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HARBOUR APPROACH CHANNELS DESIGN GUIDELINES

The World Association for Waterborne Transport Infrastructure

UA-88

PIANC

'Setting the course'

PIANC REPORT N° 121

MARITIME NAVIGATION COMMISSION

HARBOUR APPROACH CHANNELS DESIGN GUIDELINES

2014

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PIANC Secrétariat Général
Boulevard du Roi Albert II 20, B 3
B-1000 Bruxelles
Belgique

http://www.pianc.org

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1 GENERAL ASPECTS

1.1 Scope

This report provides guidelines and recommendations for the design of vertical and horizontal dimensions of harbour approach channels and the manoeuvring and anchorage areas within harbours, along with defining restrictions to operations within a channel. It includes guidelines for establishing depth and width requirements, along with vertical bridge clearances.

The report supersedes and replaces the joint PIANC-IAPH report ‘Approach Channels – A Guide for Design’ published in 1997 (PIANC MarCom Working Group 30) in cooperation with IAPH, IMPA and IALA. This report has been widely accepted worldwide by port designers. This new report has again been compiled in close co-operation with IAPH (International Association of Ports & Harbours), IMPA (International Maritime Pilots Association) and IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities).

1.2 Introduction

1.2.1 Terms of Reference

The Terms of Reference set by the Maritime Commission of PIANC (MarCom) for Working Group 49 (WG 49) are given in Appendix A of this report and are summarised below.

1.2.1.1 Objective

The objectives of the Working Group were to review, update and, where appropriate, expand on the design recommendations on vertical and horizontal dimensioning as presented in the Working Group 30 report of 1997 on approach channels. Recent developments in ship design, better understanding of ship manoeuvrability and behaviour in waves and further research in ship simulation and modelling required a comprehensive update to the 1997 report.

1.2.1.2 Matters Investigated

The Working Group has paid particular attention to:

- Vertical motions of ships in approach channels (due to squat, wave-induced motions, dynamic effects, etc.)
- Air draught for vertical clearances under bridges, overhead cables, etc.
- Horizontal dimensions of channels and manoeuvring areas
- Simulation of ships in channels
- New and future generation ship dimensions/manoeuvring characteristics
- Wind effect on ship navigation and manoeuvring
- Human errors and project uncertainties
- Environmental issues
- Safety criteria, assessment of levels of risk and appropriate clearance margins

C.2 Japanese Statistical Analysis of Ship Dimensions

The Japanese Ministry of Land, Infrastructure, Transport and Tourism (2007) has performed extensive statistical analysis of the basic ship types from the Lloyd's Maritime Intelligence Unit Shipping Data (2004) and Lloyd's Register Fairplay Data (2006). For the eight ship types they analysed (cargo ships including bulk carriers, container ships, oil tankers, RoRo, PCC (Pure Car Carrier), LPG, LNG and passenger ships), they found that ship dimensions such as L_{oa}, L_{pp}, B, T, and H_{kt} are proportional to the 1/3 power of GT or DWT. They defined a 'coverage rate' (P), similar to confidence limits, to contain more of the maximum values of these ship dimensions. Additional information on H_{kt} is contained in Appendix F.

Table C-2 lists values of P = 95 % for the 'weight' class of ships as a function of DWT and the 'volume' class of ships as a function of GT. The P = 95 % coverage rate in Table C-2 implies that in repeated sampling from the population of all ships of this type and size, 95 % will contain (less than or equal) the listed value of ship dimension, and by chance, only 5 % will not (i.e. exceed this value). For example, for a 300,000 DWT oil tanker, the full load draught T equals 24.0 m for P = 95 % coverage rate. Similarly, for a 100,000 GT passenger ship, the moulded breadth or beam B equals 33.5 m for P = 95 % coverage. This example illustrates how these data should be considered with care since they are based on statistics and real ships would not necessarily have B = 33.5 m. Due to the Panama Canal restrictions, ships were not built in the beam range between 32.2 and 36 m for a long time. However, there are some ships with beams in this range and larger now. Interested readers may check Takahashi (2006) for P = 75 % data.

Table C-2 is designed as a 'backup' and 'second opinion' for Table C-1 values. Although most of the sizes overlap, some do not, so it is useful to have access to both tables. The user should remember that Table C-1 values are based on real ship dimensions, whereas Table C-2 values are a statistical value based on many ships and do not necessarily represent as 'as-built' ship. Rather than trying to confuse users, it is our intent that users should use Table C-2 as a backup to Table C-1 and to look elsewhere if necessary. This is especially true as new generation vessels are continually being added to the world-wide fleet and will require additional research.

GT	L_{oa} (m)	L_{pp} (m)	B (m)	T (m)	H_{KT} (m)
Roll-on/Roll-off Ship					
5,000	137	120	24.0	7.0	40.2
7,000	154	136	26.0	7.8	42.8
10,000	174	155	28.2	8.8	45.5
15,000	200	179	30.9	10.0	48.6
20,000	222	199	33.0	11.0	50.7
40,000	204	179	32.3	9.9	56.0
50,000	217	201	32.3	9.9	57.7
60,000	217	201	32.3	9.9	59.1
Pure Car Carrier Ship					
5,000	119	98	19.0	6.4	37.3
7,000	132	112	20.5	7.0	39.9
10,000	147	128	22.1	7.7	42.6
15,000	166	150	24.2	8.6	45.7
20,000	181	167	25.8	9.3	47.8
30,000	205	196	28.2	10.4	50.9
40,000	192	182	33.4	10.0	53.1
50,000	214	204	32.4	11.2	54.8
60,000	214	204	32.4	11.2	56.2
LPG Ship					
5,000	123	116	19.9	8.4	37.0
7,000	137	129	21.9	9.3	39.4
10,000	153	145	24.3	10.3	41.9
15,000	174	165	27.3	11.5	44.8
20,000	191	181	29.6	12.5	46.9
30,000	217	206	33.3	14.0	49.8
50,000	255	243	38.5	16.2	53.4
60,000	270	258	40.5	17.1	54.7
LNG Ship					
5,000	116	108	18.8	6.6	
7,000	130	121	20.8	7.1	
10,000	146	137	23.2	7.7	
15,000	167	156	26.2	8.4	
20,000	183	172	28.6	9.0	
30,000	209	197	32.4	9.9	
50,000	247	234	37.8	11.1	
70,000	275	262	41.9	11.9	60.4
100,000	309	295	46.7	13.0	71.5
Passenger Ship					
5,000	137	129	23.4	7.2	43.0
7,000	153	144	25.3	8.1	46.0
10,000	173	162	27.5	9.1	49.1
15,000	199	186	30.2	10.4	52.7
20,000	220	204	32.3	8.9	55.2
30,000	253	234	35.6	8.9	58.8
50,000	302	277	33.5	8.9	63.4
70,000	339	309	33.5	8.9	66.3
100,000	383	348	33.5	8.9	69.5

DWT	L_{oa} (m)	L_{pp} (m)	B (m)	T (m)	H_{KT} (m)
Cargo Ship					
5,000	118	108	18.5	7.4	36.0
7,000	130	119	20.4	8.3	38.2
10,000	145	133	22.6	9.3	40.6
15,000	163	150	25.4	10.6	43.3
20,000	177	164	27.5	11.7	45.2
30,000	200	186	30.9	11.2	47.9
50,000	232	217	35.8	13.3	51.2
70,000	256	240	39.4	14.8	53.5
100,000	285	268	43.6	16.6	55.8
150,000	321	303	48.9	18.9	58.5
200,000	349	330	53.1	20.8	60.4
300,000	394	373	59.6	23.7	63.1
Container Ship					
5,000	116	107	18.9	6.7	39.4
7,000	130	121	20.9	7.4	42.3
10,000	147	137	23.3	8.3	45.4
15,000	170	158	26.3	9.5	49.0
20,000	187	175	28.7	10.4	51.5
30,000	216	203	32.4	11.9	55.0
50,000	294	276	34.4	13.2	59.4
70,000	293	281	44.0	14.5	62.3
100,000	361	342	43.2	14.9	65.4
Oil Tanker					
5,000	108	103	18.8	7.2	
7,000	118	115	20.5	8.0	
10,000	144	135	21.6	8.8	
15,000	159	150	24.6	9.8	
20,000	171	161	26.9	10.7	
30,000	190	179	30.6	11.9	
50,000	216	204	36.0	13.8	44.1
70,000	235	223	40.1	13.8	48.9
100,000	258	244	44.9	15.8	53.9
150,000	286	271	51.0	18.5	59.7
200,000	339	326	61.0	20.6	63.8
300,000	339	326	61.0	24.0	69.6

Table C-2: Ship dimensions [Takahashi, 2006] as a function of P = 95 % coverage rate

C.3 Relationship Between DWT and H_{kt}

Table C-2 shows relationships between DWT and H_{kt}, but only for a limited data set for container ships from the earlier Japanese research. This section presents a least square fit of the existing Japanese data in Table C-2 so that it can be extrapolated for newer, larger container ships to 250,000 DWT. The data to DWT = 100,000 was extrapolated using a natural log (ln) function with R^2 correlation coefficient of 1.0. The corresponding H_{kt} = 68.9, 71.4, and 73.4 m for DWT = 150,000, 200,000 and 250,000 respectively.

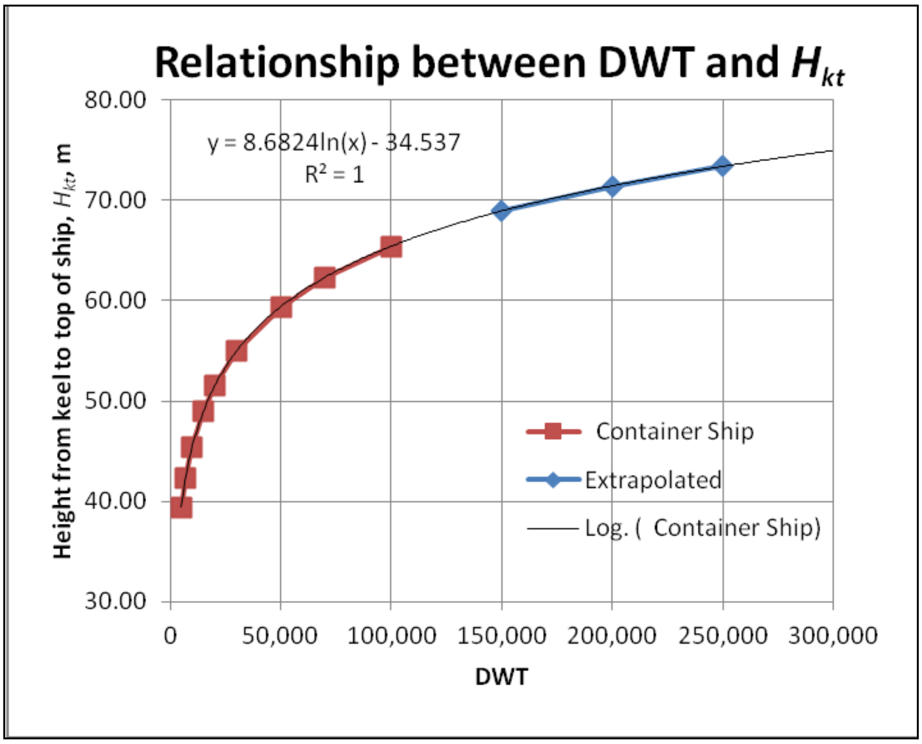

Figure C-2: Relationship between DWT and H_{kt} for container ships

11 APPENDIX F: AIR DRAUGHT

This appendix includes tables for estimating vertical air draught clearance *ADC* in Detailed Design for container ships, cargo ships, oil tankers, RoRo, PCC, LPG, LNG and passenger ships. The *ADC* is similar to the *UKC* for bottom clearance in water. The values are based on the coverage rate formulas and procedures used in Japan. Some of the material in this appendix is complementary to that in Appendix C, especially Tables C-1 and C-2.

F.1 Introduction

Dimensional values related to the height of ships are rarely indicated in the international literature. Possible reasons for this include:

- The number of available data on ship height is remarkably small in comparison with other dimensions such as L_{oa}, T, etc. For example, in the fundamental data for cargo ships (which represent the largest number of ships in analysis), the number of available data on ship height is only about 10 % of that for L_{oa}, T, etc.
- The reliability of values obtained from fundamental data related to ship height is low. The data contain numerous deviations and also include a large number of anomalous values. Because there is no clearly-defined concept of ship height analogous to that of L_{oa}, it can be supposed that there are errors in recording ship height by persons supplying the data. Therefore, the results of statistical analysis based on these fundamental data are open to question. Consequently, it is not possible to apply statistical analysis method to ship height.

On the other hand, because dimensional values for ship height are extremely important when designing bridges over fairways, arranging the relationship with the Obstruction Assessment Surface (OAS: height of ships and other obstructions which must be cleared by aircraft) in maritime airports and similar problems; indications of the dimensional values for ship height similar to those for L_{oa} and T has been an urgent requirement for many years.

Therefore, the first objective of the present Japanese research was to propose height dimensions for ships with the same accuracy as other main dimensions by solving these concerns in the follow manner.

- The dispersion of data on ship height and data on other dimensions was analysed by ship class and it was confirmed that there were no deviations in the distribution of the data for ship height corresponding to ship class. The aim of this analysis was to make it possible to obtain the same accuracy as the other dimensions, even though the number of data is much less for ship height
- New data for analysis of dimensional values were constructed by statistically eliminating anomalous values from the data. The aim here was to make it possible to obtain analytical results having high reliability, even though the number of data was reduced
- The inappropriateness of the statistical analysis technique used with L_{oa}, T, etc. to ship height was reconfirmed. Based on this, one aim of this work was to apply a new statistical analysis technique which makes it possible to obtain appropriate analytical results.

In addition, because the height from the water surface to the highest point on the ship is a practical necessity when designing bridges over fairways and arranging relationships with OAS at marine airports, the second objective of this research was to propose a table of dimensional values for the height of ships from the water surface. In summary, the objective was to (a) construct a technique for analysing the height from the water surface to the highest point on ships, (b) build a dataset of ship heights and air draughts by analysing new and previous [Takahashi, 2007] research results and (c) ensure high reliability by applying two analysis techniques. In summary, the procedure from this research can be used if actual air draught clearance values for the design ship are not known.

F.2 Air Draught Clearance (ADC)

As shown in Figure F-1, two different heights can be used to describe ship height. These include the height H_{kt} from the keel to the top (highest point) and the height from the sea or water surface to the top H_{st}, which is called 'air draught'. The water surface should include the highest probable navigable water level (e.g. high water datum such as HAT and/or tidal surge) due to tides and meteorological effects so that the air draught is correctly predicted. Of course, T is the ship's draught.

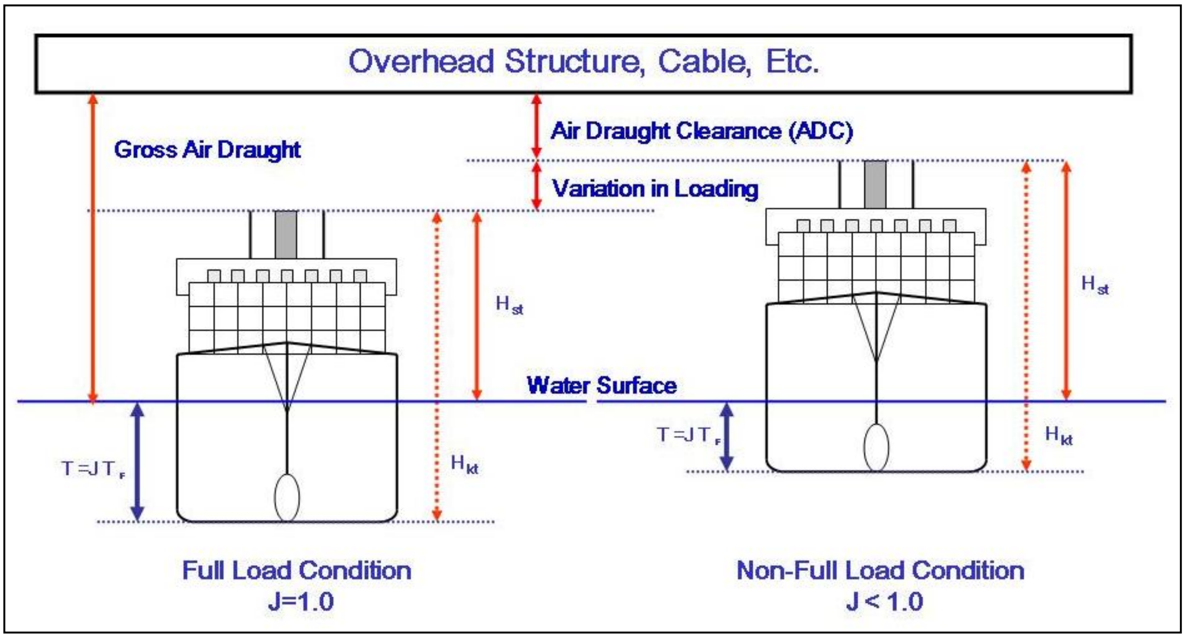

Figure F-1: Variation in air draught clearance as a function of ship loading condition [Takahashi, 2007]

The relationship among these variables is expressed by:

$$H_{st} = H_{kt} - T = H_{kt} - JT_{FL} \tag{F-1}$$

where:

J	=	Draught factor, varies from 0.5 to 1.0 according to draught
T_{FL}	=	Full-load draught (m)

The values of H_{kt} and T_{FL} of an assumed design ship are basically invariant. However, the actual draught T (= JT_{FL}) of a ship changes during navigation depending on the loading condition and other factors. The J factor is applied to account for changes in loading. It will have a maximum value of 1.0 when the ship is in a fully-loaded condition and will be less than 1.0 when less than fully-loaded. For ballast conditions, J = 0.5 for weight carriers to J = 0.8 for volume carriers (see 1.3.4.3). The H_{st} increases as J decreases, so that as the ship's draught becomes less, the clearance between the top of the ship and overhead structures such as bridges becomes smaller and may pose a danger. As a result, the H_{st} will also vary from full load to lighter load conditions. Finally, the gross air draught is the vertical distance from the water surface to the bottom (or lowest part) of the overhead structures. The *ADC* is what is left for clearance after the H_{st} and variation in ship loading is subtracted from the gross air draught.

For safety reasons, there should always be a positive distance or *ADC* between the top of the ship and the bottom of any overhead structure. A new development affecting *ADC* is that naval architects and ship designers have started to make pieces of equipment on the tops of ships (antennas and radar devices) foldable when passing beneath an overhead structure.

F.3 Concept Design

As discussed in Chapter 2 (2.3.3 and Table 2.2) and repeated here for completeness, an estimate of the ADC in the Concept Design phase can be approximated as:

$$ADC = 0.05 H_{st} \geq 2\,\mathrm{m} \tag{F-2}$$

Also, for outer channels where wave conditions can be significant, an additional allowance equal to 0.4 T should be included. The ADC must account for sag in power lines and additional clearance due to arcing of power lines. Obviously, for safety reasons, there should always be a positive distance or ADC between the top of the ship and the bottom of any overhead structure.

F.4 Detailed Design

F.4.1 Japanese Statistical Analysis of Air Draught H_{st}

A more thorough analysis of *ADC* would involve a careful examination of the heights in Eq. F-1. Japanese researchers performed an extensive statistical analysis of the air draught H_{st} in 2007 (Takahashi) that constitutes the Detailed Design phase for calculating ADC. The data used in the statistical analysis were the Lloyd's Register Fairplay Data for September 2006 (hereinafter, LRF Data). The LRF Data consists of 200,000 cases covering ship and port data that includes (a) 158,000 vessels of 100 GT or more, including newly constructed ships, existing ships and scrapped ships and (b) information on shipping lines, maritime disasters, ports and harbours, etc. For the present research, the authors obtained approximately 800 data entries on H_{kt} (mast, or stack or other highest point).

Table F-1 show Takahashi's results (2007) when H_{st} was calculated by ship type (container ships, cargo ships, oil tankers, RoRo, PCC, LPG, LNG and passenger ships) for varying H_{kt}, T_{FL}, and J from 1.0 to 0.8 (increments of 0.05) using coverage rates of 95 %. However, due to the large effect of ballast conditions in 'weight' carriers like cargo ships and tankers, calculations for these two ship types were made using a wider J range from 1.0 to 0.5 (increments of 0.1). When selecting values for J, consideration should be given to actual and planned loading conditions, bow and stern trim of the ship while sailing and other relevant factors. Table C-1 in Appendix C also lists some values of H_{kt} for comparison.

F.4.2 Detailed Design of *ADC*

In cases where the design ship can be designated, the value of H_{kt} and T_{FL} of that ship are used. However, in cases where it is not possible to designate the values of these parameters, the results of the statistical analysis described in Table F-1 can be applied. In the final analysis, a 'special investigation' for each individual site is justified due to the enormous costs of every additional metre of required *ADC*.

F.4.3 Comparison Ballast Draught with Appendix C

Tables C-1 and F-1 are based on different datasets. This section presents two examples for weight and volume carriers comparing ballasted draught T_B between these two tables that illustrates that they can be used to complement each other in the design process. The fully-loaded ballast windage W_{FL} is given by:

$$W_{FL} = W_B - (T_{FL} - T_B)\frac{(L_{pp} + L_{oa})}{2} \qquad \text{(F-3)}$$

where W_B is the ballasted windage, T_{FL} is the fully-loaded draught, L_{pp} and L_{oa} have been previously defined. Since L_{pp} is approximately 0.95 of L_{oa}, it is assumed that the average of L_{pp} and L_{oa} in Eq. (F-2) is equal to L_{oa} (actually 0.975 L_{oa}). Rearranging Eq. (F-1) for T_B gives:

$$T_B = T_{FL} - \frac{(W_B - W_{FL})}{L_{oa}} \qquad \text{(F-4)}$$

F.4.3.1 Oil tanker, 300,000 DWT

From Table C-1 for 300 000 DWT tanker: L_{oa} = 350 m, T_{FL} = 21 m, W_{FL} = 5 100 m^2 and W_B = 8,600 m^2. Inserting these values into Eq. (F-3) gives:

$$T_B = T_{FL} - \frac{(W_B - W_{FL})}{L_{oa}} = 21 - \frac{(8\,600 - 5\,100)}{350} = 11\,\text{m} \qquad \text{(F-5)}$$

From Table F-1: T_{FL} = 24 m, the air draught from the sea surface to the top of the ship $H_{st,F}$ = 45.6 m for J = 1.0 for fully-loaded draught, and $H_{st,B}$ = 57.6 m for J = 0.5 for ballasted draught. Since the height of the ship from the keel to the top H_{KT} is the same for a ship whether fully-loaded or ballasted, the value for T_B can also be estimated by:

$$T_B = T_{FL} - (H_{st,B} - H_{st,F}) = 24 - (57.6 - 45.6) = 12\,\text{m} \qquad \text{(F-6)}$$

Thus, the estimated values of T_B are within 1 m of each other using data from Table C-1 or Table F-1. This is probably reasonable for design purposes.

F.4.3.2 Container ship, 100,000 DWT

From Table C-1 for 100,000 DWT container ship: L_{oa} = 326 m, T_{FL} = 14.5 m, W_{FL} = 6,900 m^2, and W_B = 7,500 m^2. Inserting these values into Eq. (F-3) gives:

$$T_B = T_{FL} - \frac{(W_B - W_{FL})}{L_{OA}} = 14.5 - \frac{(7\,500 - 6\,900)}{326} = 12.7\text{ m} \tag{F-7}$$

From Table F-1: T_{FL} = 14.9 m, the air draught from the sea surface to the top of the ship $H_{st,F}$ = 50.6 m for J = 1.0 for fully-loaded draught and $H_{st,B}$ = 53.5 m for J = 0.8 for ballasted draught. We used a value of J = 0.8 for the ballasted draught on the container ship as this is a more realistic value for the ballasted condition of a 'volume' type of ship. The value for T_B can also be estimated by:

$$T_B = T_{FL} - (H_{st,B} - H_{st,F}) = 14.9 - (53.5 - 50.6) = 12\text{ m} \tag{F-8}$$

Thus, the estimated values of T_B are within 0.7 m of each other using data from Table C-1 or Table F-1. This is probably reasonable for design purposes.

Container Ship (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st} = H_{kt} - JT_{FL}$				
				J=1.0	J=0.95	J=0.9	J=0.85	J=0.8
95 %	10,000	45.4	8.3	37.1	37.6	38.0	38.4	38.8
	20,000	51.5	10.4	41.1	41.6	42.1	42.6	43.1
	30,000	55.0	11.9	43.1	43.7	44.3	44.9	45.5
	40,000	57.5	12.7	44.8	45.5	46.1	46.7	47.4
	50,000	59.4	13.2	46.3	46.9	47.6	48.2	48.9
	60,000	61.0	13.7	47.3	48.0	48.7	49.3	50.0
	100,000	65.4	14.9	50.6	51.3	52.1	52.8	53.5

Cargo Ship (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st} = H_{kt} - JT_{FL}$					
				J=1.0	J=0.9	J=0.8	J=0.7	J=0.6	J=0.5
95 %	1,000	25.4	4.4	21.0	21.4	21.9	22.3	22.7	23.2
	2,000	30.0	5.5	24.5	25.0	25.6	26.1	26.7	27.2
	3,000	32.6	6.3	26.3	27.0	27.6	28.2	28.9	29.5
	5,000	36.0	7.4	28.6	29.4	30.1	30.8	31.6	32.3
	10,000	40.6	9.3	31.3	32.2	33.2	34.1	35.0	35.9
	12,000	41.8	9.9	31.9	32.9	33.9	34.9	35.9	36.9
	18,000	44.5	11.3	33.2	34.3	35.4	36.6	37.7	38.8
	30,000	47.9	11.2	36.7	37.8	38.9	40.0	41.1	42.3
	40,000	49.8	12.3	37.5	38.7	39.9	41.2	42.4	43.6
	55,000	51.9	13.7	38.2	39.5	40.9	42.3	43.6	45.0
	70,000	53.5	14.8	38.7	40.1	41.6	43.1	44.6	46.1
	90,000	55.1	16.0	39.1	40.7	42.3	43.9	45.5	47.1
	120,000	57.0	17.6	39.4	41.2	42.9	44.7	46.5	48.2
	150,000	58.5	18.9	39.6	41.5	43.4	45.3	47.2	49.0

Table F-1: Air draught for container ship, cargo ship (includes bulk carrier), oil tanker, RoRo ship, PCC, LPG, LNG and passenger ship.
Note that J = 1.0 for fully-loaded condition with a low of J = 0.5 for weight carriers and J = 0.8 for volume carriers in ballast condition. [Takahashi, 2007 – Continued]

Oil Tanker (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st} = H_{kt} - JT_{FL}$					
				J=1.0	J=0.9	J=0.8	J=0.7	J=0.6	J=0.5
95 %	50,000	44.1	13.8	30.3	31.6	33.0	34.4	35.8	37.2
	70,000	48.9	13.8	35.1	36.4	37.8	39.2	40.6	42.0
	90,000	52.4	15.2	37.2	38.8	40.3	41.8	43.3	44.8
	100,000	53.9	15.8	38.1	39.7	41.3	42.9	44.5	46.0
	150,000	59.7	18.5	41.2	43.1	44.9	46.8	48.6	50.5
	300,000	69.6	24.0	45.6	48.0	50.4	52.8	55.2	57.6

Roll on/Roll-off (RoRo) Ship (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st}=H_{kt} - JT_{FL}$				
				J=1.0	J=0.95	J=0.9	J=0.85	J=0.8
95 %	3,000	36.3	5.9	30.4	30.7	31.0	31.3	31.6
	5,000	40.2	7.0	33.2	33.6	33.9	34.3	34.6
	10,000	45.5	8.8	36.7	37.1	37.6	38.0	38.4
	20,000	50.7	11.0	39.7	40.3	40.8	41.4	41.9
	40,000	56.0	9.9	46.1	46.6	47.1	47.6	48.1
	60,000	59.1	9.9	49.2	49.7	50.2	50.7	51.1

Pure Car Carrier(PCC) (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st}=H_{kt} - JT_{FL}$				
				J=1.0	J=0.95	J=0.9	J=0.85	J=0.8
95 %	3,000	33.5	5.5	28.0	28.3	28.5	28.8	29.1
	5,000	37.3	6.4	30.9	31.3	31.6	31.9	32.2
	12,000	44.0	8.1	35.9	36.3	36.7	37.1	37.5
	20,000	47.8	9.3	38.5	39.0	39.5	39.9	40.4
	30,000	50.9	10.4	40.5	41.0	41.5	42.1	42.6
	40,000	53.1	10.0	43.1	43.6	44.1	44.6	45.1
	60,000	56.2	11.2	45.0	45.5	46.1	46.6	47.2

Table F-1: Air draught for container ship, cargo ship (includes bulk carrier), oil tanker, RoRo ship, PCC, LPG, LNG and passenger ship.
Note that J = 1.0 for fully-loaded condition with a low of J = 0.5 for weight carriers and J = 0.8 for volume carriers in ballast condition. [Takahashi, 2007 – Continued]

LPG Ship (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st} = H_{kt} - JT_{FL}$				
				J=1.0	J=0.95	J=0.9	J=0.85	J=0.8
95 %	3,000	33.3	7.3	26.0	26.4	26.7	27.1	27.5
	5,000	37.0	8.4	28.6	29.0	29.4	29.8	30.2
	10,000	41.9	10.3	31.6	32.1	32.6	33.2	33.7
	20,000	46.9	12.5	34.4	35.0	35.6	36.2	36.9
	30,000	49.8	14.0	35.8	36.5	37.2	37.9	38.6
	40,000	51.8	15.2	36.6	37.4	38.1	38.9	39.7
	60,000	53.4	16.2	37.2	38.0	38.8	39.6	40.5

LNG Ship (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st} = H_{kt} - JT_{FL}$				
				J=1.0	J=0.95	J=0.9	J=0.85	J=0.8
95 %	80,000	64.5	12.3	52.2	52.8	53.5	54.1	54.7
	100,000	71.5	13.0	58.5	59.1	59.8	60.4	61.1
	120,000	77.1	13.5	63.6	64.3	65.0	65.7	66.3

Passenger Ship (m)

Coverage Rate	DWT	H_{kt}	T_{FL}	$H_{st} = H_{kt} - JT_{FL}$				
				J=1.0	J=0.95	J=0.9	J=0.85	J=0.8
95 %	3,000	38.5	6.1	32.4	32.7	33.0	33.3	33.6
	5,000	43.0	7.2	35.8	36.1	36.5	36.9	37.2
	10,000	49.1	9.1	40.0	40.5	40.9	41.4	41.8
	20,000	55.2	8.9	46.3	46.8	47.2	47.7	48.1
	30,000	58.8	8.9	49.9	50.4	50.8	51.3	51.7
	50,000	63.4	8.9	54.5	54.9	55.3	55.8	56.2
	70,000	66.3	8.3	58.0	58.4	58.9	59.3	59.7
	100,000	69.5	8.3	61.2	61.6	62.0	62.4	62.8

Table F-1: Air draught for container ship, cargo ship (includes bulk carrier), oil tanker, RoRo ship, PCC, LPG, LNG and passenger ship.
Note that J = 1.0 for fully-loaded condition with a low of J = 0.5 for weight carriers and J = 0.8 for volume carriers in ballast condition. [Takahashi, 2007 – Concluded]