13,958,000
RCO23	Capesize	174	7,898	2.20E-02	1.75E-02	181,000	0.00E+00			0.00E+00	---
	Panamax	106	15,134	7.00E-03	5.57E-03	116,000	0.00E+00			0.00E+00	---
	Handy	452	47,367	9.54E-03	7.59E-03	117,000	5.92E-03			3.17E-03	***36,906,000***
	Small Handy	0	19,478	0.00E+00	0.00E+00	66,000	0.00E+00			0.00E+00	---
	ALL	732	89,876	8.14E-03	6.48E-03	111,000	2.04E-03			1.67E-03	---