ANNEX 6 List of Risk Control Measures and Discussion

1. Method

Counter measures to prevent flooding or to mitigate consequences, i.e., to minimize the number of fatalities caused by flooding were considered as Risk Control Measures (RCMs) for the hazard identified in STEP 1 and/or the risk identified in STEP 2. With regard to estimation of risk reduction by RCOs, two different approaches were adopted. One is a simple method based on historical data. Another method is based on structural reliability model for single side skin structure.

1.1 Identification of Risk Control Options

At first, literature surveys were carried out to seek possible counter measures, which have been already applied to existing bulk carriers or proposed in previous discussions. After that, other counter measures and cost or risk of the counter measures have been examined in experts' discussions. Finally, according to the results of the Risk Analysis in STEP 2, some RCMs or sets of RCMs were selected as Risk Control Options (RCOs)

2. Literature Survey and Experts' Discussions on RCO

Results of the literature survey and the experts' discussions are summarized in a table like **Table 1**. **Table 1** shows just an example. Details are shown in **Appendix A**. Table 2 shows examples of RCM screened out according to the discussion among the research committee (RR74BC-SWG).

Table 1 An example of List of RCOs and Discussion

	No.	RCM	Convention/ Standard	Discussions (A) Current Situation (B) Concrete measures or example (C) Cost and effectiveness (D) Problem in implementation	Notes
Bow height	1	Review of ILLC	ILLC1966	(B) It might be considered with RCM No.2.)	- Under consideration in SLF. - Amendments to rational standards based on ship's motion will be appreciated.
	2	Setting up or enhancement of forecastle	ILLC1966	(B) Newly setting up forecastle of standard superstructure height or enhancement of height of forecastle with another tier of standard superstructure height (C) Design trial is needed. Effectiveness may be evaluated in results of tank tests or numerical simulation. (D) To worsen the navigation bridge visibility. Increase of hull weight in fore part	- ---
Structural strength of fore part	3	Review of wave load (Review of ILLC)	ILLC1966	(B) Ex.1) New design standards equivalent to them for hatch covers or higher, may be applied to deck structures including hatch coaming. Ex.2) Improvement of surpassability of wave by alternation of bow shape (D) In case of Ex.2, reinforcement of bow structure will be needed.	- Under consideration in SLF

	4	Reinforcement of bow structure		(A) In some ships with large bow flare, reinforcement of bow structure is carried out. (B) Application of design method for bow flare structure of vehicles carriers or container carriers	- No major damage has been reported.

Table 2 List of RCOs screened out and discussion

RCMs relating to ILLC (RCM1, 2, 3, 6, (13,) 14, 38, (45,) & 46)	Design criteria of hatch covers have been examined in WG/SLF. Therefore, in this analysis, counter measures have been examined separately at the viewpoint that hatch covers designed on the criteria of IACS UR S21 have enough strength at least in intact condition. See the Appendix A to MSC74/INF.12 in detail.
RCMs relating to securing devices of hatch covers (RCM7 & 39)	Refer to RCMs relating ILLC and RCMs relating to human element.
RCMs relating to hull girder strength (RCM31, 58, 59, 60, 64 & 65 including 57 & 63)	Hull girder strength is considered to be enough in proper use. See the Appendix D in detail. Regarding to loading instruments, loading /unloading/ballasting procedures or hull stress monitoring systems, effectiveness of them depend on human element in large scale and should be considered in line with human element.
RCMs relating to bow access (RCM16 & 17)	These facilities are seemed to be not useful because any effective operation may not be done in heavy weather.
RCMs relating to detection and pumping out of flooding (RCM23-27)	These kinds of equipment that are used after flooding and cannot be expected to mitigate risk directly, should be prior to preventive options.
RCM relating to evacuation (RCM71)	This effect should be considered in the future.
RCMs relating to human element (RCM18, 19, 48, 49, 61, 66 & 68)	This effect should be considered in the future.
RCMs relating to survey system (RCM5, 8, 12, 15, 28, 34, 36, 40, 44, 47 & 54)	Benefits of these RCMs are difficult to be judged in quantitative and should be considered in line with human element. Therefore, in this analysis, benefits of ESP that have been applied since 1993 have been examined on the basis of effect estimated in historical data analysis.

3. Discussion

3.1. Mitigating RCOs vs. preventive RCOs considering risk reduction rate

3.1.1 Generally speaking, risk reduction rates of RCOs for new building ships are better than those for existing ships. This means that RCOs with lower effectiveness are selected for existing ships due to the fact that the applications of RCOs for existing ships requires higher cost than those of new building ships relatively.

3.1.2 Risk reduction by RCO11 for small-handy bulk carriers is considerably smaller than other size of bulk carriers. The reason is that the escalating sequence of typical accidents of small-bulk carriers is not the same as that of other size of bulk carriers. It means that mitigating RCOs to prevent progressive flooding is not so effective for small-handy bulk carriers because one hold flooding of small-handy bulk carriers is likely to be fatal.

3.1.3 In this context, first barrier RCOs such as RCO15, RCO25 and RCO51, to prevent first flooding, for small-handy bulk carriers, are very important for small-handy bulk carriers. In reality, risk reduction by these RCOs is higher than others.

3.1.4 Comparing SOLAS XII related RCO (RCO10 and RCO20) and double side skin related RCOs (RCO15 and RCO25), risk reduction rates are almost same magnitude in rough estimation. On the other hands, the former is mitigating RCO and the latter is preventive RCO. Considering that the results shown in **Figures 2** to **5** includes uncertainty and is based on optimism in some extent, it had better consider effective combination of them.

3.1.5 RCOs for prevention of failures of single side skin structure that will be expected 30-40% risk reduction have been examined try and error.

3.1.6 RCOs related to hatch cover failures show significantly low risk reduction rate because risk or possibility of flooding casualties related to hatch cover failures occupies relatively small portion in total flooding casualties. In addition, it is the result of risk assessment (STEP 2) that the main causes of hatch cover related casualties is judged to be securing problem rather than hatch cover strength. Japan has noted that hatch cover related issue is a controversial topic and a number of investigations are carrying out in relation with discussion of ILLC in SLF Sub-Committee. Japan will continue to investigate this matter not only under the scope of bulk carrier FSA study but also under the scope of SLF Sub-Committee.

3.1.7 Risk reduction by RCO related flooding from fore deck fittings (accident scenario 1-3) is not investigated in the STEP 3 of this study, because of the conclusion of risk assessment (STEP 2) that accident scenario 1-3 is much smaller than others. It is noted that a number of RCOs related to deck fittings, recommended in UK/EC Assessor's Report (1998), and Japan will investigate this issue if its necessity is confirmed.

3.1.8 As indicated in **Figure 1**, weather routing related RCO (RCO53) is considered to be effective to all flooding accident scenarios. Japan has carried out a brief literature survey about weather routing and has not be able to get sufficient data and information for a quantitative assessment with regard to risk reduction so far. Japan will continue to investigate on this issue and will report a result in future. According to a paper in 1983 (J.N. Miller), the casualty rate of unrouted vessels is 32% greater than the casualty rate of routed vessels. The paper relied on data during a period from 1978 to 1982. The data was not limited for bulk carriers. Japan thinks that a same kind of investigation on weather routing is needed for quantitative evaluation of risk reduction of which the current maritime situation is reflected.

3.2 Cargo Density

.2.1 RCO12 and RCO22 are alternatives for RCO10 and RCO20 respectively with regard to cargo density. Cargo density at casualty is investigated in order to check the justification of SOLAS XII. **Table 4** shows the results. It shows that about 70% of fatal casualties were occurred in laden voyage with high-density cargo.

3.3 RCO for Small-handy bulk carrier

.3.1 According to the risk analysis in this study, Cape-size and Small-handy were focused as high risk group in bulk carriers. In the large size bulk carrier, it is well-known fact that coal loading contributes highly to the corrosion of side shell structure that causes structural failure. In case of small size bulk carrier, high probability of total loss after one hold flooding was found. However, the major contribution to the initial structural failure that causes flooding is not very clear. Even though some RCOs are evaluated in this study, it is necessary to clarify the major contributor to the casualty when practically introducing RCO to Small-handy bulk carriers.

Table 4 Ratio of high density cargo loaded at the time of casualty (Total loss in consequence of hold flooding)

Cargo Density	No. of total loss in consequence of hold					No. of Fatality in consequence of hold				
	Cape-size	Panamax	Handy-size	Small-handy	Sum	Cape-size	Panamax	Handy-size	Small-handy	Sum
All	14	16	33	30	93	174	106	446	294	1,020
γ>=1.78 t/m^3	14	9	20	17	60	174	71	291	213	749
1.78>γ>=1.00	0	1	7	1	9	0	0	32	0	32
γ<1.00 t/m^3	0	5	4	9	18	0	35	102	81	218
Ballast	0	1	1	0	2	0	0	21	0	21
Unknown	0	0	1	3	4	0	0	0	0	0
Ratio (>=1.78 t/m^3)	**100%**	**56%**	**61%**	**57%**	**65%**	**100%**	**67%**	**65%**	**72%**	**73%**
Ratio (>=1.00 t/m^3)	**100%**	**63%**	**82%**	**60%**	**74%**	**100%**	**67%**	**72%**	**72%**	**77%**

4. Brief Summary List of Selected RCO

For the purpose of conducting STEP 4, following RCOs were selected:

4.1 RCO selected for Cost Effectiveness Analysis

(1) SOLAS XII related RCO (New-building and Existing)
(2) Extension of Application of SOLAS XII related RCO to Small-handy bulk carriers (New-building and Existing)
(3) Double Side Skin related RCO (New-building and Existing)

4.2 RCO selected for Feasibility Study

(4) Extension of Application of SOLAS XII related RCO with regard to cargo density (Existing)
(5) Fore Deck Access
(6) Life Saving Appliances

4.3 RCO selected as the task for Further Study

(7) Weather routing

LIST OF APPENDIXES

Appendix A: Results of Literature Survey and Discussion of Risk Control Options

APPENDIX A List of Risk Control Measures

Table A.1 List of RCM for prevention of flooding into fore compartment

	No.	RCM	Convention / Standard	Discussions **(A) Current Situation** **(B) Concrete measures or example** **(C) Cost and effectiveness** **(D) Problem in implementation**	Notes
Bow height	1	Review of ILLC	ILLC1966 ---	(B) It might be considered with RCM No.2.)	- Under consideration in SLF. - Amendments to rational standards based on ship's motion will be appreciated.
	2	Setting up or enhancement of forecastle	ILLC1966 ---	(B) Newly setting up forecastle of standard superstructure height or enhancement of height of forecastle with another tier of standard superstructure height (C) Design trial is needed. Effectiveness may be evaluated in results of tank tests or numerical simulation. (D) To worsen the navigation bridge visibility. Increase of hull weight in fore part	- ---
Structural strength of fore part	3	Review of wave load (Review of ILLC)	ILLC1966 ---	(B) Ex.1) New design standards equivalent to them for hatch covers or higher, may be applied to deck structures including hatch coaming. Ex.2) Improvement of surpassability of wave by alternation of bow shape (D) In case of Ex.2, reinforcement of bow structure will be needed.	- Under consideration in SLF
	4	Reinforcement of bow structure		(C) In some ships with large bow flare, reinforcement of bow structure is carried out. (D) Application of design method for bow flare structure of vehicles carriers or container carriers	- No major damage has been reported.
	5	Enhancement of inspection	--- ---	(B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin	- ---

Hatch covers and there securing devices	6	Review of wave load for hatch covers (Review of ILLC)	ILLC1966 IACS UR S21	(A) In general cases, side rolling type or end folding type hatch covers are equipped with bulk carriers. (B) Requirements for new building ships may be applied to existing ships. According to the necessity, larger wave load may be considered. (C) Cost may be considered by difference between steel weight by existing design and which by new design, and (D) Difference of rigidity between hull structure and hatch cover due to more strengthening of hatch cover, may cause other damage to hull. Strength of coaming structure should rather be considered. Increase in weight of hatch cover may require capacity-up of hydraulic systems for hatch operation.	- Serious flooding due to collapse of hatch cover is not reported.
	7	Review of securing systems for hatch covers	---	(A) Sometime cargo damage because of loose securing of hatch cover is reported. (B) Development of device for securing with more simply procedure. Monitoring device and/or alarm of indicating of packing compressed enough or not and hatch cover secured closely or not (C) Design trial is needed. Remote control closing and securing devices by hydraulic systems may be effective for hatch cover. (In this case, 15-20% cost-up should be considered.) (D) It is difficult to protect the installed monitoring devices from environment on deck in cargo area. In case of the installation of powered closing devices for hatch cover, it is difficult to keep the yearly-exhausted devices without careful maintenance in safe condition. Avoiding of human error should be given first priority.	- Well maintenance of packing and securing devices should be well maintained considering yearly exhausting. - These defects are not seemed to cause serious casualties.
	8	Enhancement of inspection	A.744	(A) Enhanced survey has been applied to hatch coaming since 1997. (B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin	- ---
Side structure of foremost cargo hold	9	Review of design standard	IACS UR S12	(A) Strictly requirements for web thickness in lower part of hold frames have been applied since 1992. Since 1997, requirements for section modulus of hold frames in fore part have been applied and after that enhanced more relating to BC Safety.	- The application to ships of length less than 150m and ships with only light cargo should be considered.

Side structure of foremost cargo hold	10	Application of double side skin	---	(A) In case of some coal carriers, double side skin construction has been applied considering well maintenance. (B) Trail design trial is needed. Both of effectiveness (e.g. prevention of flooding, protection of side structure from cargo damage and well maintenance in cargo hold) and defect such as decrease of hold capacity should be considered. (C) Difficulty of inspection Inside of double side skin structure (accuracy of inspection, harmful atmosphere or gases for human etc.) should be considered. The application of the double side skin structure to existing ships is expected to cause serious economical damage. Difference of structural design may cause another problem.	- Where the effectiveness of this RCM could not achieve the enough level, exemption of application the requirements of Ch.XII to double side skin bulk carriers may be reconsidered.
	11	Enhancement of maintenance (Paint)	---	(A) Coating had been applied in cargo hold structures in practice and has been applied compulsorily since 1992 and application area has been extended since 1999. Rapid corrosion caused by loading coal and iron ore alternately and hold washing by seawater, have been reported. (B) Periodically repaint (e.g. after unloading, every 10 years etc.) compulsorily (D) Paint or touch-up in upper part of C.H. is difficult in service.	- Effectiveness of grade-up of coating specification. is not seemed to meet with cost because damage by cargo handling cannot be avoided.
	12	Enhancement of inspection	Ch.XII/7 (A.744)	(A) Implemented since 1993 and enhanced since 1997. (B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin (D) For maintaining paint condition, inspections are required more frequently.	- ---
Small opening s in fore part (access hatches, ventilators, air escape pipes, etc.)	13	Review of design standard	--- ---	(A) Only a trouble on small openings is not seemed to cause serious casualties. Troubles on small openings almost depend on human element including maintenance.	- Effects of small openings in flooding should be reviewed.
	14	Position, height, etc.	ILLC1966		- Effects of small openings in flooding should be reviewed.
	15	Enhancement of inspection	--- ---	(B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin	- Existing style of annual inspection may be enough.

Safety of work at fore deck in heavy weather	16	Lighting for fore deck	---	(A)Existing deck lighting devices may be used for this matter. (D) Such light is prohibited to use in principle.	- ---
	17	Safe access to fore deck			- Being studied.
Safe practice of preparation for heavy weather	18	Standardizing of safe practice in heavy weather	---	(A) Safety practice in heavy weather is various in managing companies. (B) Standardizing of practice. Manuals onboard compulsorily	- Serious casualties are seemed to depend on age of ships. This fact points out that safety level of ships cannot be kept by existing measures and cannot be achieved by operation only.
	19	Education and training of officers and crews	--- ---	--- --- ---	- Decision of captain in weather routing depends on his experience and knowledge.
Weather routing	20	Enhancement of weather information	---	(A) Progress of information technology gives possibility that operators obtain precise and simultaneous weather information. Some operators instruct their ships in detail from shore side. (B) Facilities and services for obtaining weather information as same level as it used by higher level operators, are installed with ship and/or shore station. (D) Unless operating standard for heavy weather is settled, precise weather information cannot contribute to avoid heavy weather, because the highest priority is given to cargo schedule.	- ---
	21	Duplication of main propulsion, power source or other machinery/electrical devices		(D) It is difficult to find appropriate level of requirement that cost meets with effectiveness. In addition to the above, it is not practicable for existing ships.	- ---

Table A.2 Prevention of progressive flooding in fore end compartment

	No.	RCM	Convention or standard	Discussions (A) Current Situation (B) Concrete measures or example (C) Cost and effectiveness (D) Problem in implementation	- Notes
Detection of flooding	23	Bilge or ingress alarm	--- ---	(B) Detection & alarming devices for flooding and remote operated bilge suction system are equipped. (D) Not practical for existing ships	- Ships applied with the provisions of SOLAS Ch.XII/9 are required water ingress alarming device equipped with cargo holds at 2m level from tank top.
	24	Remote sounding	---	(A) Some ships with high specification have remote sounding devices and flooding can be detected from wheelhouse or ballast control room. (B) Remote level gauging devices are equipped with each tank. (D) Not practical for existing ships	- ---
	25	Lighting for fore deck	---	(A) Existing deck lighting devices may be used for this matter. (D) It is very difficult to confirm cargo holds flooded or not.	- ---
Pumping out of ingress water	26	Emergency bilge suction system	--- ---	(B) Additional bilge suction system for water ingress above cargo Capacity up of bilge pump --- (D) Bilge suction system for water ingress above cargo is impracticable.	- Effectiveness is doubtful in case of some cargoes. - Bilge wells are needed in forward of cargo hold considering trim after fore part flooding. - Attention has to be paid to arrangement of bilge pump.
	27	Remote control of bilge suction system	---	(A) Generally, bilge suction systems for forecastle spaces and cargo holds with main line system are controlled locally. (B) Bilge suction system and gauging system are equipped.	- ---
	28	Enhancement of inspection	--- ---		- ---
Stability in flooded condition	29	Floodable in any one compartment	Ch.XII/4 (A.320 & A.514)	(A) Design change is required for small ships.	- Condition of small ships after flooding is seemed to be serious, however, many serious casualties are reported in Cape Size BC.
	30	Floodable in multi compartments	---	(A) Impracticable	- ---
	31	Hull girder strength in flooded condition	IACS UR S17		- The application to ships of length less than 150m and ships with only light cargo should be considered.

Strength of Watertight bulkhead (W.T. BHD) considering hold flooding	32	Review of design standard	Ch.XII/5&6 (IACS UR S18/19)	(A) Structural strength at initial scantling cannot meet with these requirements in more than 50% of existing ships. --- (C) Design trial and cost examination---	- The application to ships of length less than 150m and ships with only light cargo should be considered.
	33	Enhancement of maintenance (Paint)	---	(A) Paint had been applied in cargo hold structures in practice and has been applied compulsorily since 1992. Since 1999, application area has been extended. Rapid corrosion caused by loading coal and iron ore alternately and hold washing by seawater, have been reported. (B) Periodically repaint (e.g. after unloading, every 10 years etc.) compulsorily (D) Paint or touch-up in upper part of C.H. is difficult in service.	- Effectiveness of grade-up of paint spec. is not seemed to meet with cost because damage by cargo handling cannot be avoided.
	34	Enhancement of inspection	Ch.XII/7 (A.744)	(A) Implemented since 1993 and enhanced since 1997 (B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin (D) Unless paint applied compulsorily, inspection cannot be effective.	- ---
Strength of double bottom considering hold flooding	35	Review of design standard	Ch.XII/5&6 (IACS UR S20/22)	(A) Some ships of Cape Size BC can not meet with these requirements. (C) Design trial and cost examination ---	- The application to ships of length less than 150m and ships with only light cargo should be considered. - Serious trouble due to strength of D.B. structure has not been reported.
	36	Enhancement of inspection	Ch.XII/7 (A.744)	(B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin.	- Serious trouble due to strength of double bottom structure has not been reported.

Table A.3 Prevention of flooding into compartment (excluding fore end part)

	No.	RCM	Convention or standard	Discussions (A) Current Situation (B) Concrete measures or example (C) Consideration of cost and effectiveness (D) Problem in implementation	- Notes
Hatch covers and there securing devices	38	Review of wave load for hatch covers (Review of ILLC)	ILLC1966	(A) In general, side rolling type or end folding type hatch covers are equipped with bulk carriers. (B) Requirements for new building ships may be applied to existing ships. According to the necessity, larger wave load may be considered. (C) Cost may be considered by difference between steel weight by existing design and which by new design, and (D) Difference of rigidity between hull structure and hatch cover due to more strengthening of hatch cover, may cause other damage to hull. Strength of hatch coaming structure should rather be considered. Increase in weight of hatch cover may require capacity-up of hydraulic systems for hatch operation.	- Serious flooding due to collapse of hatch cover is not reported.
	39	Review of securing systems for hatch covers	--- .	(A) Sometime cargo damage because of loose securing of hatch cover is reported (B) Development of device for securing with more simply procedure. Monitoring device and/or alarm of indicating of packing compressed enough or not and hatch cover secured closely or not (C) Design trial is needed. Remote control closing and securing devices by hydraulic systems may be effective for hatch cover. (In this case, 15-20% cost-up should be considered.) (D) It is difficult to protect the installed monitoring devices from environment on deck in cargo area. In case of the installation of powered closing devices for hatch cover, it is difficult to keep the yearly-exhausted devices without careful maintenance in safe condition. Avoiding of human error should be given first priority.	- Well maintenance of packing and securing devices should be well maintained considering yearly exhausting. - These defects are not seemed to cause serious casualties.
Hatch covers and there securing devices	40	Enhancement of inspection	A.744	(A) Enhanced survey has been applied to hatch coaming since 1997. (B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin.	- ---

Side structure of foremost cargo hold	41	Review of design standard	IACS UR S12	(A) Strictly requirements for web thickness in lower part of hold frames have been applied since 1992. Since 1997, requirements for section modulus of hold frames in fore part have been applied and after that enhanced more relating to BC Safety.	- The application to ships of length less than 150m and ships with only light cargo should be considered.
	42	Application of double side skin	--- .	(A) Double side skin construction has been applied to some coal carriers considering well maintenancability (B) Double side skin construction is applied to all cargo holds or fore end hold. (C) Design trial and cost examination should include benefit such as protection of side skin structure, prevention of hold flooding directly, well maintenancability in cargo hold part, and risk such as difficulty of inspection of double side part, decrease in deadweight and hold capacity (D) Application to existing ships is considered making deep economical impact. Other type of structural fault should be considered.	- Where benefits of double side skin were considered to be not enough, application of SOLAS Ch.XII requirements have to be considered.
	43	Enhancement of maintenance (Paint)	---	(A) Paint had been applied in cargo hold structures in practice and has been applied compulsorily since 1992. Since 1999, application area has been extended. Rapid corrosion caused by loading coal and iron ore alternately and hold washing by seawater, have been reported. (B) Periodically repaint (e.g. after unloading, every 10 years etc.) compulsorily (D) Paint or touch-up in upper part of C.H. is difficult in service.	- Effectiveness of grade-up of paint spec. is not seemed to meet with cost because damage by cargo handling cannot be avoided.
	44	Enhancement of inspection	Ch.XII/7 (A.744)	(A) Implemented since 1993 and enhanced since 1997. (B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin. (D) For maintaining paint condition, inspections are required more frequently.	- ---
Small openings in fore part	45	Review of design standard	--- ---	--- --- ---	- Effects of small openings in flooding should be reviewed. - Only a trouble on small openings is not seemed to cause serious casualties. - Trouble on small openings almost depends on human element including maintenance.
Small openings in	46	Position, height, etc.	ILLC1966 ---	--- ---	- Effects of small openings in flooding should be reviewed.

fore part	47	Enhancement of inspection	--- ---	(B) Two or more surveyors attend and survey closely. Review of practical standards for steel renewal according to the corrosion margin --- ---	- Existing style of annual inspection may be enough.
Safe practice of preparation for heavy weather	48	Standardizing of safe practice in heavy weather	---	(A) Safety practice in heavy weather is various in managing companies. (B) Standardizing of practice Manuals onboard compulsorily --- ---	- Serious casualties are seemed to depend on age of ships. This fact points out that safety level of ships cannot be kept by existing measures and cannot be achieved by operation only.
	49	Education and training of officers and crews	--- ---	--- ---	- Decision of captain in weather routing depends on his experience and knowledge.
Weather routing	50	Enhancement of weather information	---	(A) Progress of information technology gives possibility that operators obtain precise and simultaneous weather information. Some operators instruct their ships in detail from shore side. (B) Facilities and services for obtaining weather information as same level as it used by higher level operators, are installed with ship and/or shore station. (D) Unless operating standard for heavy weather is settled, precise weather information cannot contribute to avoid heavy weather, because the highest priority is given to cargo schedule.	- ---
	51	Duplication of main propulsion, power source or other machinery/electrical devices	--- ---	(D) It is difficult to find appropriate level of requirement that cost meets with effectiveness. In addition to the above, it is not practicable for existing ships.	- ---

Table A.4 Prevention of failure due to hull girder stress

	No.	RCM	Convention or standard	Discussions (A) Current Situation (B) Concrete measures or example (C) Cost and effectiveness (D) Problem in implementation	Notes
Structural strength (General/ Whole part)	53	Enhancement of maintenance for ballast tanks (Paint)	Ch.II-1/3-2	(A) Painting in tank had been done practically, however, it have been done in statutory since 1991. Since 1998, use of light color paint has been recommended, but it's only applied to few ships because of cost. (B) Up-grading of specification of paint. Mandatory application of light color paint. (D) The application of bleached tar epoxy resin paint or modified epoxy resin paint require approximately twice cost because of product cost of itself and thicker application due to lack of reliability. Unless that maintenance is in compulsory, effectiveness of paint may be doubtful.	- ---
	54	Enhancement of inspection	A.744 --- ---	--- --- ---	- Diminution limit for corrosion for each structural member, especially hull girder member, should be considered in the manner of new methodology.
	55	Review of design philosophy	---	(A) Overestimation of direct calculation method may cause lack of redundancy of hull structural strength.	- Need or not to consider freak wave for hull structural design should be examined.
Loading/ unloading	57	Hull Stress Monitoring System	--- .	(A) It is reported of effectiveness for observation of hull girder by test installation (B) Centralized observation at W/H or Ballast Cont. Room by installation of HMS. (D) Installation of HMS is in danger of neglect of examining loading sequences.	- ---
	58	Cargo weight control by computerized loading instruments	Ch.XII/11 (IACS UR S1A) .	(A) Generally, loading instruments had been installed onboard before 1997. In statutory, installation of it has been mandatory since 1998 and specification of it has been enhanced since 1999. Operability of it has a room for improvement. (B) Capacity-up of ballast pump and measure of effective ballast water discharge other than air escape pipe should be considered for exchange by over-flow method. (D) Effectiveness depends on the knowledge of officers.	- Application to ships of length less than 150m should be considered.
Loading/ unloading	59	Enhancement of loading/ unloading procedures	Ch.VI/7.2 (IACS UR S1A)	(A) Since 1998, these requirements have been applied to all bulk carriers. However, these procedures only show general precaution and typical sequences. It is difficult to observe these procedures because port administrators may give higher priority to loading/unloading schedule.	- Application to ships of length less than 150m should be considered. - Effective to prevention of excessive stress for captains and officers without experience

	60	Review of design standard (Loading/ Unloading Speed, Ballast Pump Capacity, etc.)	IACS UR S1	(A) Detail and comprehensive examination is very difficult. Therefore only standardized case under some assumption is considered. --- ---	- Design and examination taking into consideration of loading/unloading sequences should be required.
	61	Education and training of officers and crews	---	(A) Some officer cannot utilize loading instruments and does not have enough knowledge of hull girder strength.	- ---
	62	Enhancement of weather information for weather routing	--- .	(A) Progress of information technology gives possibility that operators obtain precise and simultaneous weather information. Some operators instruct their ships in detail from shore side (B) Facilities and services for obtaining weather information as same level as it used by higher level operators, are installed with ship and/or shore station. (D) Unless operating standard for heavy weather is settled, precise weather information cannot contribute to avoid heavy weather, because the highest priority is given to cargo schedule.	- ---
	63	Hull Stress Monitoring System	---	(A) It is reported of effectiveness for observation of hull girder by test installation. (B) Centralized observation at W/H or Ballast Cont. Room by installation of HMS. (D) Effectiveness to serious casualties is seemed doubtful.	- ---
	64	Enhancement of ballast exchange procedures	Ch.VI/7.2 (IACS UR S1A)	(A) Since 1998, these requirements have been applied to all bulk carriers. However, these procedures only show general precaution and typical sequences. At the viewpoint of safety at sea, ballast water exchange have been done by over-flow method. (B) Capacity-up of ballast pump and measure of effective ballast water discharge other than air escape pipe should be considered for exchange by over-flow method.	- Application to ships of length less than 150m should be considered.
	65	Ballast weight control by computerized loading instruments	Ch.XII/11 (IACS UR S1A)	(A) Generally, loading instruments had been installed onboard before 1997. In statutory, installation of it has been mandatory since 1998 and specification of it has been enhanced since 1999. Operability of it has a room for improvement.	- Application to ships of length less than 150m should be considered.
In voyage	66	Education and training of officers and crews	--- ---	--- --- ---	- Almost casualties may be prevented by appropriate inspection and maintenance by officers and crews. Obstructive factor of appropriate crew activities should be considered.

In heavy weather	67	Duplication of main propulsion, power source or other machinery/electrical devices	--- ---	--- --- (D) It is difficult to find appropriate level of requirement that cost meets with effectiveness. In addition to the above, it is not practicable for existing ships.	- ---
In heavy weather	68	Education and training of officers and crews	--- ---		- ---

Table A.5 Mitigating consequence by evacuation

	No	RCM	Convention or standard	Discussions (A) Current Situation (B) Concrete measures or example (C) Cost and effectiveness (D) Problem in implementation	- Notes
Escape	70	Cargo hold flooding scenarios	Ch.XII/9.3 (IACS UI SC154)	(B) Guideline for escape according to results of flooding calculation hour by hour should be prepared.	- Simulative analysis of event after flooding to evacuation has to be examined.
	71	Review of evacuation equipment		(B) Replacement of means of escape (Old type lifeboat is limited in use) -	- ---

***