Stability & Trim of 3,700 TEU Container Carrier(3,700 TEU 컨테이너선 복원성)

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Advanced
Ship
Design
Automation
Laboratory

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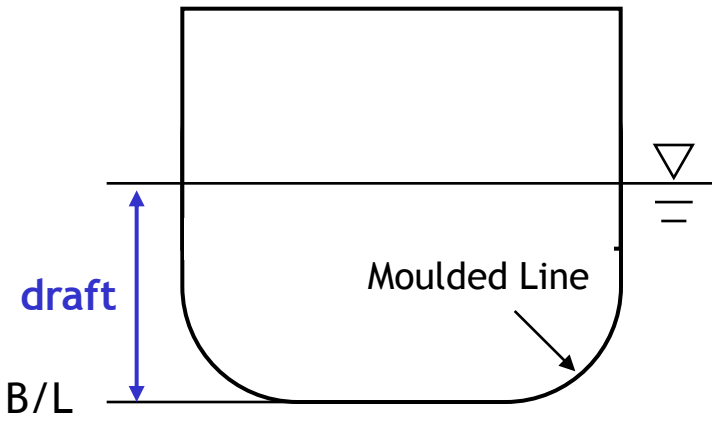
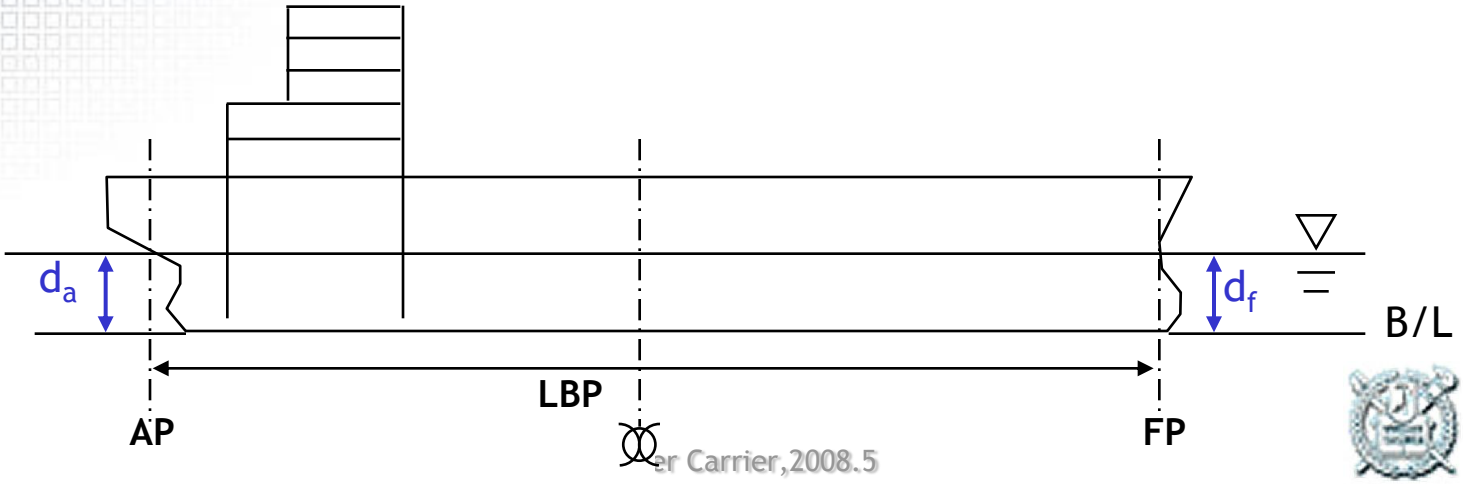
용어 정리 (I)

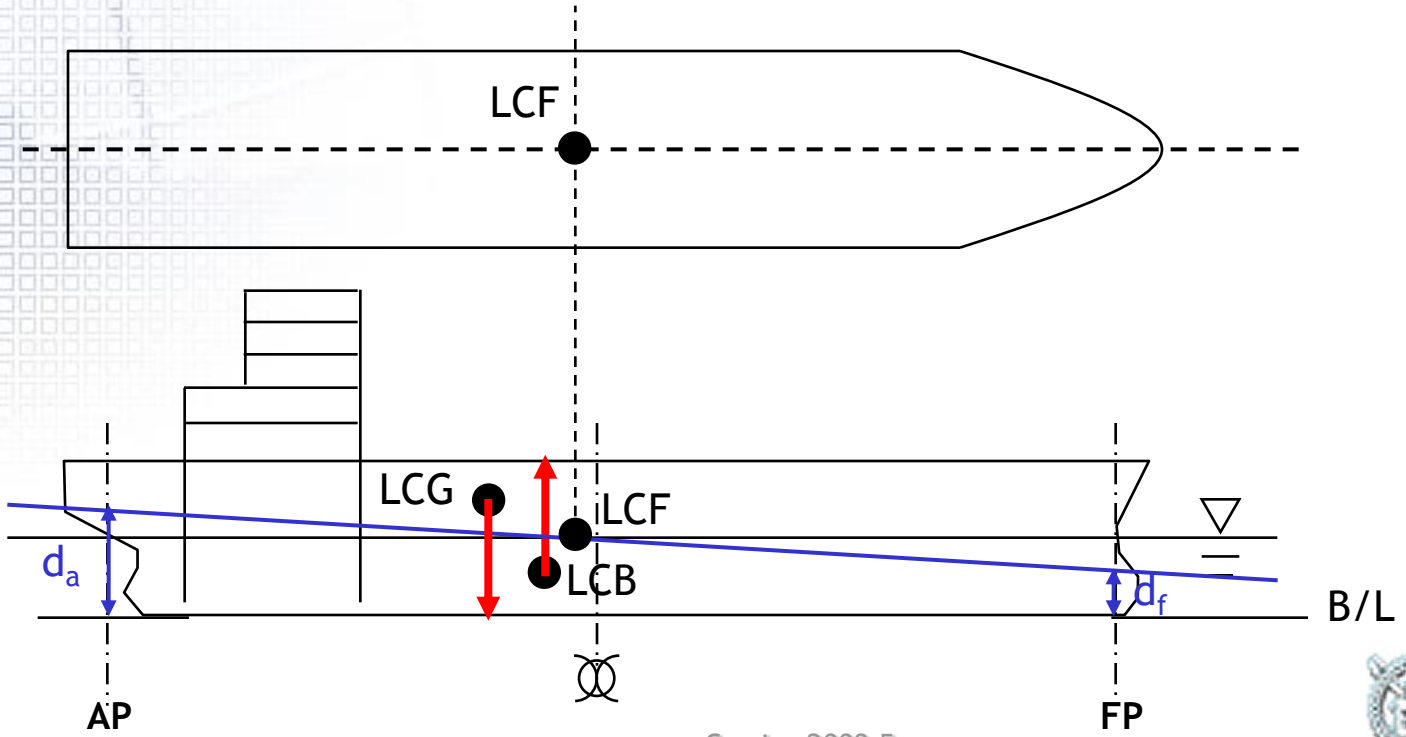
- draft : Mean draft above baseline
- d_a : draught above baseline at AP
- d_f : draught above baseline at FP
- LBP : length between perpendiculars
- FP : forward perpendicular
- AP : after perpendicular





용어 정리 (II)

- DISP(MLD) : DISPLACEMENT MOULDED (CUBIC METER)
- DISP(EXT.) : DISPLACEMENT EXTREME (TONNES) S.G = 1.025
- LCB : Longitudinal center of buoyancy
- LCF : Longitudinal center of floatation
- LCG : Longitudinal center of gravity



용어 정리 (III)

- Trim : d_a - d_f (**양수이면 선미트림, 음수이면 선수 트림**)
- MTC : moment to change trim one centimeter over the LBP
  (1cm trim**이 생기는데 필요한 모멘트**)

$Trim \times MTC \times 100$

Trim**이 발생하여 배가 받는 모멘트**

=

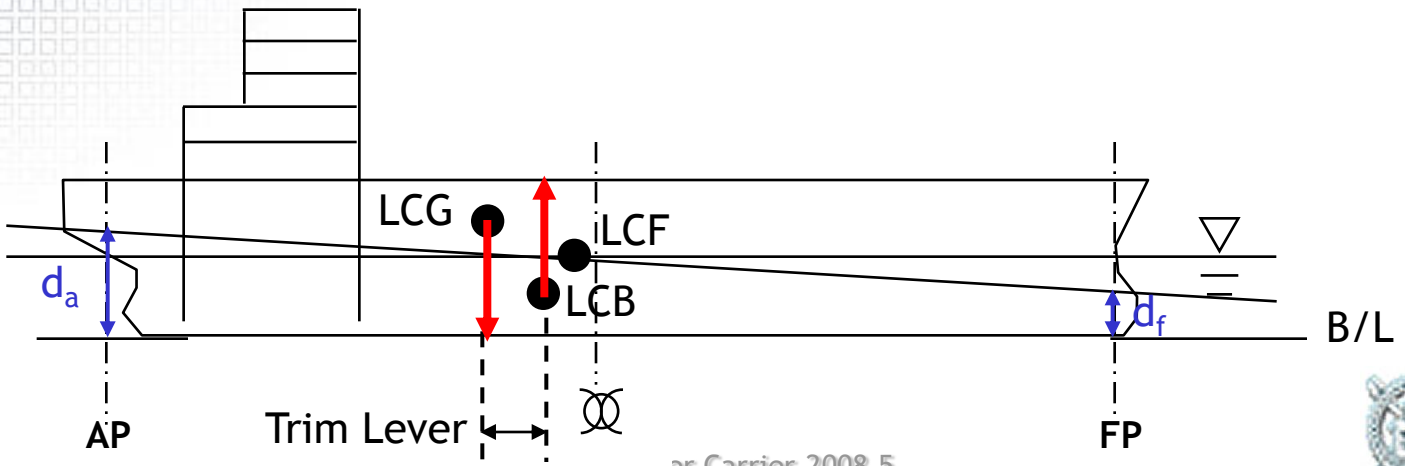
$\Delta \times Trim \quad Lever$

부력 중심과 무게 중심의 위치 차이 때문에 생기는 모멘트

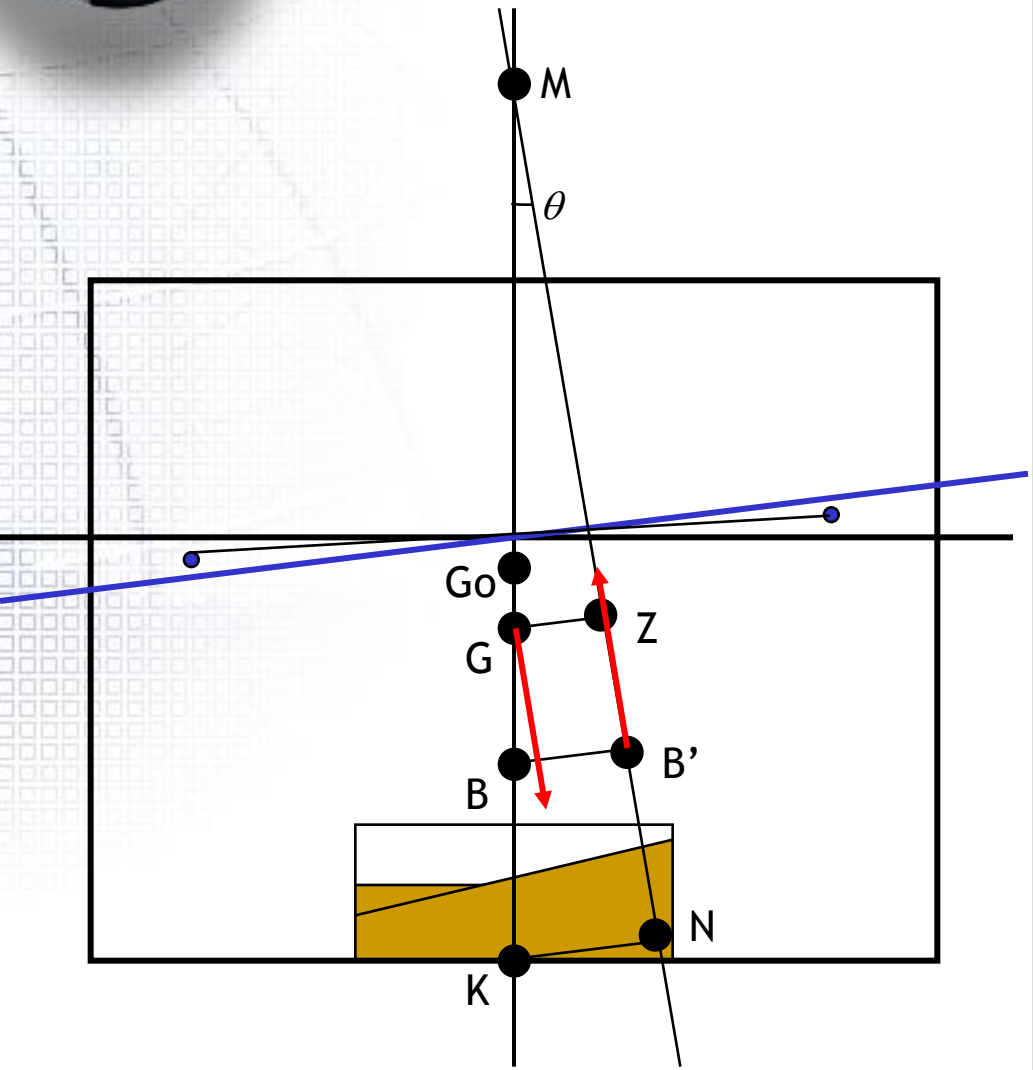
$$Trim \quad Lever = LCB - LCG$$

$$Trim\ [m] = \frac{\Delta \times Trim \quad Lever}{MTC \times 100}$$

$$MTC = \frac{\Delta \times GM_L}{100 \times LBP}$$

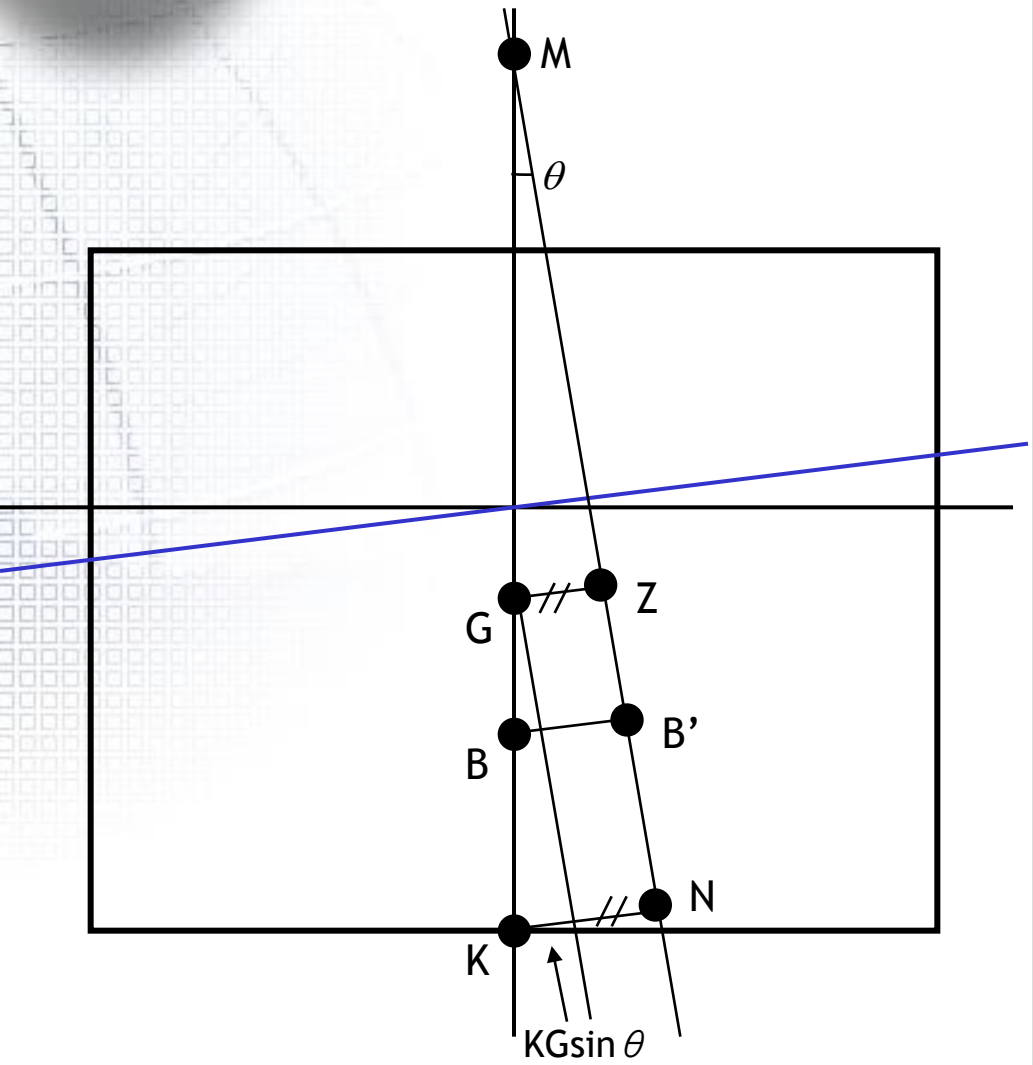


용어 정리 (IV)



- GGo : free surface correction
- GM : initial transverse metacentric height
- GoM : initial transverse metacentric height corrected for free surface
- GZ : the transverse righting lever
- KG : height of the center of gravity of the sihp above the base line
- KGo : height of the center of gravity of the sihp above the base line corrected for free surface
- KMT : height of initial transverse metacenter above base line
- KN : the righting lever with the ship heeled to angle 0 degrees when the center of gravity of the vessel is assumed to be at the base line

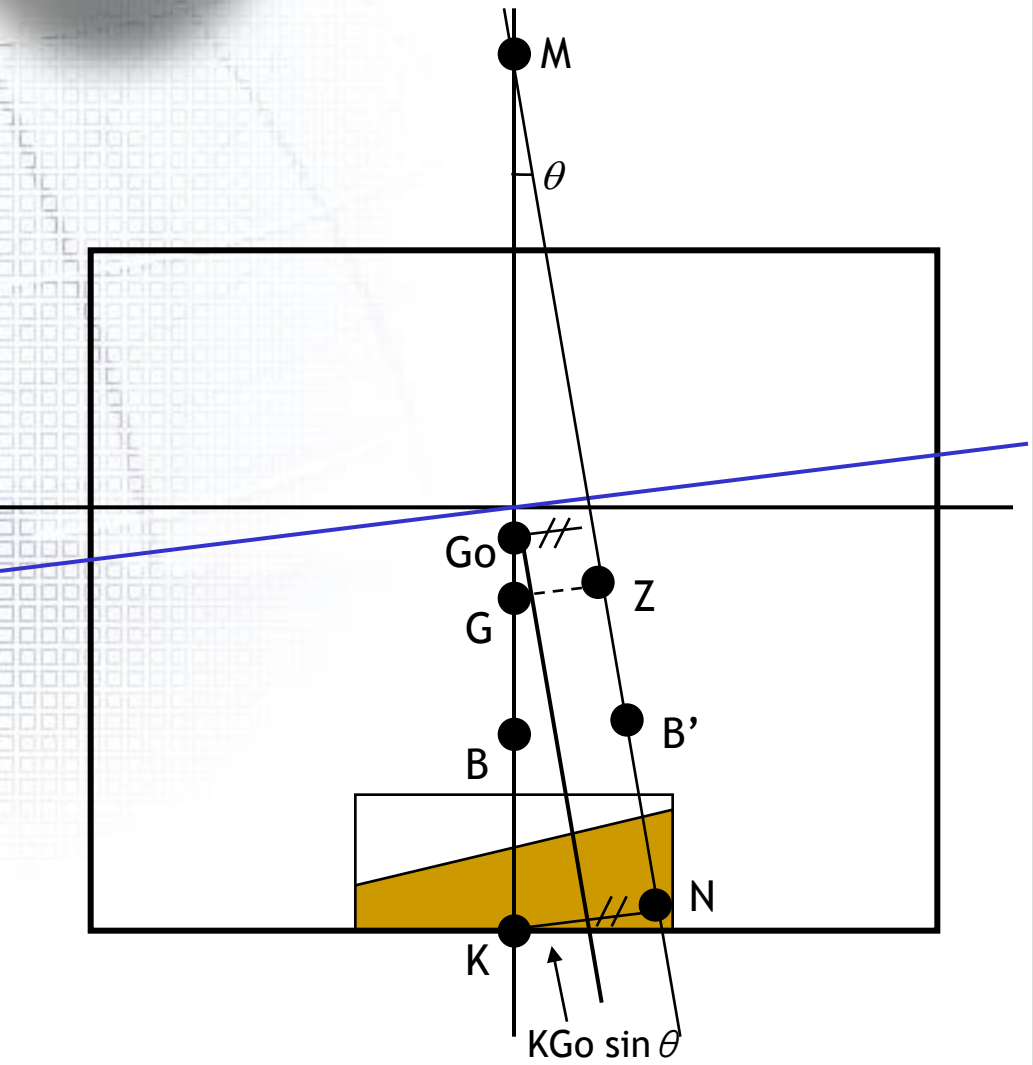
용어 정리 (V)



- G, B, B' 의 위치는 계산에 의한 결과값

- KG, KB, KN, KMT can be measured
- GM = KMT - KG
- GZ = KN – KG sin θ

용어 정리 (VI)



- Free Surface Effect
  : **자유표면을 가진 액체 화물에 의해 선박이 경사질 경우 무게 중심의 위치가 올라가는 효과가 나타남**

→ GoZ < GZ **이므로 복원암이 짧아지는 결과. 즉, 복원력이 작아짐**

- $GGo = \frac{\sum FSM_i}{\Delta} = \frac{\sum I_i \times \rho_i}{\Delta}$

(FSM : Free Surface Moment,

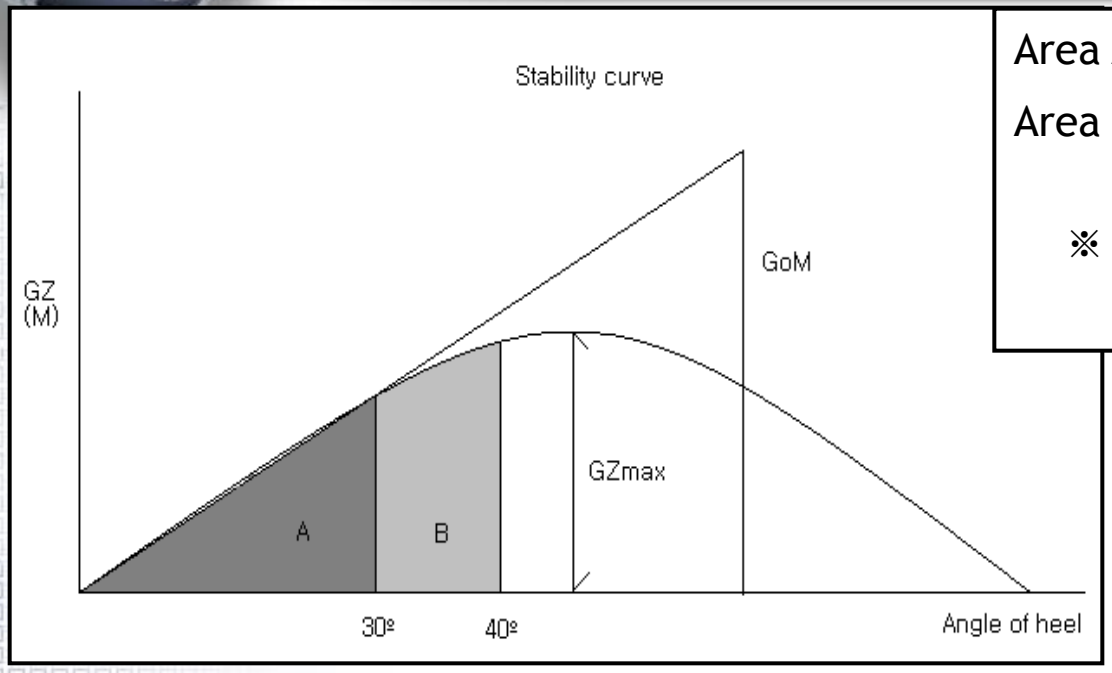
I : Area Moment of Inertia, ρ: **화물의 밀도)**

- GoM = GM - GGo
- KGo = KG + GGo
- GZ(GoZ) = KN – KGo sin θ

Specific Gravity (Density) & Filling Ratio

Name	Specific Gravity	Filling Ratio
Heavy Fuel Oil	0.990	98%
Diesel	0.860	98%
Lubricating Oil	0.900	98%
Fresh Water	1.000	100%
Sea Water	1.025	100%

Intact Stability Criteria (IMO Res.A-749(18) chapt.3.1)



Area A : Heel Angle**이** 0°~ 30°**까지의 면적**

Area B : Heel Angle**이** 30° ~ 40°
(40°**와** θ_f **중 작은 값)까지의 면적**

※ θ_f : an angle of heel at which openings in the hull

(a) Area A ≥ 0.05 m-rad

Area A + B ≥ 0.09 m-rad

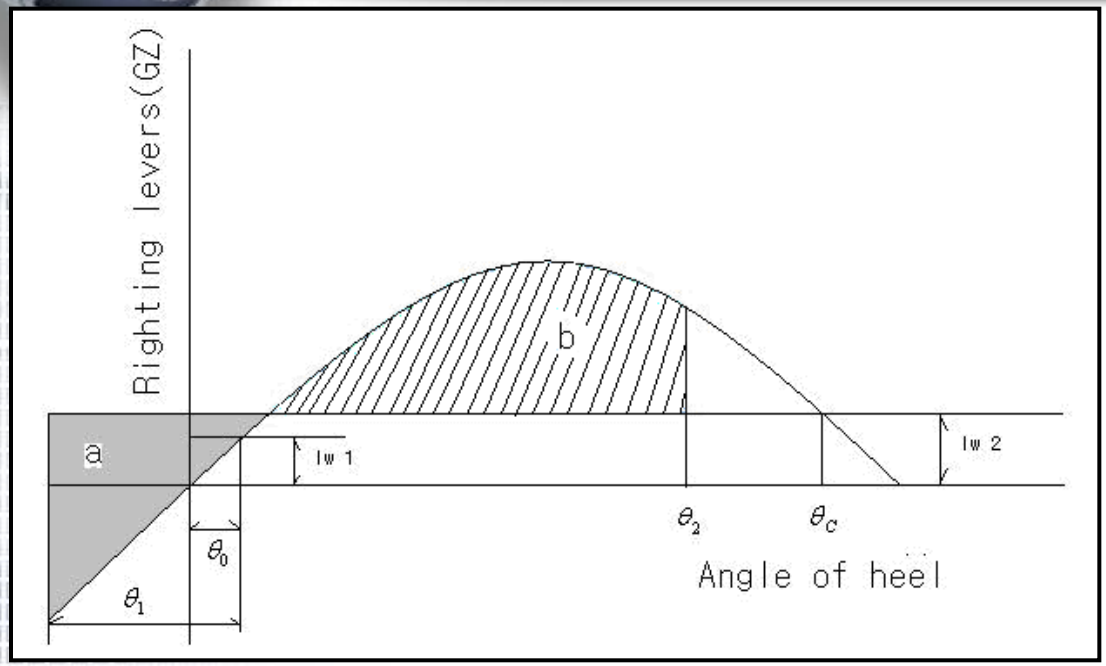
(b) Area B ≥ 0.030 m-rad

(c) Heel Angle**이** 30° **이상에서의** GZ**은** 0.200 m **이상이어야 한다.**

(d) GZ**이 최대가 되는** Heel Angle**은** 25° **이상이어야 한다.**

(e) Heel Angle**이** 0° **일때의** GM(GoM)**은** 0.150 m **이상이어야 한다.**

Intact Stability Criteria (IMO Res.A-749(18) chapt.3.2)



(a) area “b” ≥ area “a”

(b) θ_0는 16° 와 갑판의 끝단이 침수되는 각도(θ_f)의 80% 중 작은 값보다 작아야 한다.

Tank Summary Table

Name	Specific Gravity	Filling Ratio
Heavy Fuel Oil	0.990	98%

ex) $1214.6 \times 0.99 = 1202.4$

$1118.6 \times 0.99 = 1107.4$

HEAVY FUEL OIL TANKS

(S.G.= .990)

COMPARTMENT	LOCATION (FR.NO.)	CAPACITIES VOLUME 100%FULL (M**3)	VOLUME 98%FULL (M**3)	WEIGHT 98%FULL (TONNES)	100% FULL L.C.G FROM A.P (M)	V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
NO.1 H.F.O TK (P)	180-218	1239.3	1214.6	1202.4	159.046	6.949	622
NO.1 H.F.O TK (S)	180-218	1239.3	1214.6	1202.4	159.046	6.949	622
NO.2 H.F.O TK (P)	88-126	1141.5	1118.6	1107.4	85.692	7.112	395
NO.2 H.F.O TK (S)	88-126	1141.5	1118.6	1107.4	85.692	7.112	395
NO.3 H.F.O TK (P)	52- 88	593.9	582.0	576.2	57.377	2.352	1126
NO.3 H.F.O TK (S)	52- 88	593.9	582.0	576.2	57.377	2.352	1126
HFO SERV. TK(P)	44- 52	59.3	58.1	57.5	38.213	13.142	19
NO.1 HFO SETT. TK(P)	48- 52	122.5	120.0	118.8	40.010	10.887	112
NO.2 HFO SETT. TK(P)	44- 48	117.2	114.9	113.7	36.813	10.850	112
T O T A L		6248.4	6123.4	6062.0			

FSM (Free Surface Moment)

계산에 사용

Water Ballast Tank

(S.G.= 1.025)

COMPARTMENT	LOCATION (FR.NO)	CAPACITIES VOLUME 100% FULL (M**3)	CAPACITIES WEIGHT 100% FULL (TONNES)	100% FULL L.C.G FROM A.P (M)	100% FULL V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
F.P TK (C)	292-317	522.9	535.9	240.444	5.980	109
NO.1 W.W.B TK (P)	254-284	972.0	996.3	212.092	8.003	312
NO.1 W.W.B TK (S)	254-284	972.0	996.3	212.092	8.003	312
NO.2 D/B W.B TK (P)	218-254	528.1	541.3	186.645	2.136	868
NO.2 D/B W.B TK (S)	218-254	528.1	541.3	186.645	2.136	868
NO.2 W.W.B TK (P)	218-254	965.2	989.3	187.893	9.662	578
NO.2 W.W.B TK (S)	218-254	965.2	989.3	187.893	9.662	578
NO.3 D/B W.B TK (P)	184-218	354.3	363.2	159.025	.852	1253
NO.3 D/B W.B TK (S)	184-218	354.3	363.2	159.025	.852	1253
NO.4 D/B W.B TK (P)	144-180	362.4	371.5	129.040	.850	1029
NO.4 D/B W.B TK (S)	144-180	362.4	371.5	129.040	.850	1029
NO.4 W.W.B TK (P)	144-180	1199.1	1229.1	128.858	6.435	475
NO.4 W.W.B TK (S)	144-180	1199.1	1229.1	128.858	6.435	475
NO.5 D/B W.B TK (P)	126-144	181.2	185.7	107.680	.850	515
NO.5 D/B W.B TK (S)	126-144	181.2	185.7	107.680	.850	515
NO.5 W.W.B.TK (P)	126-144	605.8	621.0	107.718	6.391	250
NO.5 W.W.B.TK(S)	126-144	605.8	621.0	107.718	6.391	250
NO.6 D/B W.B TK (P)	92-126	336.9	345.3	87.269	.861	971
NO.6 D/B W.B TK (S)	92-126	336.9	345.3	87.269	.861	971
NO.7 W.W.B TK (P)	52- 88	906.6	929.2	54.797	9.176	767
NO.7 W.W.B TK (S)	52- 88	906.6	929.2	54.797	9.176	767
A.P TK (C)	-2- 14	455.2	466.6	6.018	11.899	3897
T O T A L		13801.3	14146.3			

Fresh Water Tank

(S.G.= 1.000)

COMPARTMENT	LOCATION (FR.NO.)	CAPACITIES VOLUME 100% FULL (M**3)	CAPACITIES WEIGHT 100% FULL (TONNES)	100% FULL L.C.G FROM A.P (M)	100% FULL V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
F.W TK (P)	5- 14	172.9	172.9	7.326	15.113	275
F.W TK (S)	5- 14	189.8	189.8	7.634	15.111	295
T O T A L		362.7	362.7			

Heavy Fuel Oil Tank

(S.G.= .990)

COMPARTMENT	LOCATION (FR.NO.)	CAPACITIES VOLUME 100%FULL (M**3)	CAPACITIES VOLUME 98%FULL (M**3)	CAPACITIES WEIGHT 98%FULL (TONNES)	100% FULL L.C.G FROM A.P (M)	100% FULL V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
NO.1 H.F.O TK (P)	180-218	1239.3	1214.6	1202.4	159.046	6.949	622
NO.1 H.F.O TK (S)	180-218	1239.3	1214.6	1202.4	159.046	6.949	622
NO.2 H.F.O TK (P)	88-126	1141.5	1118.6	1107.4	85.692	7.112	395
NO.2 H.F.O TK (S)	88-126	1141.5	1118.6	1107.4	85.692	7.112	395
NO.3 H.F.O TK (P)	52- 88	593.9	582.0	576.2	57.377	2.352	1126
NO.3 H.F.O TK (S)	52- 88	593.9	582.0	576.2	57.377	2.352	1126
HFO SERV. TK(P)	44- 52	59.3	58.1	57.5	38.213	13.142	19
NO.1 HFO SETT. TK(P)	48- 52	122.5	120.0	118.8	40.010	10.887	112
NO.2 HFO SETT. TK(P)	44- 48	117.2	114.9	113.7	36.813	10.850	112
T O T A L		6248.4	6123.4	6062.0			

Diesel Oil Tank

(S.G.= .860)

COMPARTMENT	LOCATION (FR.NO.)	CAPACITIES VOLUME 100%FULL (M**3)	CAPACITIES VOLUME 98%FULL (M**3)	CAPACITIES WEIGHT 98%FULL (TONNES)	100% FULL L.C.G FROM A.P (M)	100% FULL V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
D.O SERV. TK (P)	14- 29	56.1	55.0	47.3	21.200	13.421	12
D.O STOR. TK (P)	24- 29	358.3	351.2	302.0	16.855	15.000	125
T O T A L		414.4	406.2	349.3			

Lubrication Oil Tank

(S.G.= .900)

COMPARTMENT	LOCATION (FR.NO.)	CAPACITIES VOLUME 100%FULL (M**3)	CAPACITIES VOLUME 98%FULL (M**3)	CAPACITIES WEIGHT 98%FULL (TONNES)	100% FULL L.C.G FROM A.P (M)	100% FULL V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
M/E L.O SUMP TK(C)	27- 48	50.6	49.6	44.6	29.278	1.222	22
M/E L.O SETT. TK(S)	36- 42	41.7	40.8	36.8	31.211	13.462	4
M/E L.O STOR. TK(S)	42- 52	70.8	69.4	62.5	37.607	13.427	6
NO.1 CYL.OIL TK(S)	25- 29	130.2	127.6	114.9	21.617	12.865	131
NO.2 CYL.OIL TK(S)	21- 25	121.1	118.7	106.8	18.422	13.041	131
G/E L.O SETT. TK(S)	17- 19	54.2	53.1	47.8	14.407	13.279	65
G/E L.O STOR. TK(S)	19- 21	56.8	55.7	50.1	16.006	13.182	65
T O T A L		525.4	514.9	463.5			

Miscellaneous Tank

COMPARTMENT	LOCATION FRAMES	CAPACITIES VOLUME 100% FULL (M**3)	100% FULL L.C.G FROM A.P (M)	100% FULL V.C.G ABOVE B.L(M)	MAX. MT OF INERTIA (M**4)
SEWAGE HOLDING TK(P)	32- 34	8.3	26.402	13.452	1
BILGE HOLDING TK(C)	14- 25	62.9	16.279	1.478	75
S/T L.O DRAIN TK(C)	24- 25	3.0	19.600	1.695	1
RESIDUE TK(S)	29- 44	25.0	30.577	1.754	10
DIRTY OIL TK (S)	29- 36	46.0	26.042	13.549	4
L.O SLUDGE TK(P)	37- 39	4.4	30.422	10.570	2
HFO SLUDGE TK(P)	32- 43	58.8	31.176	10.148	61
C.F.W DRAIN TK(S)	44- 47	9.4	36.433	1.666	6
HFO/LO LEAK O.TK(P)	29- 36	7.4	26.438	1.836	1
C.W TK (C)	7.3- 14	35.5	9.480	3.554	6
F.O OVERFLOW TK	36- 50	45.9	35.974	1.525	328
STUFF.L.O DRAIN TK(P)	25- 26	4.4	20.403	1.428	2
STUFF.L.O DRAIN TK(S)	25- 26	4.4	20.403	1.428	2
T O T A L		315.4			

LCG (Longitudinal Center of Gravity) 계산

① $$LCG_{DWT} = \frac{\sum LCG_i \times \rho_i V_i}{DWT}$$

- LCG_i : Tank에 실린 화물의 길이방향 무게 중심
- ρ_i : Tank에 실린 화물의 밀도
- V_i : Tank에 실린 화물의 부피

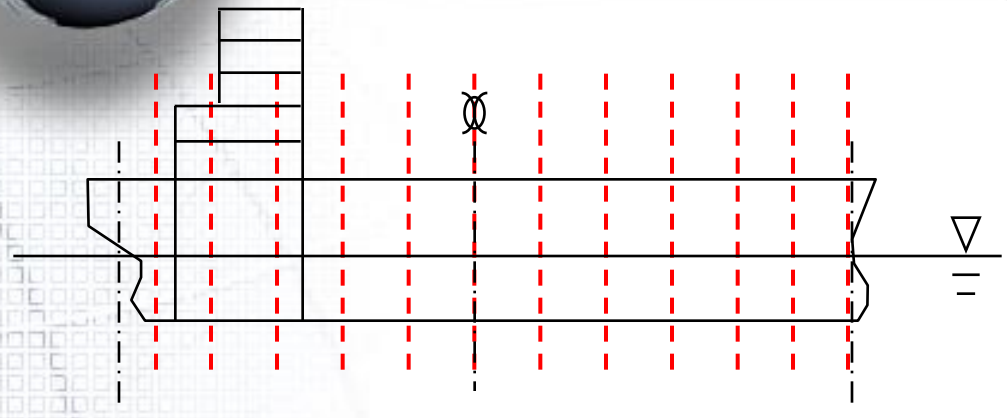
② $$LCG_{LWT} = \frac{\sum LCG_j \times W_j}{LWT}$$

- LCG_j : 길이 방향의 일정 구간에 분포하는 LWT의 무게 중심
- W_j : 길이 방향의 일정 구간에 분포하는 LWT

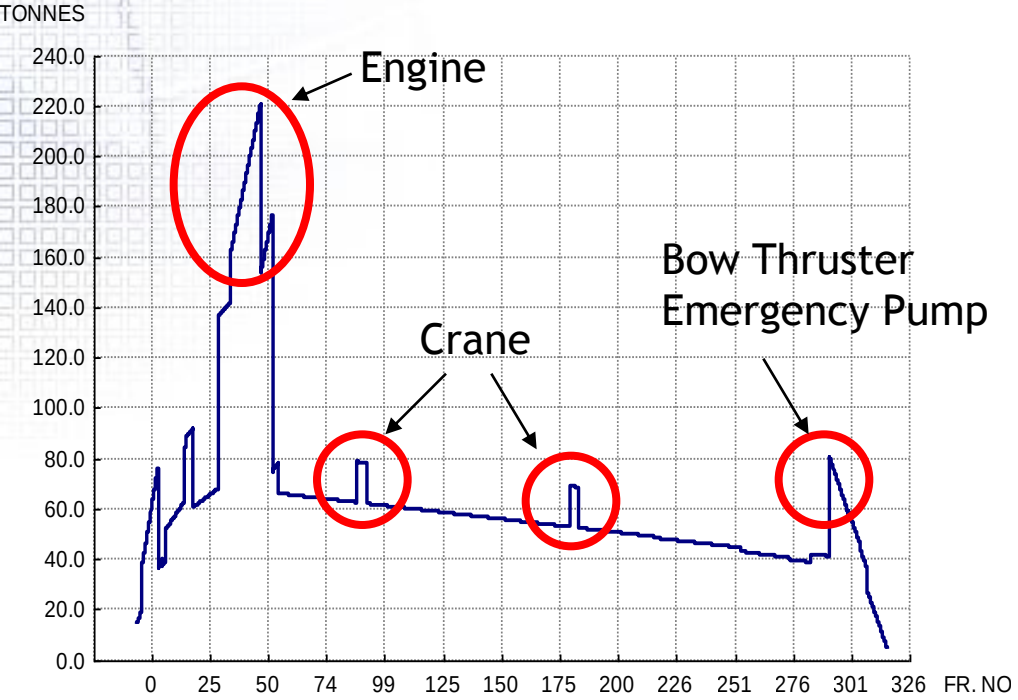
- LCG_{DWT} 의 위치는 Loading Condition에 따라 달라짐
- LCG_{LWT} 의 위치는 항상 일정함

$$\therefore LCG = \frac{LCG_{DWT} \times DWT + LCG_{LWT} \times LWT}{\Delta}$$

Lightweight summary



LIGHTWEIGHT DISTRIBUTION DIAGRAM

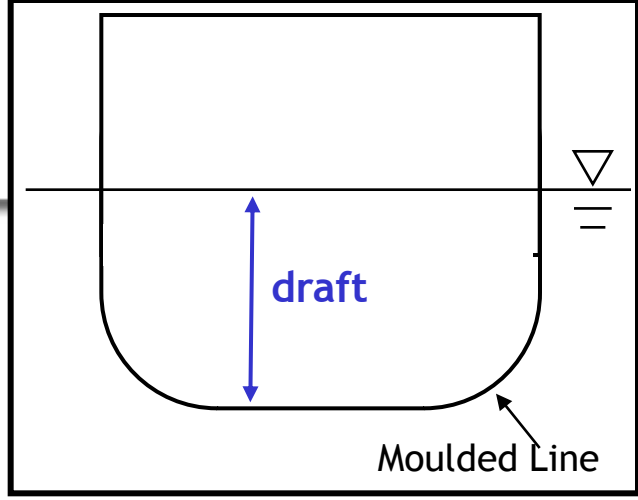


LIGHT WEIGHT SUMMARY

Hull No. : 1329. 3,700 TEU CONTAINER VESSEL

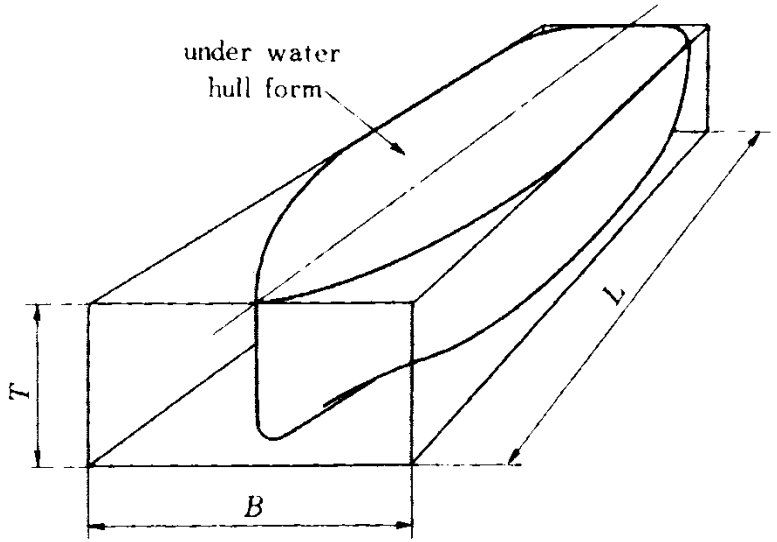
NO	AFT END	FORE END	WEIGHT	L.C.G	MOMENT
1	-5.000	14.350	616.00	7.000	4312.0
2	14.350	43.400	1387.10	31.400	43554.9
3	43.400	232.320	7591.50	128.620	976418.7
4	232.320	252.240	732.30	239.280	175224.7
5	27.200	41.600	476.40	35.800	17055.1
6	.000	245.240	30.00	122.620	3678.6
7	43.400	232.320	340.00	134.200	45628.0
8	-3.600	232.320	119.00	114.400	13613.6
9	-3.400	2.400	151.90	.000	.0
10	.000	252.240	224.00	120.000	26880.0
11	202.240	232.320	137.90	217.000	29924.3
12	43.400	202.240	1053.00	121.700	128150.1
13	143.280	146.680	55.00	144.980	7973.9
14	70.480	73.880	55.00	72.180	3969.9
15	14.350	232.320	115.90	114.360	13254.3
16	-3.600	232.320	128.00	114.360	14638.1
17	232.320	245.240	118.30	238.600	28226.4
18	36.000	170.000	3.00	81.000	243.0
19	-5.000	4.000	50.00	-.500	-25.0
20	29.000	41.600	15.50	37.100	575.0
21	-3.500	4.000	19.20	.000	.0
22	4.000	11.200	34.30	7.600	260.7
23	41.600	173.900	62.50	105.760	6610.0
24	226.160	232.320	20.40	229.240	4676.5
25	239.000	243.000	5.40	241.000	1301.4
26	11.200	232.320	39.20	121.700	4770.6
27	11.200	232.320	191.30	121.700	23281.2
28	27.200	41.600	214.50	36.000	7722.0
29	23.230	37.600	979.00	30.400	29761.6
30	11.200	41.600	289.50	22.000	6369.0
31	5.000	23.230	111.30	11.200	1246.6
32	12.000	41.600	150.70	28.000	4219.6
33	11.200	41.600	158.60	28.000	4440.8
34	11.200	41.600	95.90	28.000	2685.2
35	11.200	218.480	165.00	114.240	18849.6
36	27.200	41.600	8.50	36.000	306.0
37	11.200	41.600	43.00	30.000	1290.0
38	27.200	41.600	4.30	36.000	154.8
39	27.200	41.600	5.70	36.000	205.2
LIGHT SHIP TOTAL =			15998.10	103.228	651446.5

Hydrostatics Table



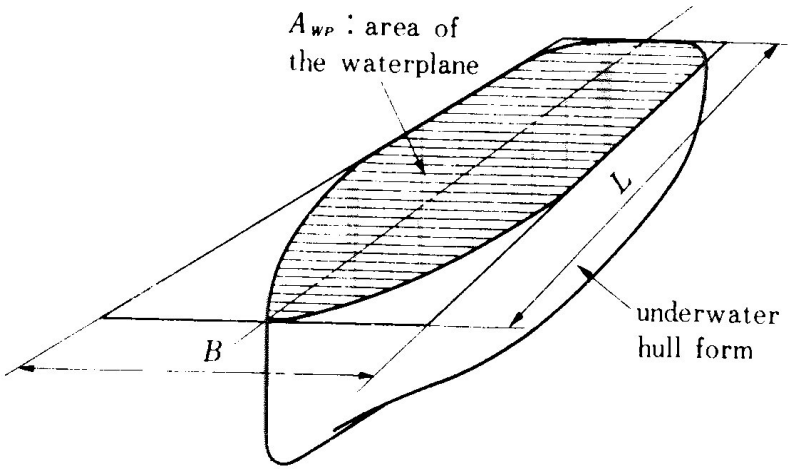
- DRAFT MLD : Draft from baseline , moudled (m)
- DISP.MLD : Displacement moulded (m^3)
- DISP.EXT : Displacement Extreme (tonnes) S.G. = 1.025
- VCB : Verrtical Center of Buoyancy above Base line (m)
- LCB : Longi. Center of Buoyancy from midship (-.AFT / +. FWD)
- LCF : Longi. Center of Floatation from midship (-.AFT / +. FWD)
- KMT : Trans. Metacenter height above base line (m)
- KML : Long. Metacenter height above base line (m)
- MTC : Moment to change trim one centimeter (Tonnes-m)
- TPC : increase in Disp.MLD per one centimeter immersion
- WSA : Wetted Surface Area (m^2)
- C.B. : Block Coefficient
- C.W. : Water plane Area Coefficient
- C.P. : Prismatic Coefficient
- C.M. : Midship section area Coefficient

Hydrostatics Table



- C_B : Block Coefficient

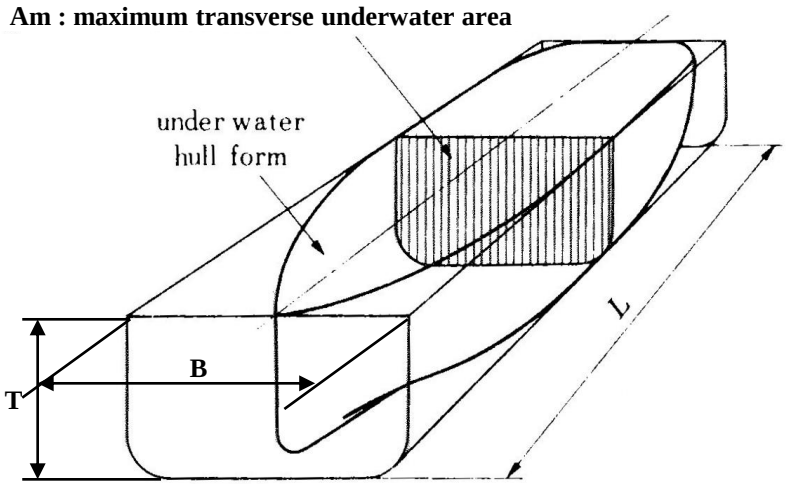
$$C_B = \frac{\Delta}{L \times B \times T \times \rho_{sea}} = \frac{\nabla}{L \times B \times T}$$



- C_{WP} : Water plane Area Coefficient

$$C_{WP} = \frac{A_{WP}}{L \times B}$$

Hydrostatics Table



- C_m : Midship Section Coefficient

$$C_m = \frac{A_m}{B \times T}$$

- C_p : Prismatic Coefficient

$$C_p = \frac{\nabla}{A_m \times L} = \frac{C_b \times L \times B \times T}{C_m \times L \times B \times T} = \frac{C_b}{C_m}$$

DRAFT MLD [M]	DISP MLD [M3]	DISP EXT [T]	LCF [M]	LCB [M]	VCB [M]	TPC [T]	MTC [T-M]	KML [M]	KMT [M]	WSA [M2]	CB	CP	CW	CM
3,00	11326,7	11693,7	-3,33	-3,32	1,63	46,7	479,2	1016,5	23,83	5114,7	0,474	0,506	0,572	0,937
3,05	11562,7	11936,2	-3,31	-3,32	1,66	46,9	482,1	1001,8	23,57	5145,3	0,475	0,507	0,574	0,938
3,10	11798,8	12178,7	-3,30	-3,32	1,68	47,1	484,9	987,7	23,32	5175,8	0,477	0,509	0,576	0,938
3,15	12034,9	12421,2	-3,28	-3,32	1,71	47,2	487,7	974,1	23,08	5206,3	0,479	0,510	0,578	0,939
3,20	12271,0	12663,6	-3,26	-3,31	1,74	47,4	490,5	961,0	22,86	5236,8	0,481	0,512	0,580	0,940
3,25	12507,1	12906,1	-3,25	-3,31	1,77	47,5	493,4	948,4	22,64	5267,3	0,483	0,513	0,582	0,941
3,30	12743,2	13148,6	-3,23	-3,31	1,79	47,7	496,2	936,3	22,43	5297,8	0,484	0,514	0,584	0,942
3,35	12979,2	13391,1	-3,21	-3,31	1,82	47,9	49							
3,40	13215,3	13633,6	-3,20	-3,30	1,85	48,0	50							
3,45	13451,4	13876,1	-3,18	-3,30	1,88	48,2	50							
3,50	13687,5	1411					50							
3,55	13923,6	143					51							
3,60	14159,7	146					51							
3,65	14395,7	14846,0	-3,11	-3,29	1,99	48,8	515,9	862,6	21,18	5511,4	0,495	0,522	0,597	0,947
3,70	14631,8	15088,5	-3,10	-3,29	2,02	49,0	518,8	853,4	21,02	5541,9	0,496	0,523	0,599	0,948
3,75	14919.7	15400.8	2.025	118.394	119.002	21.691	838.95	525.6	49.7	5602.1	.5072	.6127	.5421	.9356
3,80	15160.8	15648.4	2.051	118.403	119.048	21.524	830.42	528.6	49.9	5631.7	.5086	.6145	.5431	.9364
3,85	15401.8	15896.1	2.076	118.412	119.093	21.362	822.15	531.6	50.0	5661.4	.5099	.6163	.5441	.9372
3,90	15644.8	16145.8	2.103	118.422	119.132	21.201	813.71	534.3	50.1	5690.8	.5113	.6180	.5451	.9380
3,95	15891.1	16398.8	2.133	118.434	119.159	21.037	804.83	536.7	50.3	5719.8	.5127	.6196	.5462	.9388
4,40	18047,3	18596,3	-2,94	-3,24	2,40	50,9	554,2	740,4	19,16	5960,4	0,514	0,538	0,623	0,956
4,45	18297,2	18852,9	-2,93	-3,24	2,43	51,1	556,5	733,4	19,05	5989,9	0,516	0,539	0,625	0,956
4,50	18547,1	19109,5	-2,92	-3,23	2,46	51,2	558,8	726,6	18,94	6019,3	0,517	0,540	0,626	0,957
4,55	18796,9	19366,1	-2,91	-3,23	2,48	51,3	561,1	720,0	18,84	6048,7	0,518	0,541	0,628	0,957
4,60	19046,8	19622,7	-2,91	-3,22	2,51	51,4	563,4	713,5	18,74	6078,2	0,519	0,542	0,629	0,958
4,65	19296,7	19879,3	-2,90	-3,22	2,54	51,6	565,7	707,3	18,64	6107,6	0,520	0,543	0,631	0,958
4,70	19546,6	20135,9	-2,89	-3,21	2,57	51,7	568,0	701,1	18,54	6137,1	0,522	0,544	0,632	0,959
4,75	19796,4	20392,5	-2,88	-3,21	2,60	51,8	570,3	695,2	18,45	6166,5	0,523	0,545	0,634	0,959
4,80	20046,3	20649,1	-2,87	-3,21	2,62	51,9	572,6	689,4	18,36	6195,9	0,524	0,546	0,635	0,959
4,85	20296,2	20905,7	-2,87	-3,20	2,65	52,1	574,9	683,7	18,27	6225,4	0,525	0,547	0,637	0,960
4,90	20546,1	21162,3	-2,86	-3,20	2,68	52,2	577,3	678,2	18,19	6254,8	0,526	0,548	0,639	0,960
4,95	20795,9	21418,9	-2,85	-3,19	2,71	52,3	579,6	672,8	18,11	6284,3	0,527	0,549	0,640	0,961
5,00	21045,8	21675,5	-2,84	-3,19	2,73	52,4	581,9	667,5	18,03	6313,7	0,528	0,549	0,642	0,961
5,05	21306,9	21943,6	-2,85	-3,18	2,76	52,5	584,0	661,8	17,94	6342,6	0,529	0,550	0,643	0,961
5,10	21568,0	22211,7	-2,85	-3,18	2,79	52,7	586,1	656,3	17,85	6371,5	0,530	0,551	0,644	0,962
5,15	21829,1	22479,8	-2,85	-3,18	2,82	52,8	588,3	650,8	17,76	6400,4	0,532	0,553	0,646	0,962
5,20	22090,2	22747,9	-2,85	-3,17	2,84	52,9	590,4	645,5	17,68	6429,2	0,533	0,554	0,647	0,963
5,25	22351,3	23016,0	-2,85	-3,17	2,87	53,0	592,5	640,4	17,59	6458,1	0,534	0,555	0,648	0,963
5,30	22612,4	23284,1	-2,86	-3,17	2,90	53,1	594,6	635,3	17,51	6487,0	0,535	0,556	0,649	0,963
5,35	22873,5	23552,2	-2,86	-3,16	2,93	53,2	596,8	630,4	17,44	6515,9	0,536	0,557	0,651	0,964
5,40	23134,6	23820,3	-2,86	-3,16	2,95	53,3	598,9	625,6	17,36	6544,8	0,537	0,557	0,652	0,964
5,45	23395,7	24088,4	-2,86	-3,16	2,98	53,4	601,0	620,8	17,29	6573,7	0,538	0,558	0,653	0,964
5,50	23656,8	24356,5	-2,86	-3,15	3,01	53,5	603,1	616,2	17,22	6602,6	0,539	0,559	0,655	0,965
5,55	23917,9	24624,6	-2,87	-3,15	3,04	53,6	605,3	611,7	17,15	6631,4	0,540	0,560	0,656	0,965
5,60	24179,0	24892,7	-2,87	-3,15	3,07	53,7	607,4	607,3	17,09	6660,3	0,542	0,561	0,657	0,965
5,65	24440,1	25160,8	-2,87	-3,14	3,10	53,8	609,5	603,0	17,02	6689,2	0,543	0,562	0,659	0,966
5,70	24701,2	25428,9	-2,87	-3,13	3,13	53,9	611,6	598,8	16,96	6718,1	0,544	0,563	0,660	0,966
5,75	24962,3	25697,0	-2,88	-3,13	3,16	54,0	613,8	594,6	16,90	6747,0	0,544	0,564	0,661	0,966
5,80	25223,4	25965,1	-2,88	-3,13	3,19	54,2	615,9	590,6	16,84	6775,9	0,545	0,564	0,663	0,966
5,85	25484,5	26233,2	-2,88	-3,13	3,21	54,3	618,0	586,6	16,79	6804,7	0,546	0,565	0,664	0,967
5,90	25745,6	26501,3	-2,88	-3,12	3,23	54,4	620,1	582,7	16,73	6833,6	0,547	0,566	0,665	0,967
5,95	26006,7	26769,4	-2,88	-3,12	3,26	54,5	622,3	578,9	16,68	6862,5	0,548	0,567	0,667	0,967
6,00	26267,8	27037,5	-2,89	-3,12	3,28	54,7	624,4	575,1	16,62	6891,4	0,549	0,568	0,668	0,968
6,05	26528,9	27305,6	-2,89	-3,12	3,31	54,8	626,5	571,3	16,57	6920,3	0,550	0,569	0,669	0,968
6,10	26790,0	27573,7	-2,90	-3,12	3,34	54,9	628,6	567,6	16,51	6949,2	0,551	0,570	0,670	0,968
6,15	27051,1	27841,8	-2,90	-3,12	3,36	55,0	630,7	563,9	16,46	6978,1	0,552	0,571	0,672	0,968
6,20	27312,2	28109,9	-2,91	-3,12	3,39	55,1	632,8	560,2	16,41	7007,0	0,553	0,572	0,673	0,968
6,25	27573,3	28378,0	-2,91	-3,12	3,41	55,2	634,9	556,6	16,36	7035,9	0,554	0,573	0,674	0,969
6,30	27834,4	28646,1	-2,92	-3,12	3,44	55,3	636,9	553,0	16,31	7064,8	0,555	0,574	0,675	0,969
6,35	28095,5	28914,2	-2,92	-3,12	3,46	55,4	639,0	549,4	16,26	7093,7	0,556	0,575	0,676	0,969
6,40	28356,6	29182,3	-2,93	-3,12	3,49	55,5	641,0	545,9	16,21	7122,6	0,557	0,576	0,677	0,969
6,45	28617,7	29450,4	-2,93	-3,12	3,51	55,6	643,1	542,4	16,16	7151,5	0,558	0,577	0,678	0,969
6,50	28878,8	29718,5	-2,94	-3,12	3,54	55,7	645,1	538,9	16,11	7180,4	0,559	0,578	0,679	0,969
6,55	29139,9	29986,6	-2,94	-3,12	3,56	55,8	647,1	535,5	16,07	7209,3	0,560	0,578	0,681	0,970
6,60	29401,0	30254,7	-2,95	-3,12	3,59	55,9	649,1	532,1	16,02	7238,2	0,561	0,579	0,682	0,970
6,65	29794,8	30658,9	-3,28	-3,12	3,64	55,9	653,3	531,4	16,02	7265,9	0,562	0,579	0,684	0,971
6,70	30066,2	30937,5	-3,31	-3,12	3,67	56,0	655,6	528,4	15,98	7294,7	0,563	0,580	0,685	0,971
6,75	30337,5	31216,0	-3,34	-3,12	3,70	56,1	657,8	525,5	15,94	7323,5	0,564	0,580	0,687	0,971
6,80	30608,8	31494,6	-3,37	-3,12	3,72	56,2	660,0	522,7	15,91	7352,3	0,565	0,581	0,688	0,971
6,85	30880,1	31773,2	-3,40	-3,12	3,75	56,3	662,2	519,9	15,87	7381,1	0,565	0,582	0,689	0,972
6,90	31151,4	32051,7	-3,43	-3,12	3,78	56,4	664,5	517,2	15,84	7409,9	0,566	0,583	0,690	0,972
6,95	31422,7	32330,3	-3,46	-3,12	3,81	56,5	666,7	514,5	15,81	7438,7	0,567	0,583	0,692	0,972
7,00	31694,0	32608,9	-3,49	-3,12	3,84	56,6	668,9	511,8	15,78	7467,5	0,568	0,584	0,693	0,972
7,05	31975,1	32897,5	-3,54	-3,13	3,86	56,7	671,2	509,1	15,74	7496,5	0,569	0,585	0,694	0,972
7,10	32256,2	33186,1	-3,59	-3,13	3,89	56,8	673,5	506,5	15,71	7525,4	0,570	0,586	0,695	0,973
7,15	32537,3	33474,7	-3,64	-3,14	3,92	56,9	675,8	503,9	15,67	7554,3	0,571	0,587	0,697	0,973
7,20	32818,4	33763,3	-3,69	-3,15	3,95	57,0	678,2	501,3	15,64	7583,3	0,572	0,588	0,698	0,973
7,25	33099,5	34051,9	-3,75	-3,15	3,97	57,1	680,5	498,8	15,61	7612,2	0,573	0,588	0,699	0,973
7,30	33380,6	34340,4	-3,80	-3,16	4,00	57,2	682,8	496,4	15,58	7641,2	0,573	0,589	0,700	0,973
7,35	33661,7	34629,0	-3,85	-3,17	4,03	57,3	685,1	493,9	15,55	7670,1	0,574	0,590	0,701	0,974
7,40	33942,8	34917,6	-3,90	-3,17	4,06	57,4	687,4	491,6	15,52	7699,0	0,575	0,591	0,703	0,974
7,45	34223,9	35206,2	-3,95	-3,18	4,08	57,5	689,7	489,2	15,49	7728,0	0,576	0,592	0,704	0,974

X 1.025 X C

- Moulded Line이므로 철판의 두께 고려해야함
- 선체 부가물의 부력을 포함시켜야 함

Loading Condition Examples

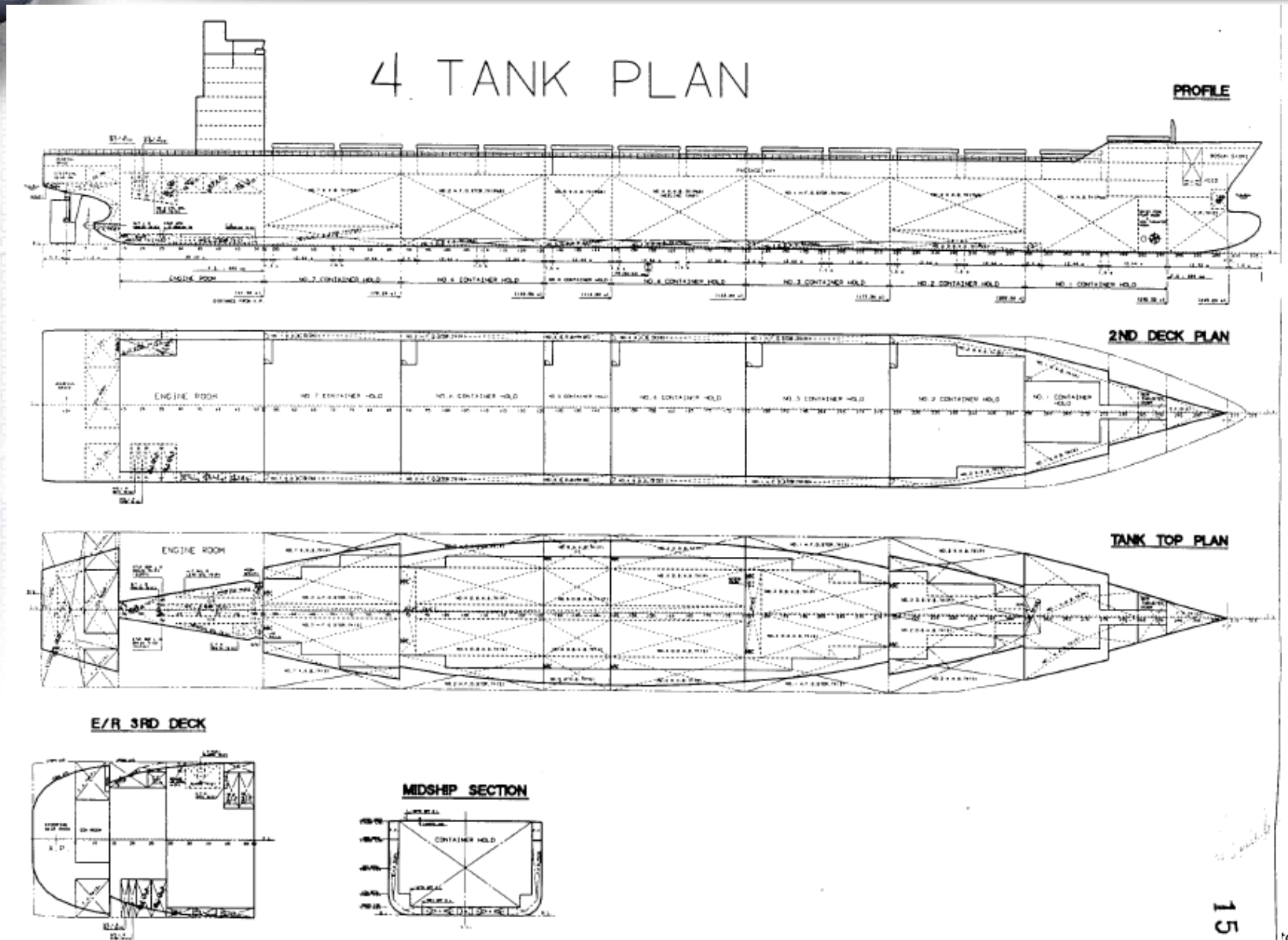
Advanced
Ship
Design
Automation
Laboratory

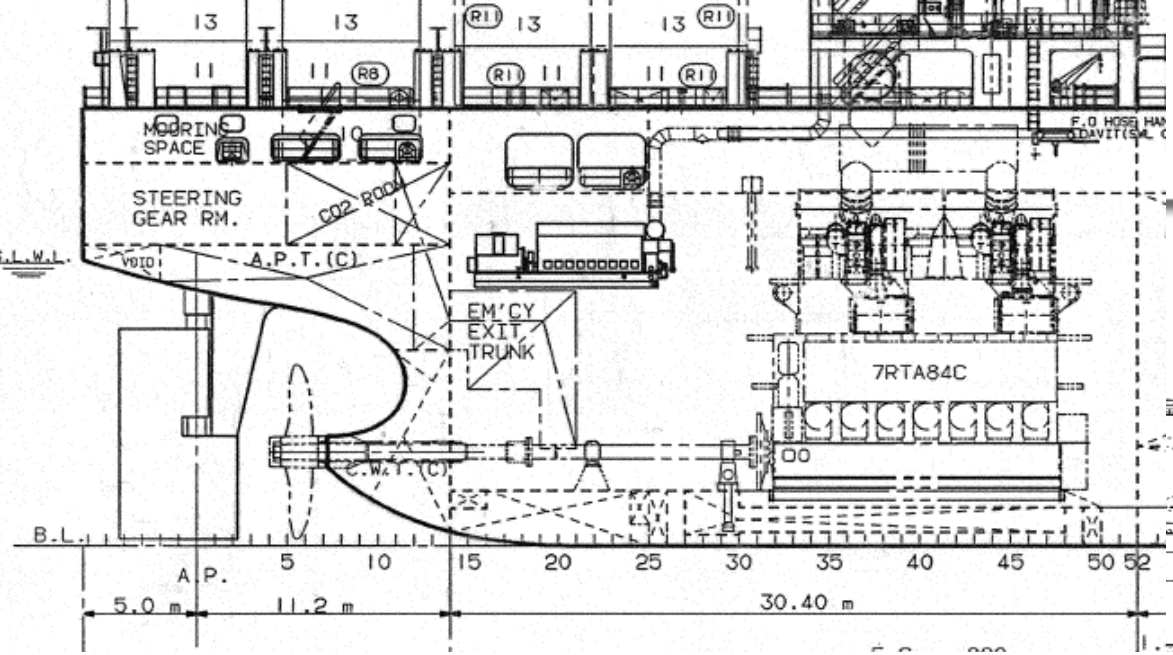
대상 선박

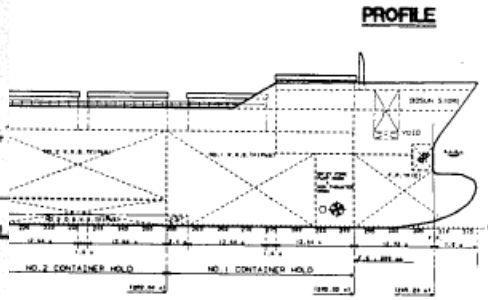
- 3,700 TEU Contaioner Vessel

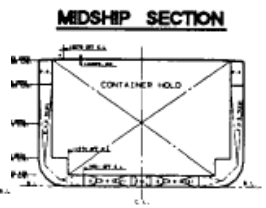
- Principal Dimensions
  - × LOA 257.368 M
  - × LBP 245.240 M
  - × BREDTH MOULDED 32.20 M
  - × DEPTH MOULDED 19.30 M
  - × DESIGNED DRAUGHT MOULED 10.10 M
  - × SCANTLING DRAUGHT MOULED 12.50 M

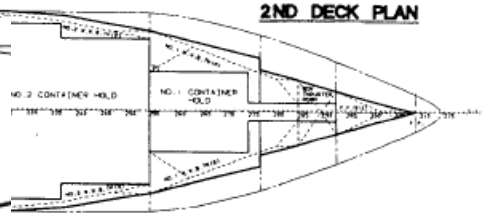
3,700 TEU Container ship –Tank Plan

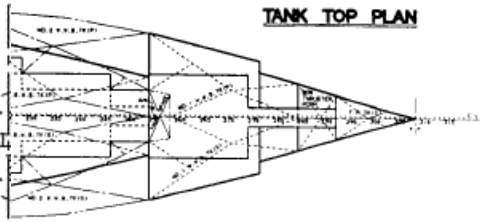


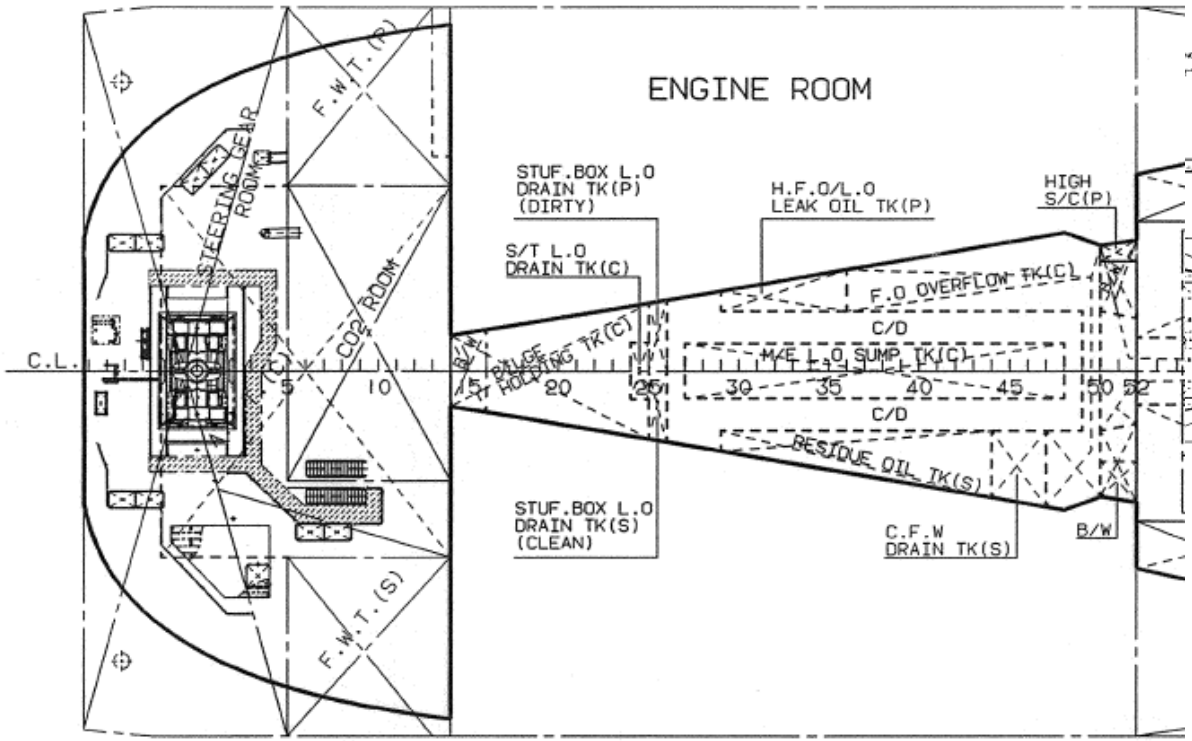






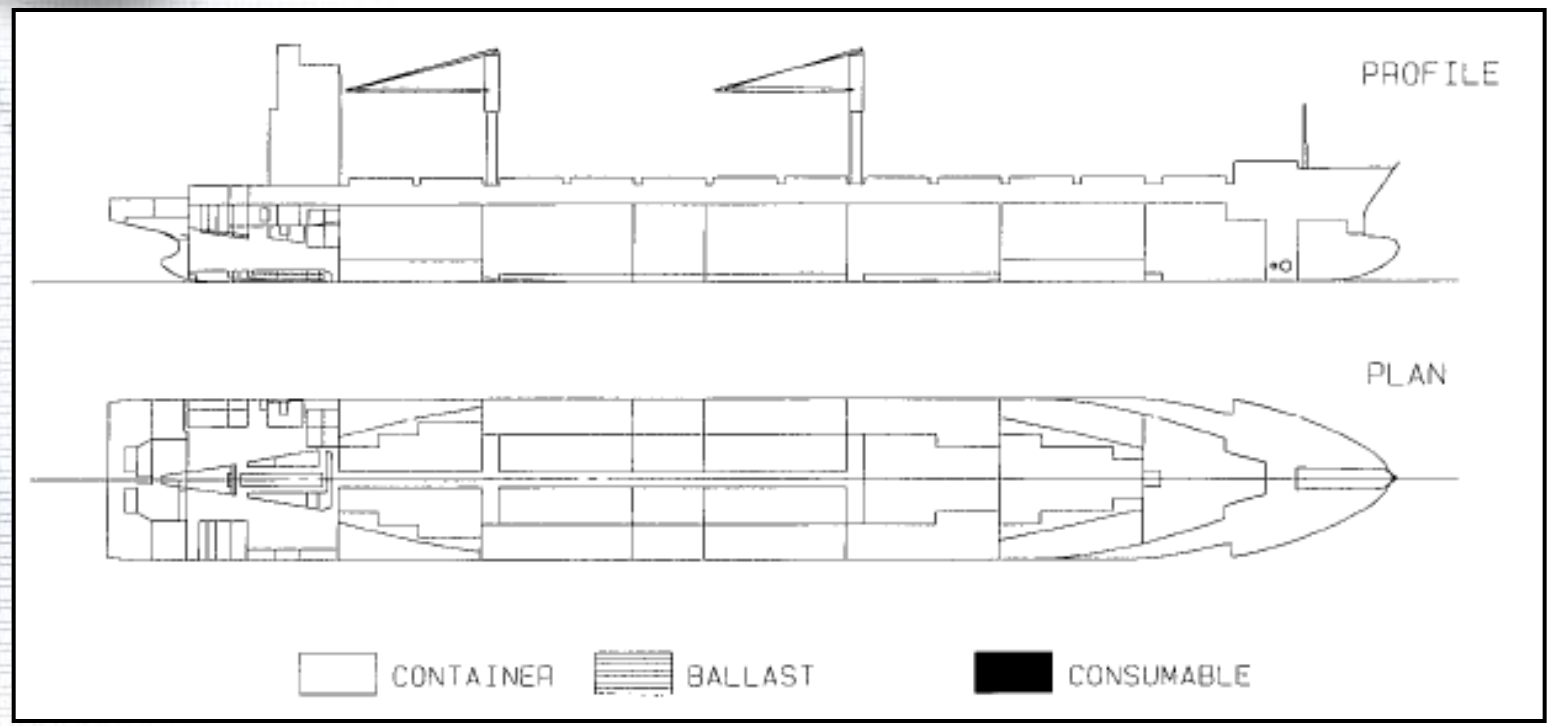






Loading Conditions Example (I) – Lightship condition

- Lightship condition : **배에 아무 것도 싣지 않은 상태**



Loading Conditions Example (I) – Lightship condition

DRAUGHT F.P	=	1.526 M	K.M.T	=	21.296 M
DRAUGHT MIDSHIP	=	3.806 M	KG (SOLID)	=	13.200 M
DRAUGHT A.P	=	6.086 M	GM (SOLID)	=	8.096 M
TRIM BY STERN	=	4.560 M	FREE SURF. CORR.(GGo)	=	.000 M
PROPELLER I/D	=	74.0 %	GoM (FLUID)	=	8.096 M
DISPLACEMENT	=	15998.1 T	KGo ACTUAL (FLUID)	=	13.200 M
DRAUGHT AT LCF	=	3.871 M	① TRIM (DIS*A)/(MTC*100)	=	4.560 M
LCB FROM A.P	=	118.416 M	FREE SURF. MOM.	=	0 T-M
LCG FROM A.P	=	103.228 M	M.T.C.	=	532.8 T-M
TRIM LEVER : A	=	15.188 M	LCF FROM A.P	=	119.110 M

① Hydrostatics table의 결과 사용

DRAFT (M)	DISP MLD(M3)	DISP EXT(T)	VCB (M)	LCB (M)	LCF (M)	KMT (M)	KML (M)	MTC (T-M)	TPC (TON)	WSA (M2)	C B	C W	C P	C M
3.75	14919.7	15400.8	2.025	118.394	119.002	21.691	838.95	525.6	49.7	5602.1	.5072	.6127	.5421	.9356
3.80	15160.8	15648.4	2.051	118.403	119.048	21.524	830.42	528.6	49.9	5631.7	.5086	.6145	.5431	.9364
3.85	15401.8	15896.1	2.076	118.412	119.093	21.362	822.15	531.6	50.0	5661.4	.5099	.6163	.5441	.9372
3.90	15644.8	16145.8	2.103	118.422	119.132	21.201	813.71	534.3	50.1	5690.8	.5113	.6180	.5451	.9380
3.95	15891.1	16398.8	2.133	118.434	119.159	21.037	804.83	536.7	50.3	5719.8	.5127	.6196	.5462	.9388

선형 보간 하면, draft at LCF =3.871에서 $VCB\ (= KB) = 2.087\,[m], KML = 818.38\,[m]$

$$\left(BM_L = KML - KB = 818.38 - 2.087 = 816.293\right)$$

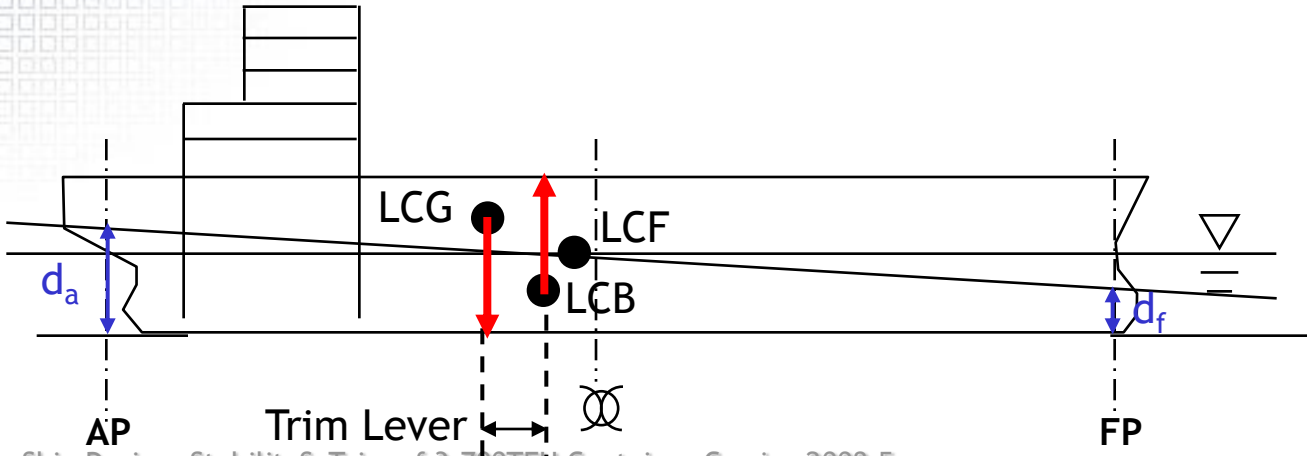
$$MTC = \frac{\Delta \times GM_L}{100 \times LBP} \approx \frac{\Delta \times BM_L}{100 \times LBP} = \frac{15998.1 \times 816.293}{100 \times 245.24} = 532.5\,[T-m]$$

Loading Conditions Example (I) – Lightship condition

DRAUGHT F.P	=	1.526 M	K.M.T	=	21.296 M
DRAUGHT MIDSHIP	=	3.806 M	KG (SOLID)	=	13.200 M
DRAUGHT A.P	=	6.086 M	GM (SOLID)	=	8.096 M
TRIM BY STERN	=	4.560 M	FREE SURF. CORR.(GGo)	=	.000 M
PROPELLER I/D	=	74.0 %	GoM (FLUID)	=	8.096 M
DISPLACEMENT	=	15998.1 T	③ KGo ACTUAL (FLUID)	=	13.200 M
② DRAUGHT AT LCF	=	3.871 M	TRIM (DIS*A)/(MTC*100)	=	4.560 M
LCB FROM A.P	=	118.416 M	FREE SURF. MOM.	=	0 T-M
LCG FROM A.P	=	103.228 M	M.T.C.	=	532.8 T-M
TRIM LEVER : A	=	15.188 M	LCF FROM A.P	=	119.110 M

② $Trim\ \ Lever\ = LCB - LCG = 118.416 - 103.228 = 15.188\,[m]$

③ $Trim\ [m] = \dfrac{\Delta \times Trim\ \ Lever}{MTC \times 100} = \dfrac{15998.1 \times 15.188}{532.8 \times 100} = 4.560\,[m]$

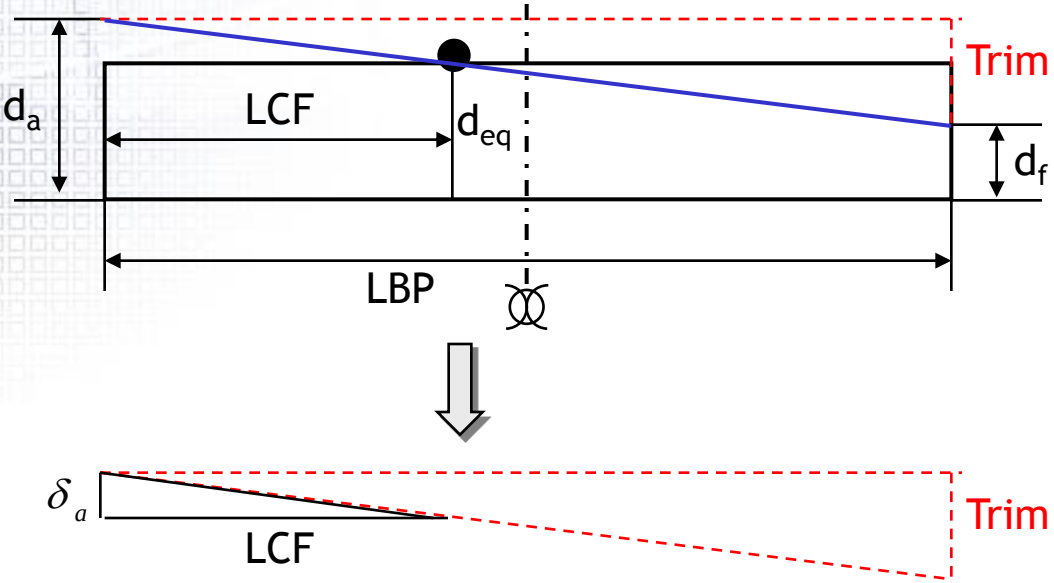


Loading Conditions Example (I) – Lightship condition

④

DRAUGHT F.P	=	1.526 M	K.M.T	=	21.296 M
DRAUGHT MIDSHIP	=	3.806 M	KG (SOLID)	=	13.200 M
DRAUGHT A.P	=	6.086 M	GM (SOLID)	=	8.096 M
TRIM BY STERN	=	4.560 M	FREE SURF. CORR.(GGo)	=	.000 M
PROPELLER I/D	=	74.0 %	GoM (FLUID)	=	8.096 M
DISPLACEMENT	=	15998.1 T	KGo ACTUAL (FLUID)	=	13.200 M
DRAUGHT AT LCF	=	3.871 M	TRIM (DIS*A)/(MTC*100)	=	4.560 M
LCB FROM A.P	=	118.416 M	FREE SURF. MOM.	=	0 T-M
LCG FROM A.P	=	103.228 M	M.T.C.	=	532.8 T-M
TRIM LEVER : A	=	15.188 M	LCF FROM A.P	=	119.110 M

④



$$LBP : Trim = LCF : \delta_a$$

$$\delta_a = \frac{LCF}{LBP} \times Trim$$

$$d_a = d_{eq} + \delta_a = d_{eq} + \frac{LCF}{LBP} \times Trim$$

$$= 3.871 + \frac{119.110}{245.24} \times 4.560$$

$$= 6.086\,[m]$$

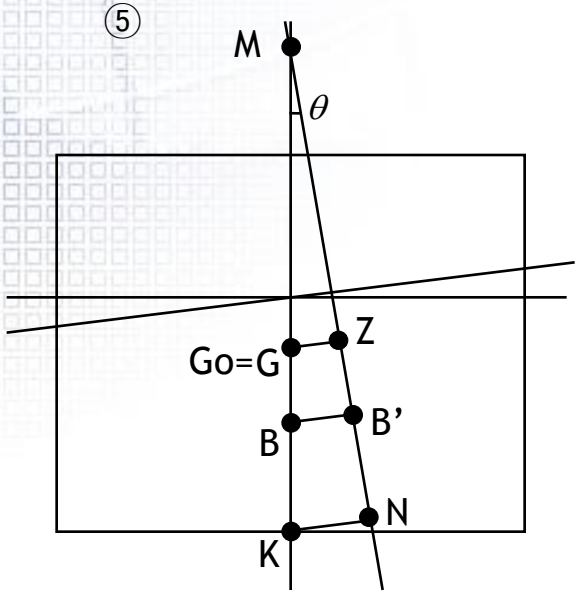
$$d_f = d_a - Trim$$

$$= 6.086 - 4.560 = 1.526\,[m]$$

Loading Conditions Example (I) – Lightship condition

DRAUGHT F.P	=	1.526 M	⑤ K.M.T	=	21.296 M
DRAUGHT MIDSHIP	=	3.806 M	KG (SOLID)	=	13.200 M
DRAUGHT A.P	=	6.086 M	GM (SOLID)	=	8.096 M
TRIM BY STERN	=	4.560 M	FREE SURF. CORR.(GGo)	=	.000 M
PROPELLER I/D	=	74.0 %	GoM (FLUID)	=	8.096 M
DISPLACEMENT	=	15998.1 T	KGo ACTUAL (FLUID)	=	13.200 M
DRAUGHT AT LCF	=	3.871 M	TRIM (DIS*A)/(MTC*100)	=	4.560 M
LCB FROM A.P	=	118.416 M	FREE SURF. MOM.	=	0 T-M
LCG FROM A.P	=	103.228 M	M.T.C.	=	532.8 T-M
TRIM LEVER : A	=	15.188 M	LCF FROM A.P	=	119.110 M

⑤



KMT : Hydrostatics table**로 부터 얻음** (KMT = 21.296 [m])

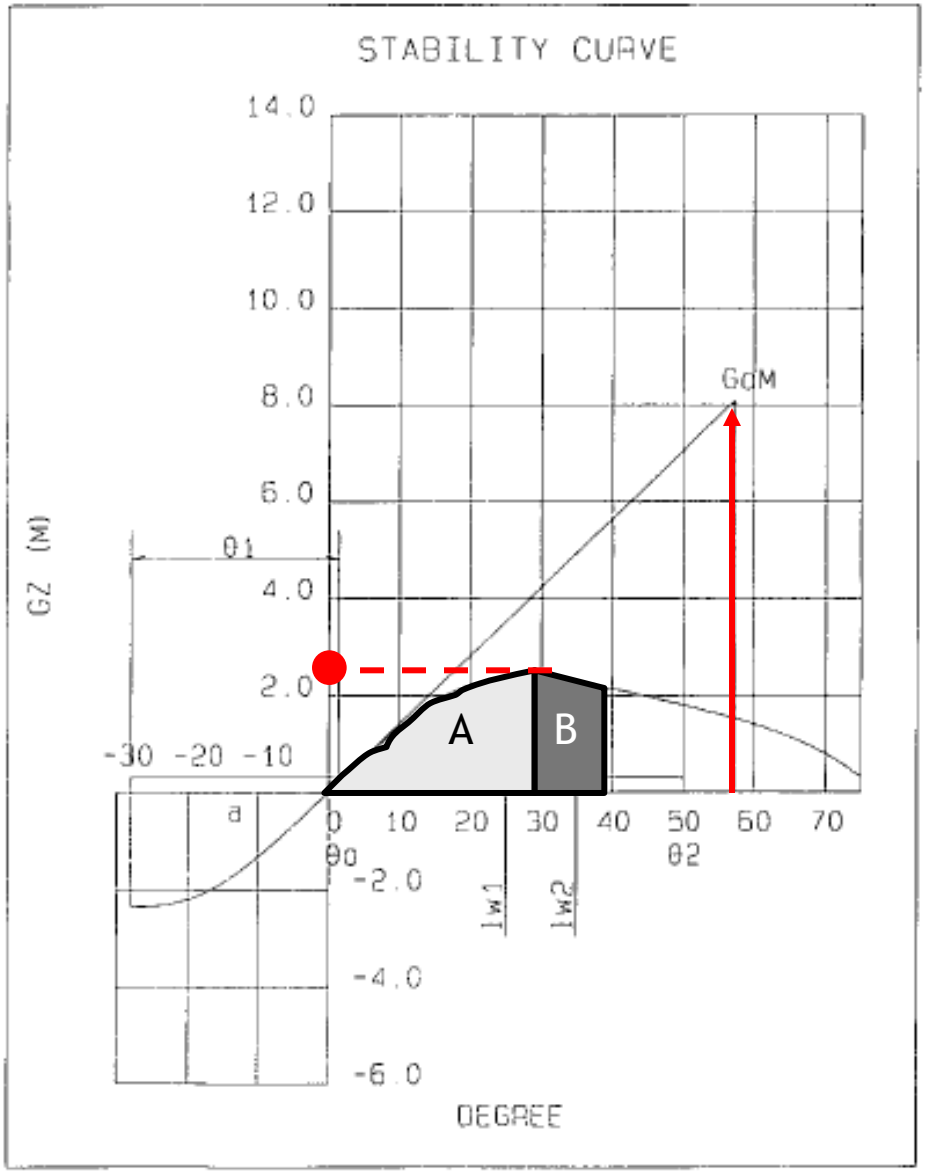
KG : LWT**와** DWT**의 분포로 부터 얻음** (KG = 13.2 [m])

GM = KMT – KG (GM = 21.296 – 13.2 = 8.096 [m])

GGo = 0 (∵ Lightship condition**이므로 액체 화물 없음**)

∴ KGo = KG = 13.2

Loading Conditions Example (I) – Lightship condition



IMO A-749(18) CHAP.3.1 CRITERION

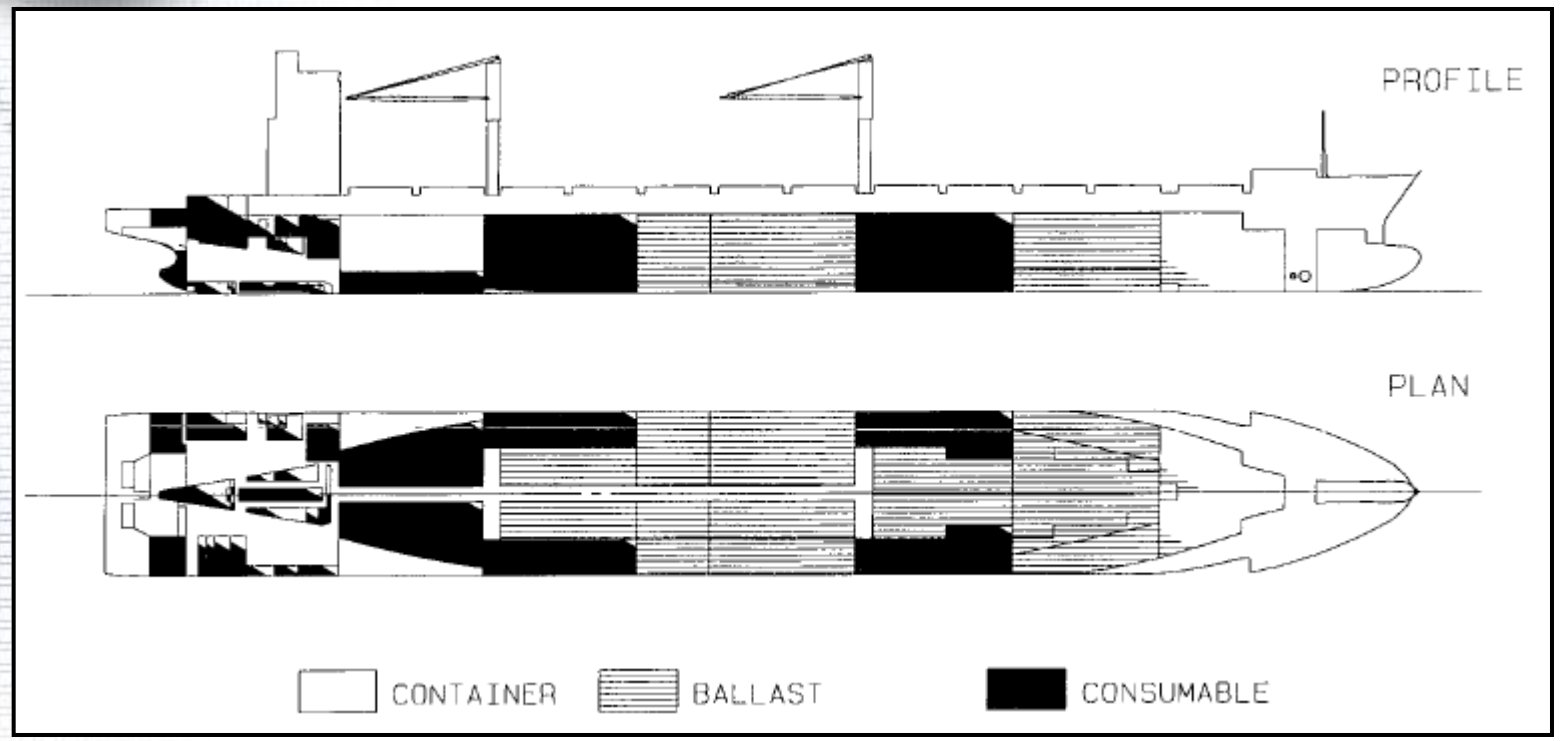
	ACTUAL	REQ.	
MIN. GoM	8.096	0.150	M
AREA 0-30	.849	0.055	M-RAD
AREA 0-40(θf)	1.236	0.090	M-RAD
AREA 30-40(θf)	.387	0.030	M-RAD
MAX. GZ	2.352	0.200	M
MAX. GZ OCCURS AT	27.2	25.00	DEG.
FLOODING ANGLE IS	90.0		DEG.

IMO A-749(18) CHAP.3.2 CRITERION

WIND AREA				4849	M^2
Z	=			13.017	M
ROLLING PERIOD				10.4	SEC.
AREA a	=	.914	b =	1.323	M-RAD
lw1	=	.203	lw2 =	.304	M
θo	=	1.4	θ1 =	29.3	DEG.
θ2	=	50.0	θc =	75.1	DEG.

Loading Conditions Example (II) – Ballast Departure Condition

- Ballast Departure condition : Ballast Tank 및 운항에 필요한 Consumable 화물을 실은 상태



Loading Conditions Example (II) – Ballast Departure Condition

DRAUGHT F.P	=	5.553 M	K.M.T	=	15.728 M
DRAUGHT MIDSHIP	=	6.998 M	KG (SOLID)	=	9.584 M
DRAUGHT A.P	=	8.443 M	GM (SOLID)	=	6.144 M
TRIM BY STERN	=	2.890 M	FREE SURF. CORR. (GGo)	=	.177 M
PROPELLER I/D	=	105.1 %	GoM (FLUID)	=	5.967 M
DISPLACEMENT	=	32980.1 T	KGo ACTUAL (FLUID)	=	9.761 M
DRAUGHT AT LCF	=	7.044 M	TRIM (DIS*A)/(MTC*100)	=	2.890 M
LCB FROM A.P	=	118.910 M	① FREE SURF. MOM.	=	5847 T-M
LCG FROM A.P	=	113.116 M	M.T.C.	=	661.3 T-M
TRIM LEVER : A	=	5.794 M	LCF FROM A.P	=	118.707 M

① Hydrostatics table의 결과 사용

DRAFT (M)	DISP MLD(M3)	DISP EXT(T)	VCB (M)	LCB (M)	LCF (M)	KMT (M)	KML (M)	MTC (T-M)	TPC (TON)	WSA (M2)	C B	C W	C P	C M
7.00	31782.0	32730.5	3.802	118.912	118.753	15.763	498.01	659.6	56.4	7422.2	.5770	.6945	.5976	.9655
7.05	32056.1	33012.2	3.829	118.910	118.701	15.724	495.22	661.5	56.5	7450.0	.5779	.6956	.5983	.9658
7.10	32332.2	33296.0	3.858	118.907	118.639	15.686	492.45	663.4	56.5	7478.0	.5787	.6966	.5991	.9660
7.15	32608.3	33579.8	3.886	118.903	118.577	15.649	489.74	665.3	56.6	7506.0	.5796	.6977	.5998	.9662
7.20	32884.4	33863.6	3.914	118.900	118.516	15.613	487.07	667.2	56.7	7534.1	.5804	.6987	.6005	.9665

선형 보간 하면, draft at LCF =7.044에서 $VCB\ (= KB) = 3.826\,[m],\ KML = 495.55\,[m]$

$$\left(BM_L = KML - KB = 495.55 - 3.826 = 491.724\right)$$

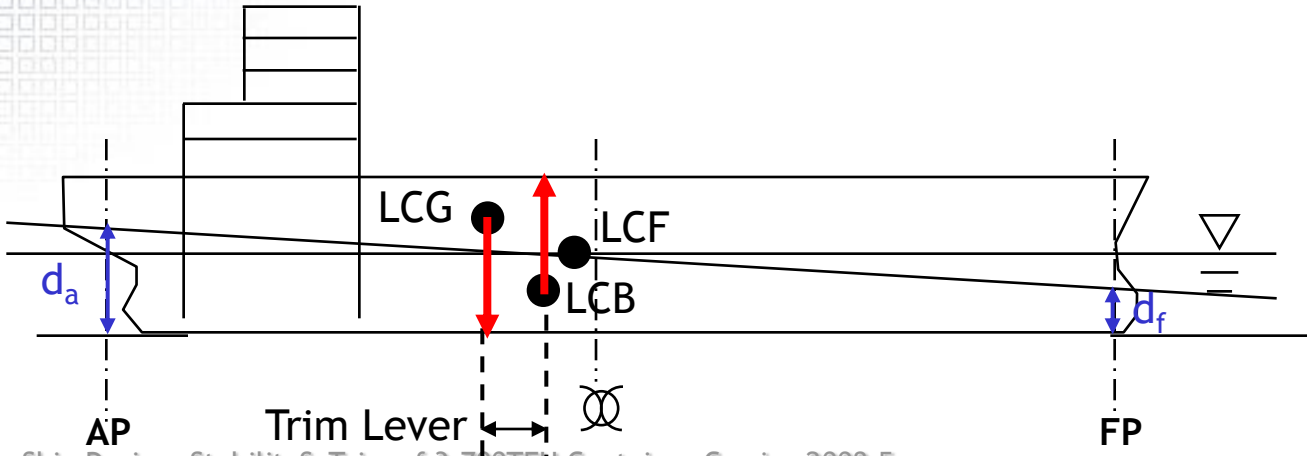
$$MTC = \frac{\Delta \times GM_L}{100 \times LBP} \approx \frac{\Delta \times BM_L}{100 \times LBP} = \frac{32980.1 \times 491.724}{100 \times 245.24} = 661.3\,[T-m]$$

Loading Conditions Example (III) – Ballast Departure Condition

DRAUGHT F.P	=	5.553 M	K.M.T	=	15.728 M
DRAUGHT MIDSHIP	=	6.998 M	KG (SOLID)	=	9.584 M
DRAUGHT A.P	=	8.443 M	GM (SOLID)	=	6.144 M
TRIM BY STERN	=	2.890 M	FREE SURF. CORR.(GGo)	=	.177 M
PROPELLER I/D	=	105.1 %	GoM (FLUID)	=	5.967 M
DISPLACEMENT	=	32980.1 T	③ KGo ACTUAL (FLUID)	=	9.761 M
② DRAUGHT AT LCF	=	7.044 M	TRIM (DIS*A)/(MTC*100)	=	2.890 M
LCB FROM A.P	=	118.910 M	FREE SURF. MOM.	=	5847 T-M
LCG FROM A.P	=	113.116 M	M.T.C.	=	661.3 T-M
TRIM LEVER : A	=	5.794 M	LCF FROM A.P	=	118.707 M

② $Trim\ \ Lever\ = LCB - LCG = 118.910 - 113.116 = 5.794\,[m]$

③ $Trim\ [m] = \dfrac{\Delta \times Trim\ \ Lever}{MTC \times 100} = \dfrac{32980.1 \times 5.794}{661.3 \times 100} = 2.890\,[m]$

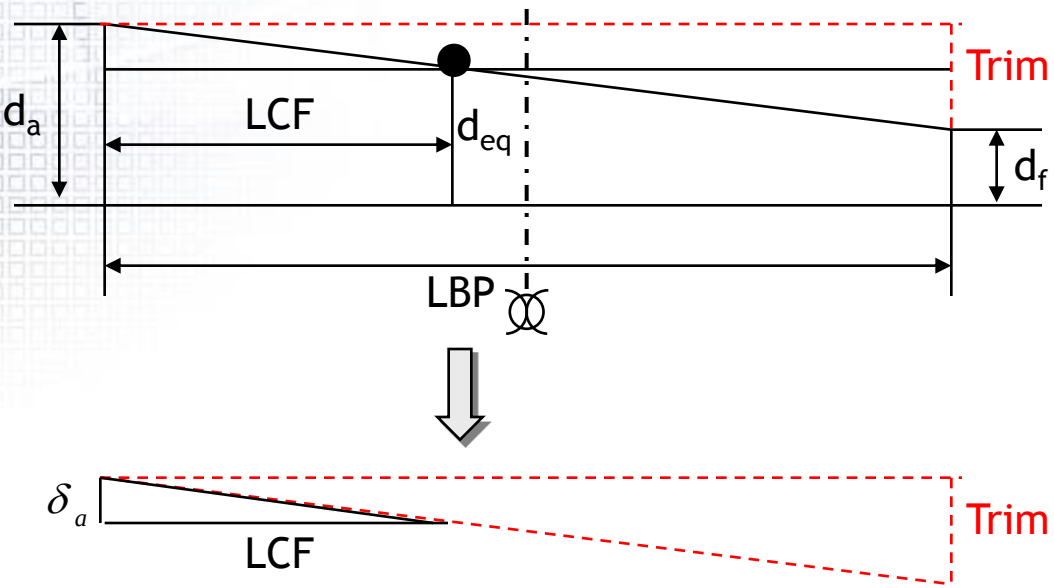


Loading Conditions Example (III) – Ballast Departure Condition

④

DRAUGHT F.P	=	5.553 M	K.M.T	=	15.728 M
DRAUGHT MIDSHIP	=	6.998 M	KG (SOLID)	=	9.584 M
DRAUGHT A.P	=	8.443 M	GM (SOLID)	=	6.144 M
TRIM BY STERN	=	2.890 M	FREE SURF. CORR.(GGo)	=	.177 M
PROPELLER I/D	=	105.1 %	GoM (FLUID)	=	5.967 M
DISPLACEMENT	=	32980.1 T	KGo ACTUAL (FLUID)	=	9.761 M
DRAUGHT AT LCF	=	7.044 M	TRIM (DIS*A)/(MTC*100)	=	2.890 M
LCB FROM A.P	=	118.910 M	FREE SURF. MOM.	=	5847 T-M
LCG FROM A.P	=	113.116 M	M.T.C.	=	661.3 T-M
TRIM LEVER : A	=	5.794 M	LCF FROM A.P	=	118.707 M

④



$$LBP : Trim = LCF : \delta_a$$

$$\delta_a = \frac{LCF}{LBP} \times Trim$$

$$d_a = d_{eq} + \delta_a = d_{eq} + \frac{LCF}{LBP} \times Trim$$

$$= 7.044 + \frac{118.707}{245.24} \times 2.890$$

$$= 8.443\,[m]$$

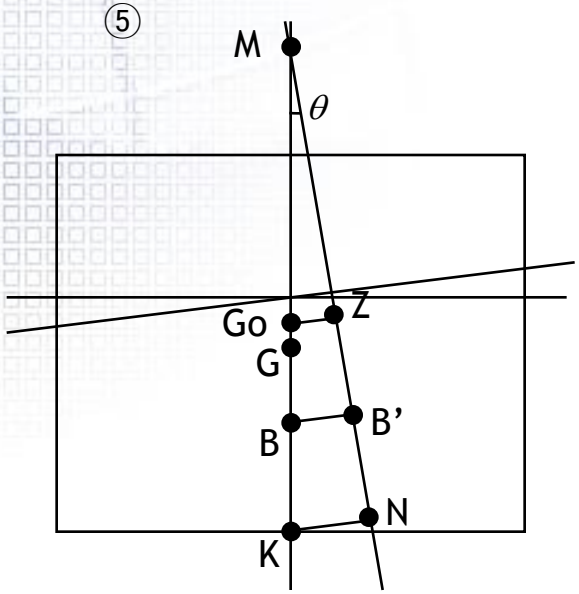
$$d_f = d_a - Trim$$

$$= 8.443 - 2.890 = 5.553\,[m]$$

Loading Conditions Example (II) – Ballast Departure Condition

DRAUGHT F.P	=	5.553 M	⑤	K.M.T	=	15.728 M
DRAUGHT MIDSHIP	=	6.998 M		KG (SOLID)	=	9.584 M
DRAUGHT A.P	=	8.443 M		GM (SOLID)	=	6.144 M
TRIM BY STERN	=	2.890 M		FREE SURF. CORR.(GGo)	=	.177 M
PROPELLER I/D	=	105.1 %		GoM (FLUID)	=	5.967 M
DISPLACEMENT	=	32980.1 T		KGo ACTUAL (FLUID)	=	9.761 M
DRAUGHT AT LCF	=	7.044 M		TRIM (DIS*A)/(MTC*100)	=	2.890 M
LCB FROM A.P	=	118.910 M		FREE SURF. MOM.	=	5847 T-M
LCG FROM A.P	=	113.116 M		M.T.C.	=	661.3 T-M
TRIM LEVER : A	=	5.794 M		LCF FROM A.P	=	118.707 M

⑤



KMT : Hydrostatics table**로 부터 얻음** (KMT = 15.728 [m])

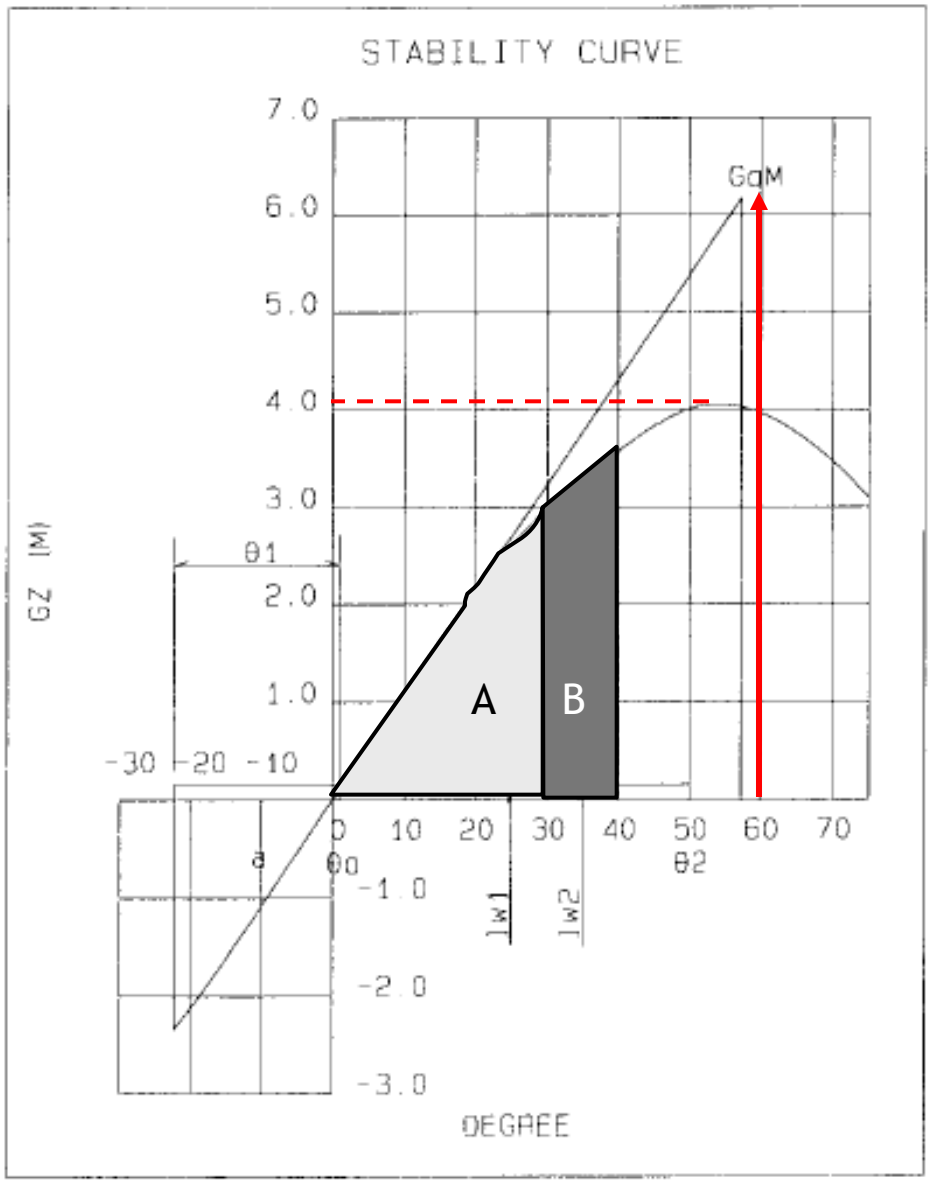
KG : LWT**와** DWT**의 분포로 부터 얻음** (KG = 9.584 [m])

GM = KMT – KG (GM = 15.728 – 9.584 = 6.144 [m])

GGo = 0.177

∴ KGo = KG + GGo = 5.967 [m]

Loading Conditions Example (III) – Ballast Departure Condition



IMO A-749(18) CHAP.3.1 CRITERION

	ACTUAL	REQ.	
MIN. GoM	6.177	0.150	M
AREA 0-30	.827	0.055	M-RAD
AREA 0-40(θf)	1.404	0.090	M-RAD
AREA 30-40(θf)	.577	0.030	M-RAD
MAX. GZ	4.056	0.200	M
MAX. GZ OCCURS AT	54.1	25.00	DEG.
FLOODING ANGLE IS	77.0		DEG.

IMO A-749(18) CHAP.3.2 CRITERION

WIND AREA				4283	M^2
Z	=			13.173	M
ROLLING PERIOD				10.1	SEC.
AREA a	=	.525	b =	1.935	M-RAD
lw1	=	.103	lw2 =	.155	M
θo	=	1.0	θ1 =	23.2	DEG.
θ2	=	50.0	θc =	90.0	DEG.