Annex A

Bill of Lading for *Swanland*, 26 November 2011

CEMEX UK Materials Ltd – North West

Bags Marks & Numbers

ORIGINAL
BILL OF LADING
(Charter Party)

SHIPPED in good order and condition by **CEMEX UK Materials Ltd - North West** in and upon the good ship or vessel called the **SWANLAND** where of Y. SHMELEV is Master for the present voyage and now lying in the port of **LLANDDULAS** and bound for **COWES (IOW)** with liberty to sail without Pilots, to call at any ports in any order for bunkering or other purposes, or to make trial trips after notice, or adjust compasses, all as part of the contract voyage.

LIMESTONE IN BULK

being marked and numbered as per margin, and to be delivered in the like good order and condition at the said port of **COWES** unto **ISLE OF WIGHT AGGREGATES** or to his or their assigns Freight being paid for the same as per Charter Party dated.....AS AGREED.....2007 All the terms, conditions and exception contained in which Charter Party are herewith incorporated.

General Average (if any) shall be settled according to the York-Antwerp Rules 1950.
Salvage shall be for the Shipowners benefit.
Cargo, which is stated herein as being carried on deck, and is so carried, is carried at the risk of the owners of the Cargo.

Type 1

2730 Tonnes

All the terms, provisions and conditions of the Carriage of Goods by Sea Act, 1924, and the Schedule thereto, are to apply to the contract contained in this Bill of Lading, and the Carriers are to be entitled to the benefits of all privileges, rights and immunities contained in such Act, and the Schedule thereto, as if the same were herein specifically set out. If or to the extent that any term of this Bill of Lading is repugnant to or inconsistent with anything in such Act or Schedule it shall be void.

IN WITNESS whereof the Master or Agents of the said Vessel hath signed **three** Bills of Lading all of this tenor and date, any one of which being accomplished the others shall be void.

Dated in **RAYNES JETTY** 26-11-11
Shipped Weight, Contents and Quality unknown

M.V. SWANLAND OFF. NO. 1367 AVATIU

....Master

Annex B

Extracts of the Meteorological Offices Marine Weather Legal Report Vessel: MV *Swanland*

Met Office

Marine Weather Legal Report
Vessel: MV SWANLAND

Location: Irish Sea; west of Lleyn Peninsula

Dates: 27th November 2011

For M.A.I.B
(Marine Accident investigation Branch)

Author: [redacted] (Senior Marine Weather Consultant)
Met Office reference: msc/11/DEC/051

Contents

1. TERMS OF ENGAGEMENT

1.1 To provide a legal marine weather hindcast for the vessel MV SWANLAND on the 27th November 2011. The tabulated data hindcast applies to a grid point closest to the location of interest, please see map in Figure 4.1. The hindcast was ordered by [redacted] of MAIB, Mountbatten House, Grosvenor Square, Southampton SO15 2JU in [redacted] email of 2nd December 2011.

2. CONTENTS OF REPORT

2.1 In section 4, maps of the location of interest is presented. In Fig 4.1 the location of interest is plotted relative to the Buoys and RAF Valley and Aberdaron. In Fig 4.2 the L.O.I. is plotted in bright red against the NAE wave model grid array. The nearest point (52.81°N 005.16°W) has been used as a basis for the hindcast. For reference, in section 5, modelled wind and wave data is presented in Table 5.1 at 1 hourly GMT positions with respect to the L.O.I. Available ship / buoy observations are presented in Table 52 to 5.7.

2.2 Weather data are collected and exchanged internationally according to universal Time Co-ordinated (UTC) convention. Unless otherwise stated, the times referred to in this report are UTC, which is Greenwich Mean Time (GMT).

3. DATA AND INFORMATION SOURCES

3.1 Marine hindcast data from the Met Office computer wave model archive
3.2 Ship / buoy observations from the Met Office marine data base.
3.3 Buoy 62019 report from Met Eireann
3.4 Synoptic weather charts from Met Office FRASIA archive
3.5 Analysis charts from Met Office Atmospheric Dispersion archive
3.6 Rainfall radar charts from Met Office Radar Archive
3.6 ASCAT data from NOAA NESDIS
3.7 Met Office; Forecaster's Reference book, 1997

4. POINTS TO NOTE

4.1 The tables provide an indication of the general wind and sea states over open waters. Without local knowledge, it is not always possible to estimate the effects of shelter or enhancement due to coastal topographical features.

4.2 The strength of the wind may have increased locally in shower or thunderstorm activity to above that given in the assessment. This would have been only a temporary increase above the assessed values. Over the sea, gusts can be expected to be around 1.4 times the assessed strength of the mean wind, so mean winds of gale force (34-40 knots) could be accompanied by gusts of around 48-56 knots.

4.3 The wave heights (crest to trough) given in the assessment are defined as the average of the highest third of all waves within the wave train, also known as the significant wave height and in this case the resultant wave height. The resultant wave height is the total obtained from the individual wave and swell components. It is considered to be the equivalent of the significant wave height that would be measured by a wave recorder, to which it is also accepted that visual observations of wave height approximate. Naturally individual wave heights will vary around these average conditions and the maximum wave height may be around two times the quoted significant wave height. There may be further variations in these heights close to the coast due to tidal and shallow water effects.

4.5 When the significant wave height is discussed using descriptive terminology, the term sea state is often used. Refer to appendix A to see the WMO Sea State scale (WMO stands for the World Meteorological Organisation).

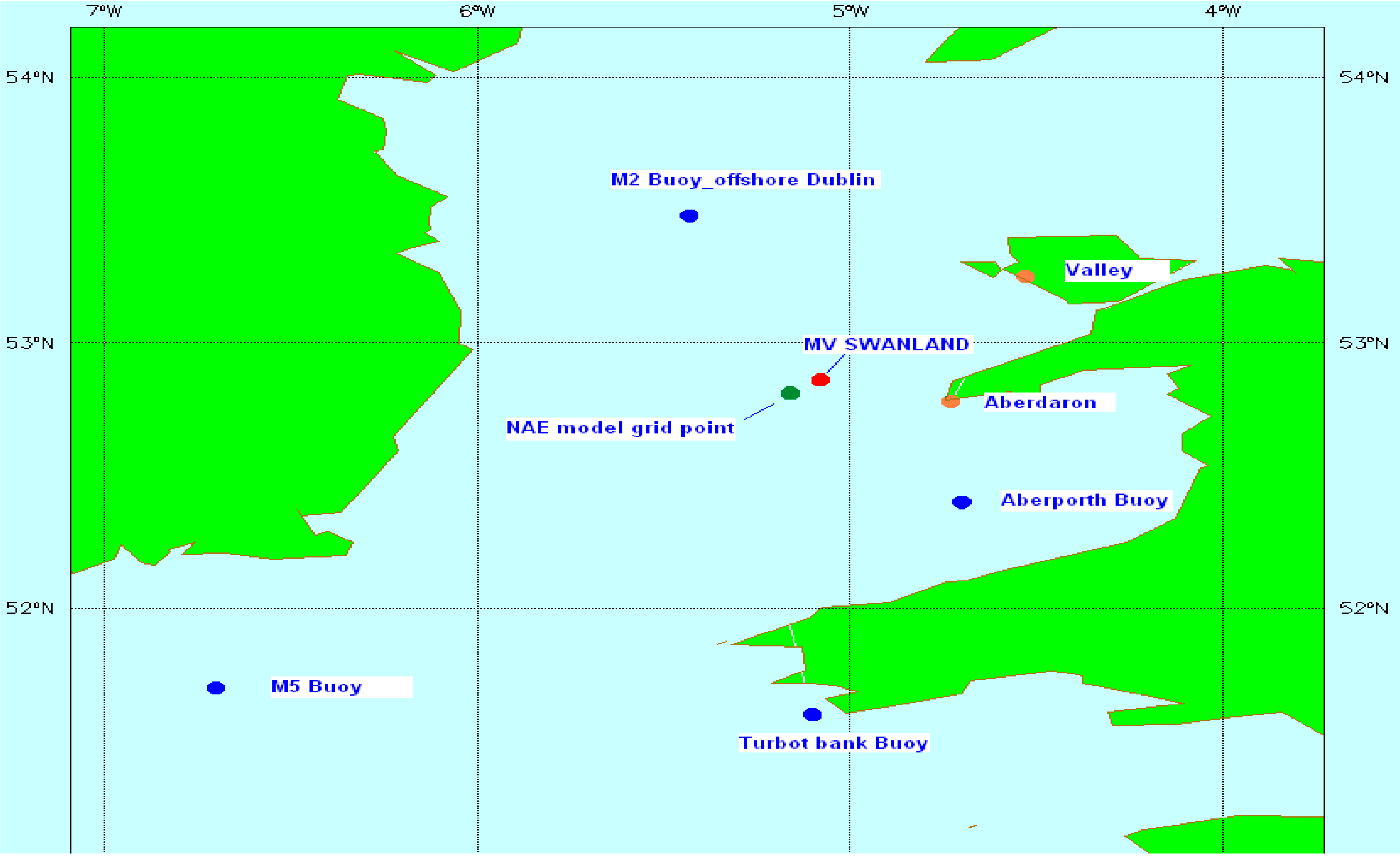
4.6 Wind waves, often called “sea”, are generated by the local winds blowing over the surface of the ocean.

4.7 Swell represents wind waves that have either travelled out of the area in which they were generated, or can no longer be sustained by the winds in the generating area. The direction is that from which the swell is running. It is possible that there may be swells from one or more than one direction

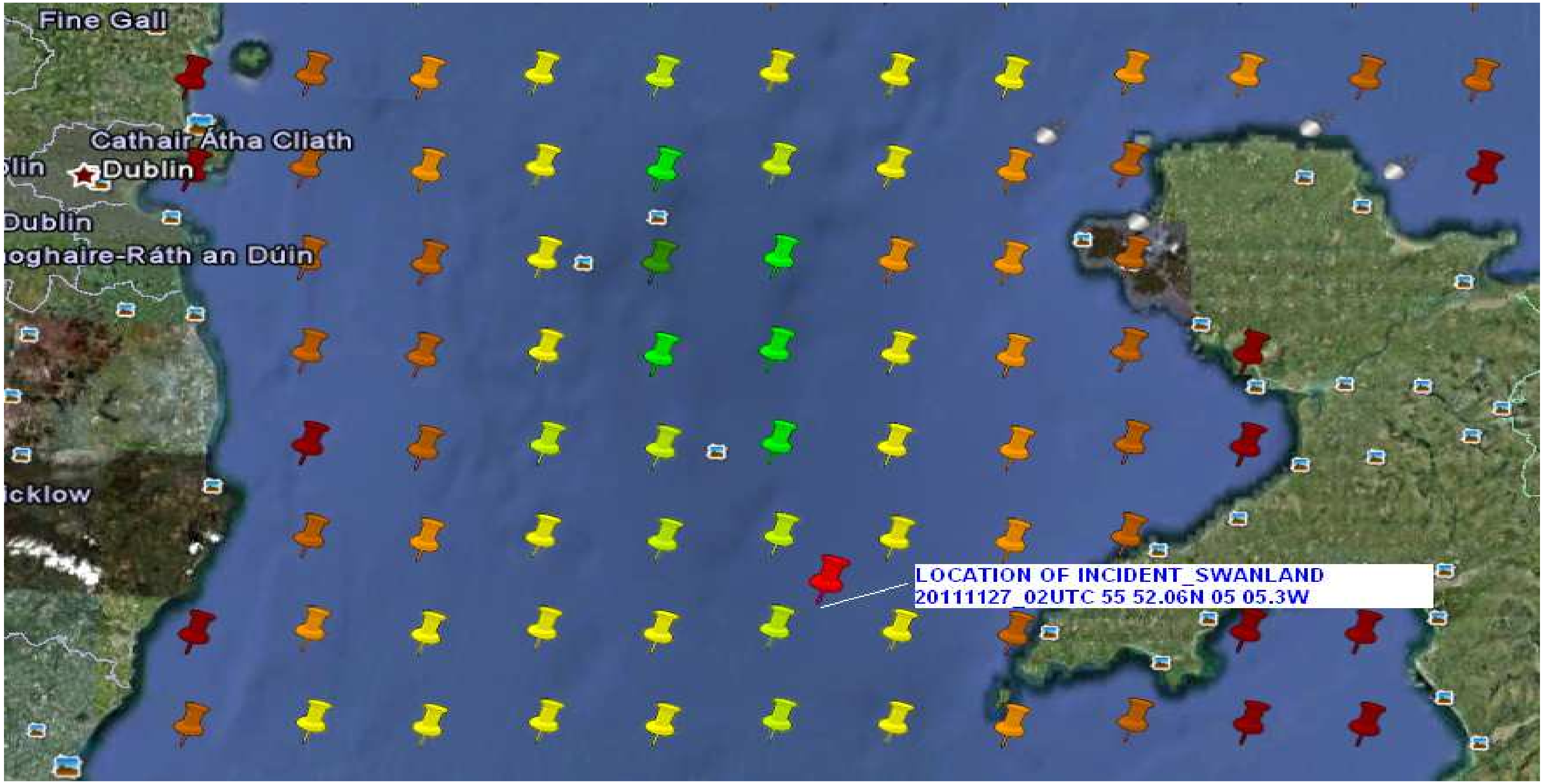
4.8 Resultant wave height can be considered as the combination of wind wave and swell wave. When two or more wave trains are combined, the resultant wave height is determined from the square root of the sum of the squares of the heights of the separate trains. This is because wave energy is proportional to the square of the wave height and it is the energy which is additive.

4.9 Wavelength λ is calculated from the relationship: λ = 1.56 * Tp^2, where Tp is peak period. Peak period is defined as the period of the wave within the wave spectrum at any marine location which contains the most energy. Two wave trains can combine (i.e wind wave and swell wave) to give a bi modal sea with two peak frequencies.
In Table 5.1 peak period is modelled for wind sea (Tp_{ww}) and swell wave (Tp_{sww}) irrespective of their relative magnitudes. Tp is also modelled for the total wave spectrum and can be found in the column to the right of significant wave descriptor. Wavelengths have been calculated from peak period of wind wave and swell wave, see table 5.1.
Since, at the time and location of the incident, most of the wave energy is comprised of wind wave, Tp of significant wave height and wind wave height are similar. As a result the wavelength of wind wave is considered most appropriate.

Fig 4.1 **Map showing relative locations of MV SWANLAND (52.86°N 005.08°W: red dot) NAE model point and observation sites (buoys/ land)**



Map showing the location MV SWANLAND (red peg) on 27th November 2011 and adjacent NAE model grid point array (Courtesy of Google Maps) . The lime green point (52.81°N 005.15°W) to the southwest has been used as a basis for the hindcast.



5. TABLE OF WEATHER CONDITIONS

TABULATED DATA OF WINDS / SIGNIFICANT WAVE HEIGHT from the Met Office UK wave model is presented in the tables starting 5.1
`BF = Beaufort Force; for other terminology, see Appendix A

5.1 **General situation (see charts sequence in Appendix C and D)**

A deep depression, 977 Hpa was analysed at 59°N 15°W at 1800 UTC on the 26th November 2011. The depression deepened to 970 Hpa as it moved eastwards and was centred near 60° North 09° west at 0000 UTC beginning the 27th November. Further deepening occurred as the depression tracked eastwards; a central pressure of 967 Hpa was analysed at 61°N 00°W (on the Greenwich meridian).

A warm sector covered the Irish Sea during the time of interest. SW surface winds attained gale force with higher gusts. A cold front cleared the location of interest from the northwest between 0300 and 0330 UTC, see radar rainfall sequence in appendix C and hourly sequence of synoptic weather charts in appendix B. Thereafter winds veered to the west-southwest and decreased force 7.

Table 5.1
Marine Weather: table of wind and seas

NAE model point: 52.81N 005.16W model depth 86m (interpolated sig wave from model charts 00-06)

BF=Beaufort force / Tp = peak period, either of sig wave, wind wave or swell

Date	Time		Location		Wind			Sig Wave (model)			Wind Wave (model)				Swell Wave (model)				Current 52 48 36.0N 05 09 35.0W	
2011			°N	°W	dir	10 metres	BF	height	Descriptive	Tp	h	Wave length λ	Tp_{ww}	dir	h	Wave length λ	Tp_{sww}	dir	dir going to	speed
	UTC	local			°true	knots		m		s	m	m	s	°true	m	m	s	°true	°true	knots
26/11	18		52.81	05.16	222	31	7	3.1	Rough	7.6	3.1	90	7.6	221	0.1	165	10.3	211	158	0.16
	19		52.81	05.16	221	33	7	3.2	Rough	7.7	3.2	90	7.7	220	0.1	198	11.3	244	010	1.19
	20		52.81	05.16	225	33	7	3.2	Rough	7.7	3.2	92	7.7	220	0.1	143	9.6	166	006	2.24
	21		52.81	05.16	226	33	7	3.3	Rough	7.8	3.3	94	7.8	221	0.1	147	9.7	163	004	2.66
	22		52.81	05.16	225	35	GF8	3.4	Rough	7.8	3.4	94	7.8	221	0.1	167	10.4	167	002	2.39
	23		52.81	05.16	225	36	GF8	3.5	Rough	7.8	3.5	95	7.8	221	0.1	168	10.4	166	358	1.52
27/11	00		52.81	05.16	224	38	GF8	3.6	Rough	7.9	3.6	97	7.9	221	0.1	196	11.2	206	327	0.39
	01		52.81	05.16	223	37	GF8	3.9	Rough	8.1	3.9	100	8.1	221	0.1	197	11.2	213	201	0.99
	02		52.81	05.16	226	37	GF8	4.0	Rough	8.2	4.0	105	8.2	220	0.1	171	10.5	164	193	1.98
	03		52.81	05.16	230	37	GF8	3.9	Rough	8.3	3.9	106	8.3	221	0.2	158	10.1	158	190	2.49
	04		52.81	05.16	249	33	7	3.8	Rough	8.4	3.7	109	8.4	224	0.7	195	11.2	179	189	2.33
	05		52.81	05.16	267	31	7	3.5	Rough	8.5	3.2	111	8.5	231	1.4	166	10.3	195	187	1.63
	06		52.81	05.16	286	31	7	3.2	Rough	8.5	2.4	106	8.3	242	2.1	139	9.4	208	180	0.51

Fig 5.1

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Aberporth Buoy 62301 (52 4N 04 7W)

Yellow = Buoy: measured (winds at 3 m). Red = Model (winds at 10 m)

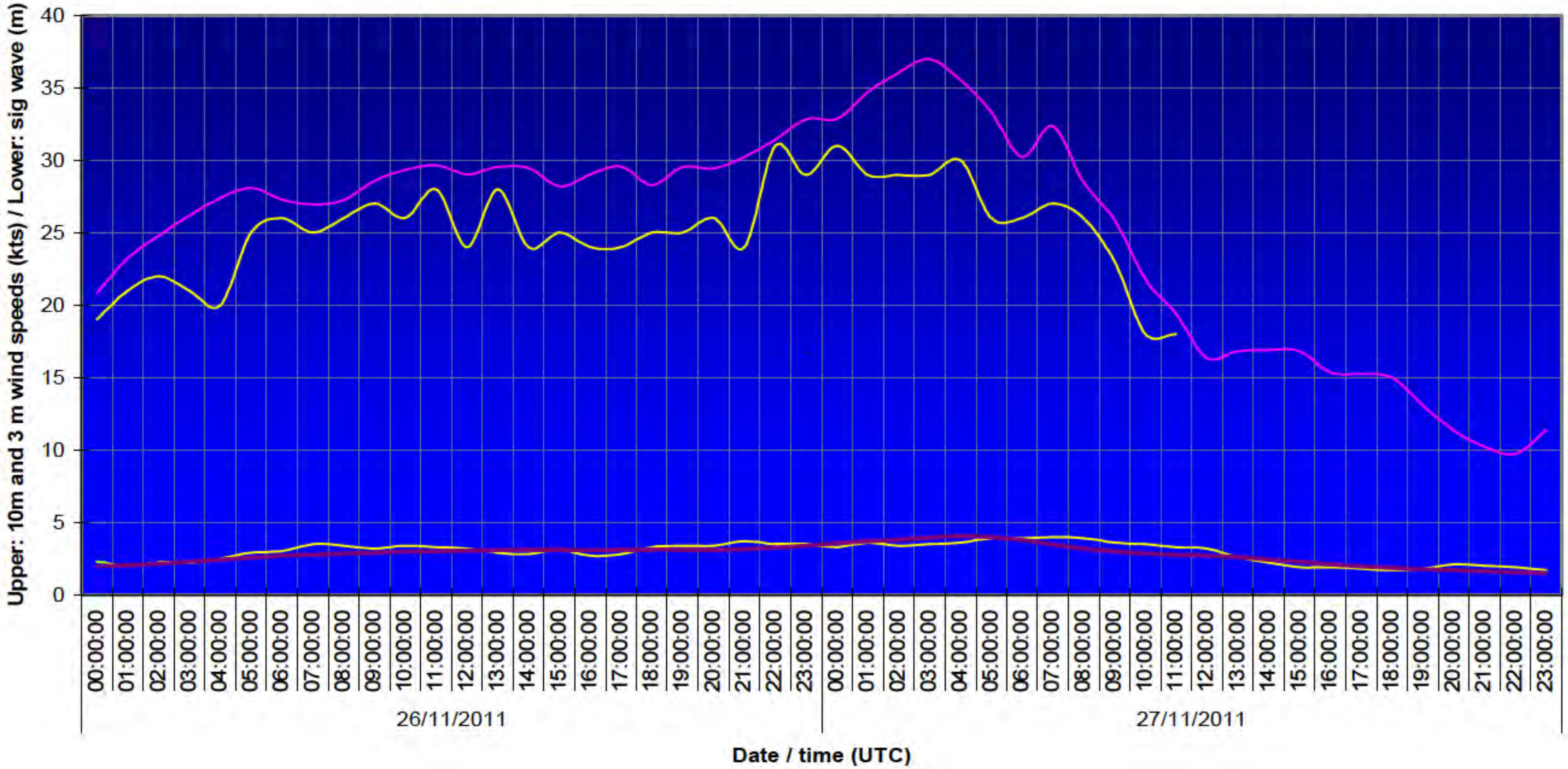


Fig 5.2

M2 Buoy (offshore Dublin 62091 (53.48N 005.43W)
Yellow = Buoy:measured (winds at 3.5m). Red = Model (winds at 10m)

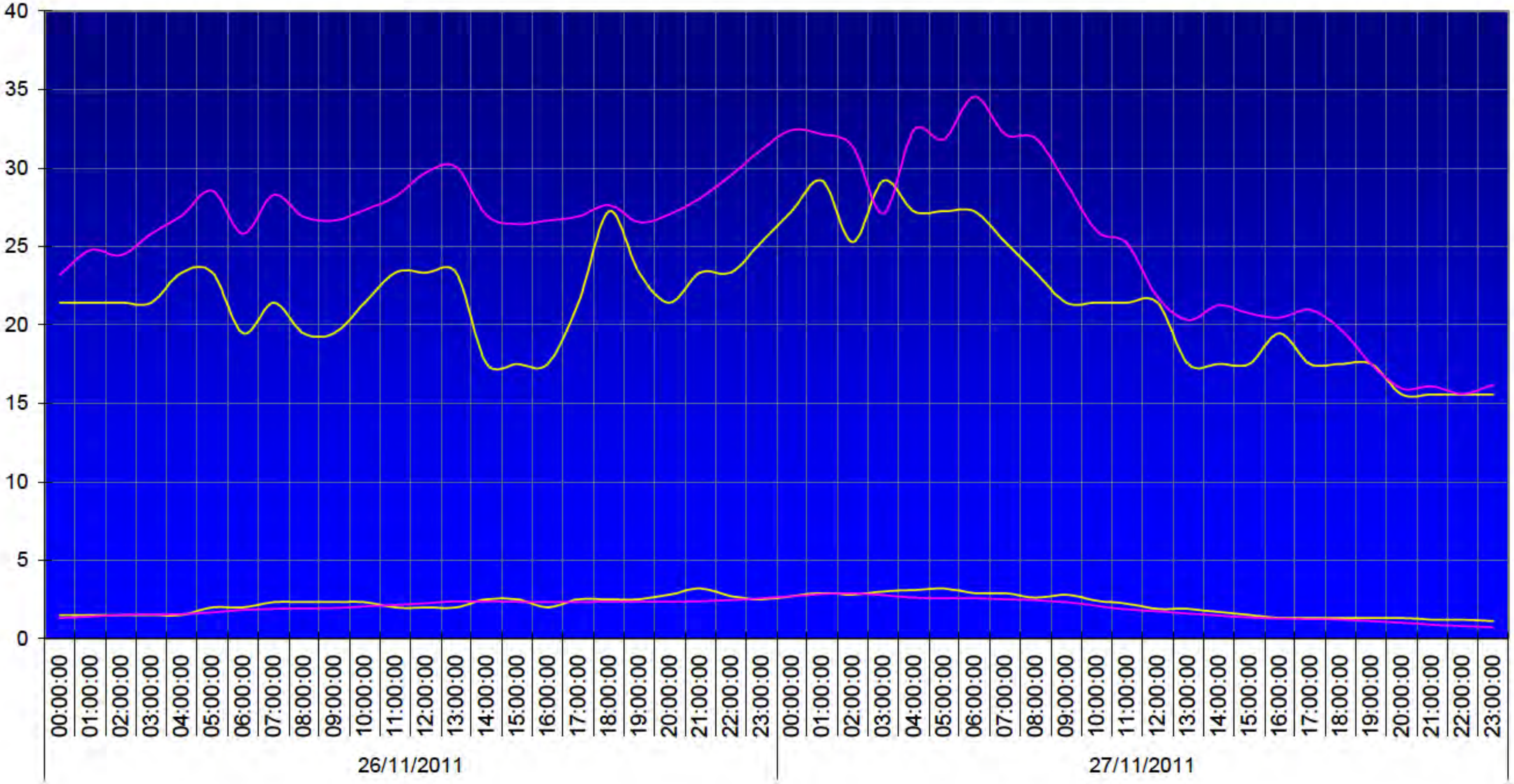


Table 5.2
Buoy data

Location: Offshore Dublin (M2) 62091 53.48N 05.43W								
Date	Month	Time UTC	Wind Direction	Wind speed	Wind gust	Measured wave height	Measured wave period	Max wave height
			°true	kts	kts	metres	seconds	metres
	Month	Time UTC	Wind Direction	Wind speed	Wind gust	Measured wave height	Measured wave period	
			°true	kts	kts	metres	seconds	
26	11	18	212	28	35	2.5	6	3.9
		19	211	23	29	2.5	6	3.2
		20	202	22	27	2.8	6	4.8
		21	211	23	31	3.2	6	4.3
		22	212	24	31	2.7	5	3.8
		23	214	25	33	2.5	5	4.1
27	11	00	215	27	36	2.7	5	3.8
		01	215	28	36	2.9	6	4.1
		02	215	25	32	2.8	6	4.0
		03	267	29	42	3.0	7	3.7
		04	273	26	38	3.1	6	4.4
		05	285	27	42	3.2	6	4.6
		06	290	28	38	2.8	6	3.9

Table 5.3
Buoy data

Location: Offshore Aberporth 62301 52.40N 04.70W							
Date	Month	Time UTC	Wind Direction	Wind speed	Wind gust	Measured wave height	Measured wave period
			°true	kts	kts	metres	seconds
26	11	18	220	25	33	3.3	6
		19	220	25	41	3.4	6
		20	220	26	41	3.4	6
		21	220	24	36	3.7	6
		22	220	31	48	3.5	6
		23	230	29	39	3.5	6
27	11	00	230	31	46	3.3	6
		01	220	29	45	3.6	7
		02	220	29	45	3.4	7
		03	220	29	41	3.5	7
		04	230	30	41	3.6	7
		05	260	26	47	3.9	7
		06	270	26	36	3.9	7

Table 5.4
Buoy data

Location: Offshore Cork (M5) 62094 51.69N 06.70W							
Date	Month	Time UTC	Wind Direction	Wind speed	Wind gust	Measured wave height	Measured wave period
			°true	kts	kts	metres	seconds
26	11	18	220	23	32	3.6	6
		19	220	25	34	3.5	6
		20	220	27	36	3.5	6
		21	220	24	33	3.2	6
		22	230	25	37	3.2	6
		23	220	26	37	3.6	6
27	11	00	220	26	35	3.9	7
		01	220	26	36	3.8	7
		02	220	27	41	4.3	7
		03	230	27	42	4.7	7
		04	250	25	41	4.7	8
		05	260	24	33	4.3	7
		06	-	-	-	3.6	6

Table 5.5
Buoy data

Location: Turbot Bank 62303 51.60N 005.10W							
Date	Month	Time UTC	Wind Direction	Wind speed	Wind gust	Measured wave height	Measured wave period
			°true	kts	kts	metres	seconds
26	11	18	221	24	30	3.3	8
		19	221	24	32	3.3	7
		20	227	25	32	3.3	7
		21	230	27	35	3.3	7
		22	230	28	39	3.4	8
		23	231	30	39	3.5	8
		00	235	30	39	3.6	8
		01	236	29	37	3.8	8
		02	230	32	38	3.9	8
		03	233	32	39	4.0	8
		04	240	32	41	4.2	8
		05	269	31	42	4.3	8
		06	278	27	40	4.2	8

Table 5.6
Valley wind data

Location: RAF Valley EGOV 53.25N 04.53W (9m amsl)					
Date	Month	Time UTC	Wind Direction	Wind speed	Wind gust Hourly max
			°true	kts	kts
26	11	1750	200	32	-
		1850	210	33	-
		1950	220	34	-
		2050	200	33	43
		2150	210	35	-
		2250	210	34	48
		2350	210	36	47
27	11	0050	200	35	47
		0150	210	36	49
		0250	220	32	46
		0350	250	29	-
		0450	260	27	40
		0550	280	28	38

Table 5.7
Aberdaron wind data

Location: Aberdaron 03405 52.78N 04.73°W (94m amsl)					
Date	Month	Time UTC	Wind Direction	Wind speed	Wind gust Hourly max
			°true	kts	kts
26	11	1750	230	39	55
		1850	230	38	50
		1950	230	41	54
		2050	220	38	51
		2150	230	40	56
		2250	230	44	63
		2350	230	47	64
27	11	0050	220	43	58
		0150	230	41	57
		0250	230	47	66
		0350	240	43	66
		0450	260	37	50
		0550	270	34	46

Table 5.8

Mean bias and standard deviation table from hourly values 26/00 to 27/23				
Location	Wind speed	SD	Hs= measured	SD
Anemometer height	Mean(OBS-Model)		Mean(OBS-Model)	
	Knots	Knots	metres	Metres
Aberporth (36 hours) 3m	-6	5	+0.1	0.3
M5 (offshore Waterford) 4.5m	-5	2	0.0	0.3
Turbot Bank 3m	-2	2	+0.2	0.4
M2 (offshore Dublin) 3.5m	-4	3	+0.2	0.2
Remarks	NAE model height: 10m			

6 DISCUSSION

6.1 **Winds (10 metres)**

Apart from four Buoy reports (Fig 4.1), there were no ships reporting wind speed and sea states between 52°N & 55°N and 8.0°W & 2.5°W.

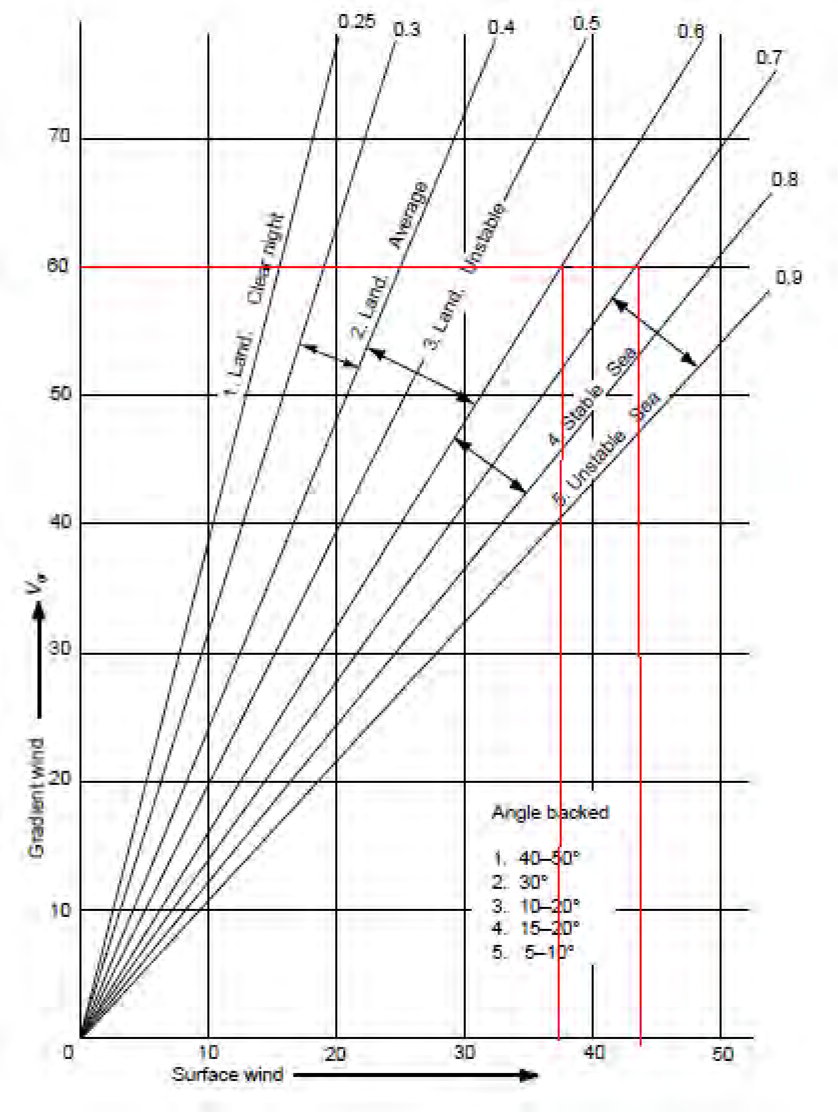
On comparing wind speeds between the Buoys (Aberporth, M2, Turbot Bank and M5) the average bias over the 48 period (26/00 to 27/23) the bias ranged from -2 to -6 knots (observation – model), Table 5.8. A negative bias is consistent with the buoy anemometers measuring wind speed at a lower elevation than 10 metres (as required by the model).

An ASCAT image, Appendix F at 2031 on the 26 h (one of a twice daily snapshot of surface winds derived from satellite data) shows a southwesterly wind of force 6 or 7 in the St George's Channel and Irish Sea broadly consistent with observations at M2 and M5. There were no ASCAT images on the 27th November for location of interest.

On land, of particular interest were the observations at Valley and Aberdaron, see map Fig 4.1. At Aberdaron, 94 metres amsl on the Lleyn Peninsula, a southwest wind blew severe gale force 9 with a maximum gust of 66 knots between the hours of 0150 and 0250 and between 0250 and 0350 UTC, Table 5.7. At a lower site, RAF Valley in Anglesey, (9 metres amsl), see Table 5.6, recorded a SSW to SW wind of gale force between the hours of 2350 and 0150 UTC. A maximum gust of 49 knots recorded between the hours of 0050 and 0150 UTC. From 0250 the winds decreased force 7 and veered WSW by 0450 UTC. On measuring a 60 knot gradient from the straight isobar spacing and a wind direction of 250° at M2 and Aberporth from the 0200 UTC chart, the air mass was considered to be stable owing to the 30° backed directional separation between gradient and surface winds, see Fig 6.1. In fact, the value 30° falls outside the average directional deviation of 15-20° for a stable airmass over the sea. Within the 'allowable' multiplier range of 0.6 to 0.8 times gradient speed, it was though that the lower value of 0.6 was more appropriate, i.e 37 knots, leading to gusts of around 52 knots, see para 4.1. The value of mean 10 minute wind agrees very closely with modelled values at the location of interest.

Fig 6.1 Relationship between geostrophic wind and 10 m winds over land and sea (knots)

A geostrophic wind (=gradient with straight isobars) of 60 knots over the sea and a stability index of 0.6 gives a surface wind of 37 knots. For comparison, a stability index of 0.7 would give a gust of 44 knots



6.2 **Waves**

A plot of model wave fields is presented in Appendix E to show the spatial variation of significant wave height in the Irish Sea and St Georges Channel.
A comparison was done between buoys M2, M5, Aberporth and Turbot Bank (see Fig 4.1 for locations) and their closest model points to ascertain how well the wave model was behaving at these locations, and by extension, how well it might have predicted reality at the location of interest, Tables 5.8. The results over a 48 hour period are tabulated in table 5.7. Mean bias values lie well within +/- 0.5 metres and standard deviations are small (0.4 metres maximum) at Turbot Bank, leading to high confidence in model output background significant wave height.
A plot of the comparisons was done for M2 and Aberporth, see Figures 5.1 and 5.2.
During the time of interest, there is good correlation between measured and model significant wave height. As a result it was thought that the modelled significant wave height of around 4 metres with peak period of 8 seconds and derived wavelength of 105 metres were acceptable values at the location of interest. (Note that the buoys measure zero upcrossing periods which are lower than peak period). A maximum individual wave (crest to trough) could have reached 1.9 times significant wave height during a 3 hour sampling period, i.e 7.6 metres.
Of particular note however, is the fact that the tidal current of around 2 knots was opposing the incoming wind wave at an angle of around 27 degrees. This would have made the waves steep during the time of interest.

6.3 **CONCLUSION**

All the available evidence indicate a rough passage for the MV SWANLAND as she sailed southwards in the Irish Sea, west of Gwynedd at 0200 UTC on the 27 h November 2011. She would have met a southwesterly gale force wind with gusts of around 50 knots. Seas would have been rough, perhaps very rough with a significant wave height of around 4.0 metres see Appendix A. Waves would have been steeper than normal due to an opposing tidal current of around 2 knots. Maximum individual waves (crest to trough) within a 3 hour sampling period could have reached 7.6 metres**.**

Annex C

Subsea Vision ROV Survey Report

Subsea Vision Ltd

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

Project Title:

MV Swanland ROV Survey for the MAIB

Document Title:

ROV Survey Report

Document No: **MAIB - Jan 2012- ROV Survey**

REV	DATE	ISSUE FOR	Originator	Checker	Approver
0	10/01/12	Client Issue	[redacted]	[redacted]	

TABLE OF CONTENTS

1.0 Abbreviations

MAIB Marine Accident Investigation Branch
SSV Subsea Vision Ltd
ROV Remotely Operated Vehicle
OP Osiris Projects

2.0 Introduction

Subsea Vision (SSV) was awarded the contract to survey the MV Swanland by the Marine Accident Investigation Branch (MAIB).

SSV chartered a vessel called the Bibby Tethra a DP class 1 survey catamaran from Osiris Projects, this vessel was deemed the most suited for the operation due to the water depth of 80 metres.

The MV Swanland sank off the Welsh coast, loaded with a full cargo of limestone, in a reported position of:
52° 52.152'N 005° 04.821'W on the 27th November 2011

The vessel's length overall was 81 metres, her beam was 13.8 metres, and her deadweight was 3137 tonnes.

Subsea Vision used one of our Falcon ROV systems to survey the vessel on the seabed.

The survey was completed in two phases:

Phase 1 – Mobilisation port was Liverpool on the 8th January 2012

9th Jan 2012
- We completed some multi beam survey work whilst waiting on the tide to ease
- Launched the ROV for its first dive on the Swanland and unfortunately lost the ROV and had a power blackout on the survey side of the bridge where the ROV was being operated.
- Due to the power loss and the lost ROV we had to abandon the survey at that time

Phase 2 – Mobilisation port was Holyhead on the 6th February 2012

6th Feb 2012
- Mobilised equipment on board the evening before
- Steamed out to location
- Completed further Multi beam survey runs over the Swanland
- Completed 3 dives on the Swanland with the Falcon ROV

7th Feb 2012
- Demobilised personnel and equipment

The Swanland was found to be upside down, the vessel was laying on the seaebed in a North to South orientation. The Bow of the vessel is located to the North.

Due to the tidal currents the dive time was restricted to approximately 1 hr. The suspension in the water hampered the visibility greatly, in some cases the water visibility was down to approximately 0.5 metre. We completed three dives in total.

Due to the tidal conditions, length of umbilical in the water column and the visibility we could not cover all of the areas on the Swanland.

There are video clips of the specific areas surveyed and these are hyperlinked within this report for ease of viewing. The complete video images are included also for further indepth viewing by the MAIB which are not hyperlinked. These files are within the Video footage

3.0 Multi beam images of the Swanland on the Seabed

General orientation of the Swanland on the seabed

Fig 1

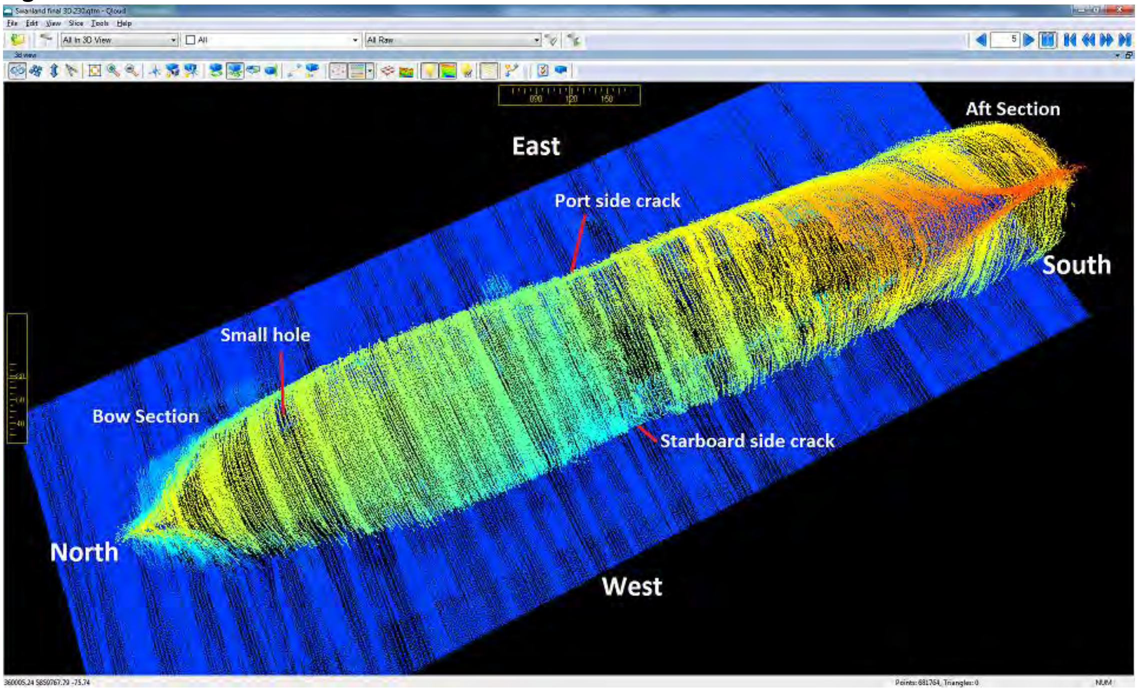


Fig 2.

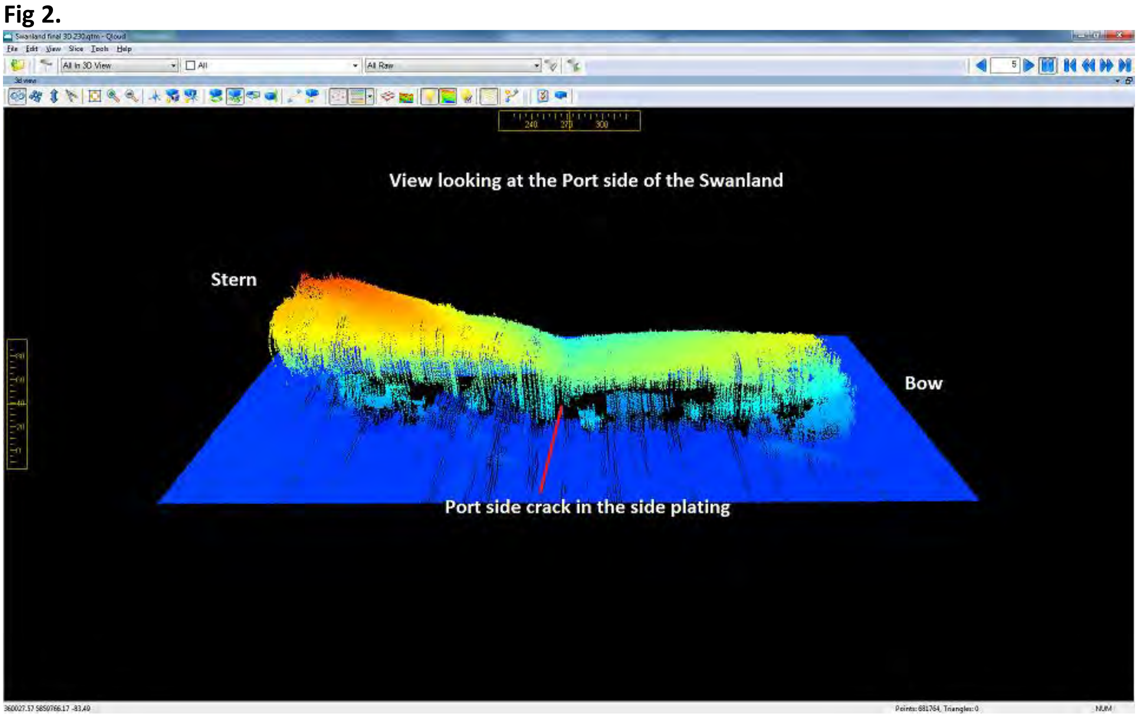


Fig 3.

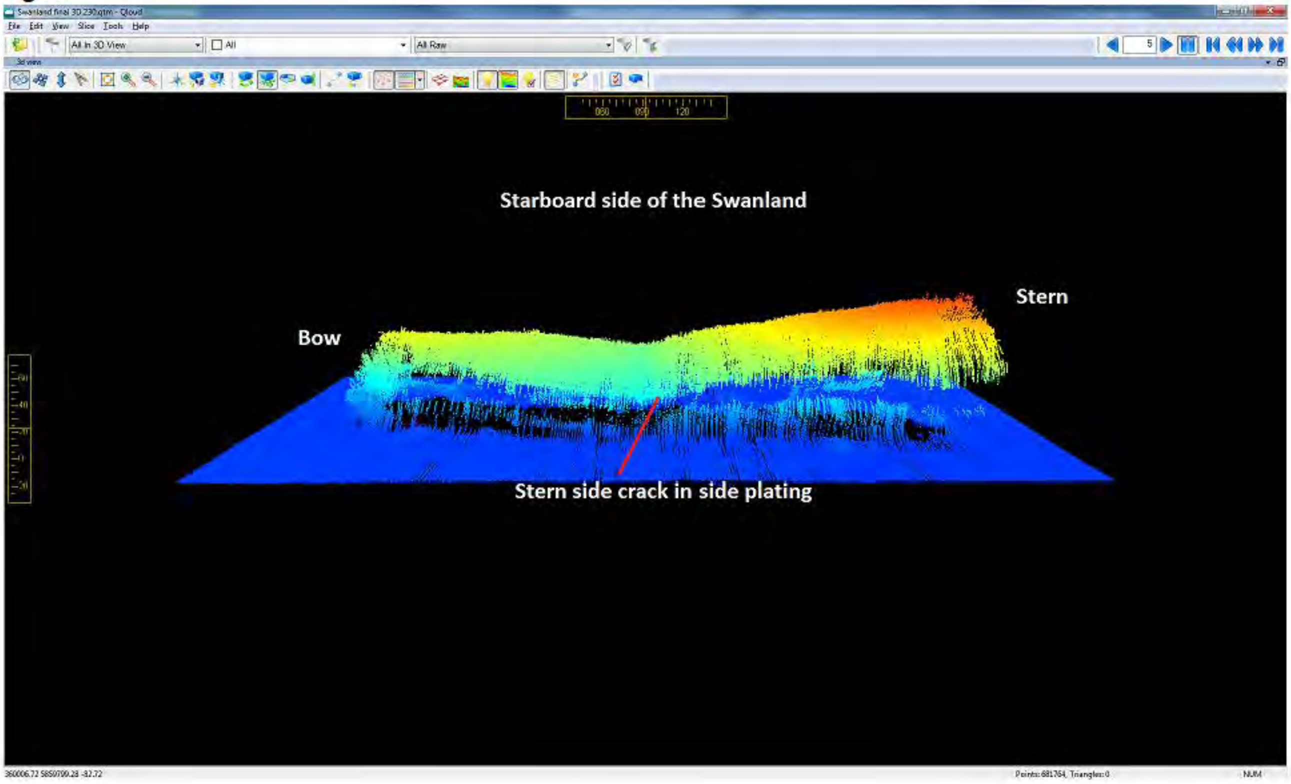
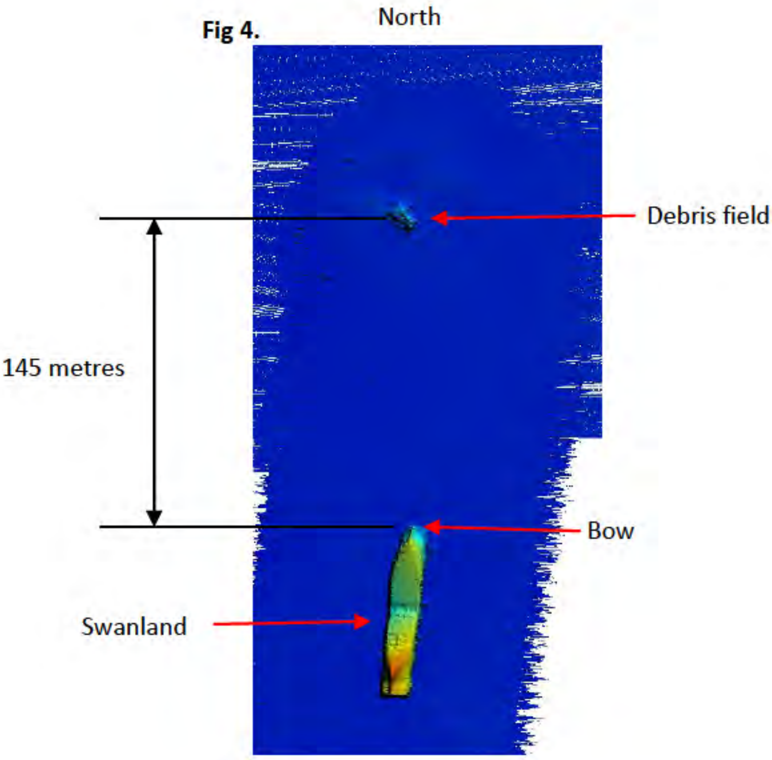

Starboard side of the Swanland
Stern
Bow
Stern side crack in side plating

Fig 4.


North
Debris field
145 metres
Bow
Swanland

4.0 Areas of interest noted

1. Hatch cover approximately 10 metres from the east side of the Swanland - Hatch cover East side
   Co ordinates – Eastings 360025.4 Northings 5859753.8

2. Crack within the Port side shell plating - Port side crack
   Co ordinates – Eastings 360015.0 Northings 5859772.7
   This area of interest was found to be approximately 33 metres from the Bow section

3. Bilge keel damage on Port side - Port side Bilge Keel by crack
   Co ordinates – Eastings 360015.0 Northings 5859772.7
   This area of interest was found to be approximately 33 metres from the Bow section

4. Small hole in the bottom shell plating on the Port side of the Swanland - Hole in the Port side close to Bow
   Co ordinates – Eastings 360015.5 Northings 5859793.7
   This area interest is 21 metres further forward from the port side crack and is approximately 12 metres from the Bow section

5. Starboard side crack - Starboard side crack
   Co ordinates – Eastings 35999.4 Northings 5859771.2
   This area of interest was found to be approximately 33 metres from the Bow section

6. Debris field North of the Swanland - Target North of the Swanland
   Co ordinates – Eastings 360012.8 Northings 5859951.7
   This area of interest was found to be approximately 145 metres North of the Bow section. Debris field is illustrated in figure 4 above on page 5

7. Bow section - Bow section
   Co ordinates – Eastings 36011.8 Northings 5859805.0
   The pinnacle point of the bow is heavily damaged towards to the lower quadrant of the bow where it joins onto the underside shell plating

8. Bottom shell plating between the cracks on the Port and Starboard side of the vessel - Bottom Shell plating Starboard side to Port side
   Co ordinates – Eastings 360006.8 Northings 5859773.4

Below are two Multi Beam video files produced from Qloud the multi beam post processing software

Swanland - Multi beam video - 1

Swanland - Multi beam video - 2

5.0 Osiris report to Subsea Vision

Introduction

The following document is designed to summarise the data deliverables from the Swanland Remote Operated Vehicle (ROV) and Multibeam Echo Sounder (MBES) investigation which took place between 06/02/2012 and 07/02/2012. The following data is specific to MBES data. All Figure names refer to the file names of each GeoTIFF or PNG deliverable.

Vertical Datum

All depth data for this survey have been corrected to the UK Vertical Offshore Reference Frame (VORF), a reference datum developed in conjunction with the UKHO by which depths can be expressed and compared uniformly across all UK EEZ waters, and reduced to Lowest Astronomical Tide (LAT), which can be defined as the least amount of water which can reasonably be expected due to tidal influences, i.e. lunar and solar gravitational forces during tidal springs.

Colour Scale

The Scale bar below depicts the colour range utilised to represent depth, with -84.5m being the deepest depth, and -65.0m the shallowest in the following images. This scale is relevant to all delivered images, including 3D PNG files.

2D images of Swanland

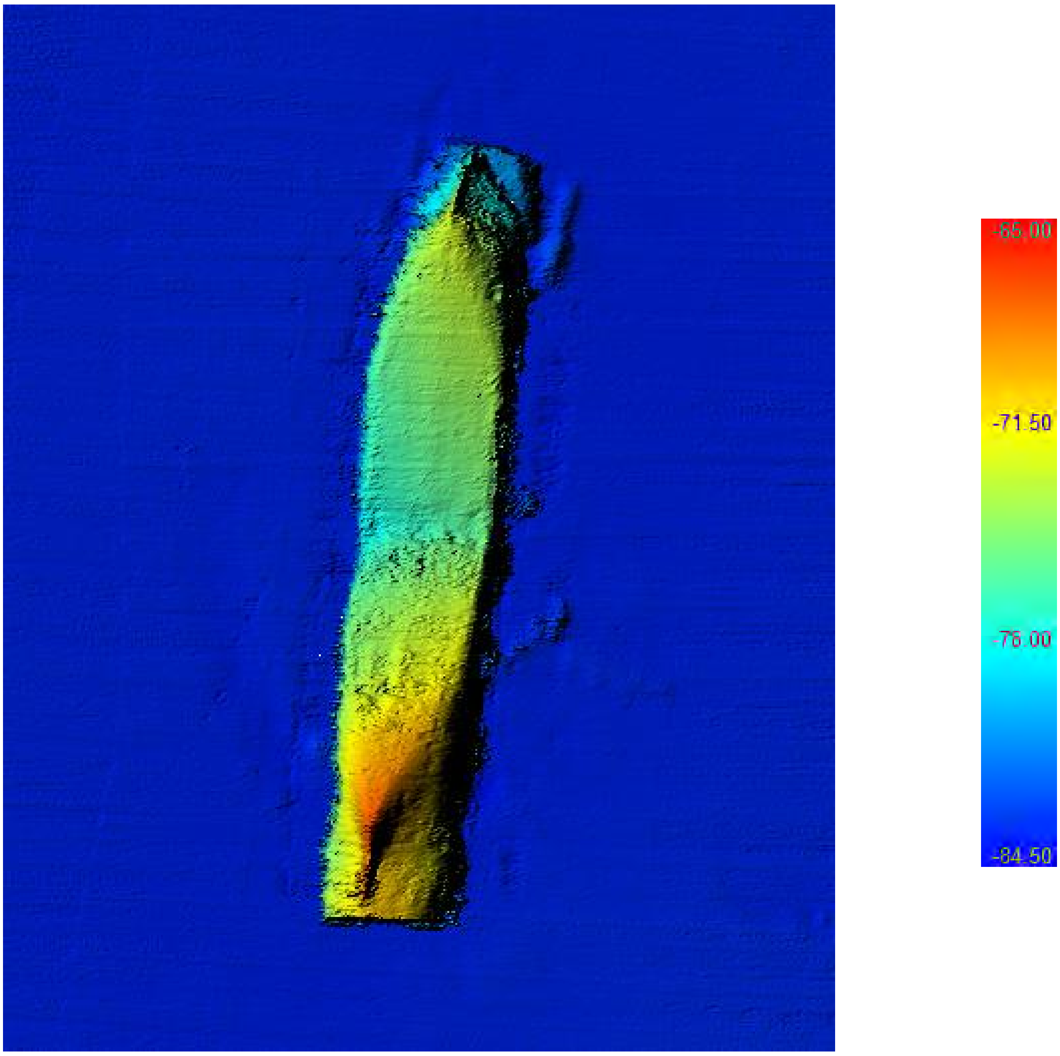


Figure 1 Swanland_2D_0.2m

Fig. 1 displays final processed MBES data gridded to a 0.2m x 0.2m bin (area of seabed represented by one pixel). Shading has been applied to provide 3D aspects to the wreck. This image is North orientated, with the bow of the Swanland offset to the North. The smooth surface and features at the stern of the Swanland indicate that the wreck is upside down, with the keel facing up. Due to this orientation of the vessel, the Port side is in the East, and Starboard side in the West.

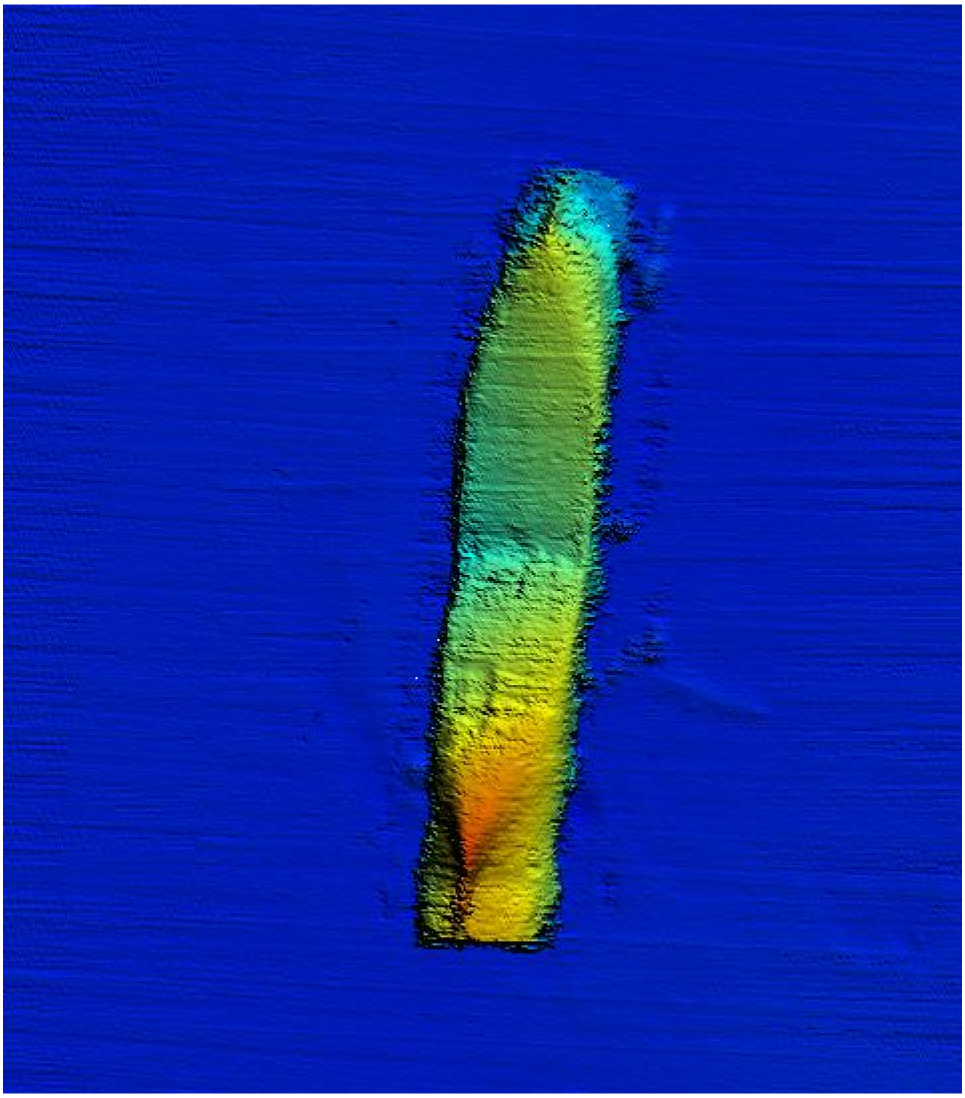


Figure 2 Swanland_2D_0.2m_2

Fig. 2 shows the same data, with the illumination angle used to provide the shading altered. This is designed to provide an alternative aspect to the image, and highlight features which may not have been as apparent in Fig. 1. Again Fig. 2 is at a 0.2m bin, with a scale of -65m to -84.5m.

Cargo Debris

The image in Fig. 3 is displayed at a lower resolution of 0.4m, however a 0.2m deliverable is provided. It shows the location of the Swanland in relation to debris to its North. The debris was hypothesised to be a pile of the Swanland's cargo, limestone, covering a partially exposed hatch cover.

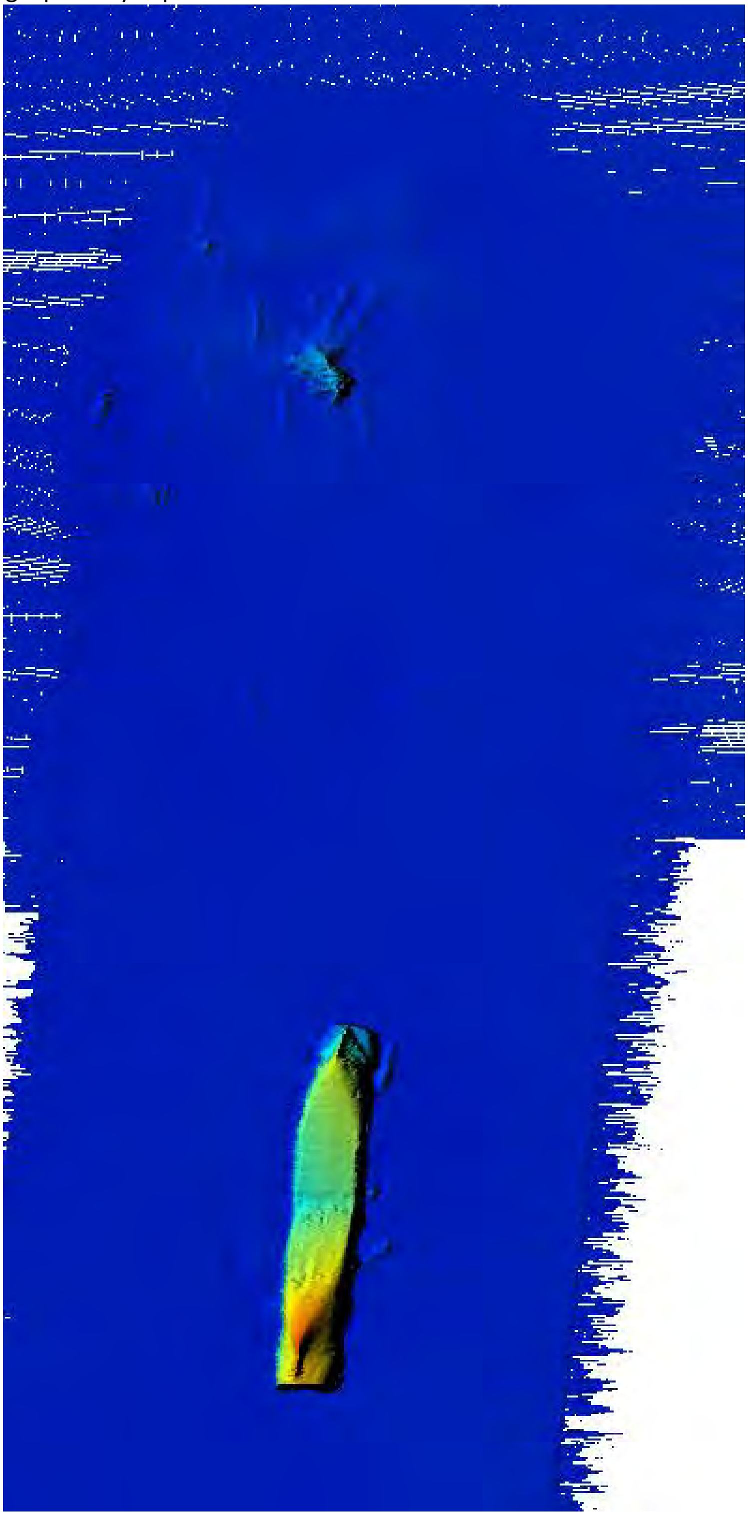


Figure 3 Swanland_2D_0.4m_boundary

Appendix A

Equipment used

Standard Falcon ROV – 300m depth rated

The Falcon ROV system is configured to be free swimming. It is adaptable, reliable and can perform varied inspection tasks from CVI to CP surveys. Various tooling packages can be integrated with the Falcon (listed below).

Falcon ROV complete with surface control units packed into transit cases and can be mobilized via air freight

The standard Falcon ROV is supplied with the following

ROV

- 5 x MCT1 thrusters
- 1 x Colour Camera
- 1 x Monochrome camera
- 1 x Mini King Sonar
- 1 x 300mtr low drag umbilical
- Tooling packages on request (additional cost)

Standard surface equipment

- 1 x Power supply unit
- 1 x System keyboard
- 1 x Pilot monitor
- 1 x Survey monitor
- 1 x VGA monitor
- 1 x Laptop PC for sonar and system paperwork
- 2 x DVD recorders
- 1 x Remote spares package including spare umbilical

Specifications of the Standard Falcon ROV

Size, Weight and Thrust

- Length	1000 mm
- Height	575 mm
- Width	600 mm
- Thrust Fwd	48 kg
- Thrust Lateral	28 kg
- Thrust Vertical	12 kg
- Weight	65kg
- Payload	10 - 15 kg

Video Overlay includes as standard

- Compass Heading
- Depth in metres or feet
- Camera tilt platform position
- Auto function status
- CP reading (optional)
- Odometer Count (optional)
- Date and Time
- Facility to export data to survey

Power requirements

- 220-240Vac single phase 16amp

Optional Tooling packages

- Contact or Proximity CP
- Innovatum Pipe / cable tracking system
- Ultra thickness measurements
- Mechanical cleaning
- Scaling cameras
- Single or 5 function manipulator
- Dye injection system

Annex D

MV *Swanland* Review of Structural History, Survey and Repair Records following the Structural Failure and Foundering on 27th November 2011, Braemar report, dated 31 May 2013

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MV SWANLAND

REVIEW OF STRUCTURAL HISTORY, SURVEY AND REPAIR RECORDS FOLLOWING THE STRUCTURAL FAILURE & FOUNDERING ON 27th NOVEMBER 2011

Report No.: 312835.1R v3.5
31st May 2013

QA 03 REV 2011/11

EXECUTIVE SUMMARY

The Cook Islands registered general cargo vessel, MV SWANLAND of 3,100 deadweight tonnes capacity, was lost in heavy weather carrying 2,730 tonnes of Type 1 Limestone during the early hours of 27th November 2011, with the loss of six of her eight crew. The weather conditions at the time were reported as gale force winds of Beaufort Force 8-9 and wave heights of between 4 and 6 metres.

MV SWANLAND was built in 1977 of all steel construction. She had a single cargo hold extending forward of her aft accommodation and protected by a raised forecastle at the bow. The two cargo hold hatch covers were of the folding type and met at a cross beam at main deck level, frames 64-66. She was constructed to the relevant Lloyds Register of Shipping (LR) Rules at the time and since 2009 was entered into the International Naval Surveys Bureau (INSB) Classification Society.

MV SWANLAND was transversely framed with additionally strengthened frames at frame numbers 46-48, 64-66 and 82-84 to provide additional resistance to lateral structural loads due to the large single hatch opening at the main deck level. The structural design of MV SWANLAND was, in our opinion, typical for a ship of her size and type. However, the large single hatch opening extending the length of the cargo hold meant that her longitudinal strength (i.e. her resistance to longitudinal hull bending and stresses) was highly dependent on the relatively narrow area of main deck structure either side of the hatch opening and the upper side shell structure.

Whilst MV SWANLAND was classified as a 'General Cargo' vessel, she was effectively operated as a bulk carrier on coastal trades, carrying bulk aggregate products and a number of potentially corrosive cargoes (such as road salt). Regular and often extensive repairs were carried out to her hold structure (side shell, side shell frames, under-deck stiffeners and tank top plating) due to the effects of mechanical damage caused by cargo loading and discharge methods such as grabs and excavators, including the excavator mounted permanently onboard from 2003. Damage was also likely to have been caused by the abrasive cargoes that were carried.

Due to the voyage pattern that MV SWANLAND was engaged in (short regular voyages in coastal areas), there would have been high numbers of cargo operations and as such, greater propensity for this kind of damage to occur. Further, the short voyages (often only a day or two), short port turnaround times and lack of regular ballast voyages would have made full and proper hull cleaning and coating maintenance difficult without specific maintenance periods (for which no such evidence has been sighted). Combined with the regular mechanical damage being experienced during cargo operations, this would have resulted in significant damage and corrosion to the vessel's structure in way of the cargo hold.

MV SWANLAND was subject to extensive and often repeated structural repairs during much of her 34 year service life. Of particular note are repeated repairs to key structural members including the cargo hold transverse frames, side shell plating, cracks in bottom longitudinals, deck plating and under-deck stiffeners, tank top plating due to heavy corrosion, cracked and corroded welds and various localised cracks following every Intermediate or Special

Classification Society survey from 1997 until 2009 when the vessel changed Classification Society and Flag. Condition surveys conducted on behalf of the vessel's insurers in 2002 also found the vessel's structure to be in 'poor' condition with no maintenance plan in place. Classification Society surveys recorded a number of structural deficiencies and notably, evidence of structural defects and repairs completed without informing the Classification Society; a serious deficiency under the International Safety Management Code (IMO Resolution A.741(18) as amended), to which the vessel must comply.

An examination of the vessel's structural condition following the 2009 INSB survey was carried out as part of this investigation. Taking the Ultrasonic Thickness Measurements (UTM) report and applying standard Classification Society corrosion rates for the different structural elements plus cargo specific corrosion rates (in particular for the extended period of voyages carrying rock salt in wet conditions), estimates have been made of the midship (frame 58) Section Modulus of MV SWANLAND at the time of the sinking. This showed that significant parts of the vessel's structure would potentially have been sufficiently corroded to cause an overall reduction in Section Modulus of approximately 18% by November 2011.

This was further exacerbated by examples of incorrect diminution calculations in the 2009 UTM report, resulting in the calculation of diminutions as less than the reality. Hence the situation occurred, where parts of the vessel's structure that should have been subjected to further, detailed inspection and UTM were not.

Up until 2009, there are extensive records of Classification surveys and the vessel's structural condition. Following the transfer of 'Class' in 2009 to INSB, this level of information had significantly reduced and includes some clear contradictions, where structural elements known to be corroded and with no evidence of repair (specifically the double bottom water ballast tanks) are described in INSB reports as 'in good condition' and 'uncoated' but described as in 'poor' condition by the owners of MV SWANLAND in 2009. The available photographic evidence shows the ballast tanks to be in poor condition prior to repair, demonstrating the level of wastage over a period between 2006 and 2009. Following repair (but no coating) the ballast tanks were again reported by INSB to be in "good condition" and coatings to be in 'fair' condition in 2010, despite there being no evidence of any repairs or coatings applied.

The available evidence provided to date, shows that at the time of her sinking, the strength of considerable parts of the MV SWANLAND's structure would likely have been significantly impaired due to corrosion and damage. Some of these elements would likely have wasted close to the relevant Classification Society limits at the time of the sinking. Other elements, with notable wastage (greater than 15% say) would have required a maintenance plan (as per International Safety Management Code, Ch.5, S10) to ensure adequate structural integrity was maintained. To the author's knowledge, there is no evidence of any maintenance plan having been provided for examination.

The 2008 INSB Rules (Part I, Ch.3, section 1.2.5) required the vessel to carry approved loading guidance and stability data, which would assist to ensure correct loading within the permissible limits for shear forces and bending moments. There is no evidence (of which we are aware) of a loading manual being carried onboard beyond 2009 and no copy of any such document available from the owners or managers.

Consequently, we consider it likely that the primary structure (midships section) of MV SWANLAND was in a weakened condition in the latter parts of her operational life. Periodic repairs would have regained structural strength but appeared to have been ‘piecemeal’ or re-active and hence the overall effect would have been that the original structural strength would possibly never have been regained. At the time of her sinking, it is our opinion that significant areas of the vessel’s critical structure with regard to hull girder strength had potentially been corroded to the point where she did not have sufficient longitudinal strength to resist the large bending moments and consequential stresses that she would have experienced on the voyage from Llandulas on 26th November 2011.

In summary, based on the available evidence and our review of the structural history of MV SWANLAND, the major contributory factors to the structural failure were, in our opinion:

- Corrosion of the critical areas of the structure of the vessel that provided her longitudinal strength, resulting in a reduction of the capacity of the structure and the structural failure of the main deck area, followed rapidly by the catastrophic failure of the main deck and side shell and subsequent sinking.
- An apparent lack of focus on the management and maintenance of the structural integrity of the vessel that allowed her primary structure to degrade over time resulting in a critical reduction in longitudinal strength.
- An apparent lack of focus by the Classification survey and inspection regime from 2009 onwards on key areas of the vessel’s structure, already requiring attention in 2009, resulting in their continued corrosion to close to the relevant Classification Society limits. There is no evidence to suggest that any subsequent surveys (from 2009) required repairs to be made in order to prevent a critical loss of hull structural strength.

The conclusions of this investigation are not, in our opinion, new to the shipping industry and have been indentified for a number of vessels lost or damaged due to structural failures.

CONTENTS

Document Information		
Project	MV SWANLAND Structural History Investigation	
Report title	MV SWANLAND: Review of Structural History, Survey and Repair Records Following the Structural Failure & Foundering on 27th November 2011	
Client	MAIB	
Case No:	312835	
Report Ref:	312835.1R.v3.5	
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Reviewed / Approved by:	Simon Burnay	Consultant Naval Architect/ Director; Marine Consultancy

Document History		
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3.2	Final Report updated with new Figures in Appendix 1	23/01/2013
3.3	Final Report updated, following clarification of certain evidence	22/02/2013
3.4	Final Report to MAIB	22/04/2013
3.5	Final Report for release modified following consultation	31/05/2013

1 TERMS OF REFERENCE

1.1. Braemar Technical Services Ltd (Braemar) were instructed by the Marine Accident Investigation Branch (MAIB) to undertake a review and investigation of the structural history of the general cargo ship MV SWANLAND, which was lost on the 27th November 2011, as part of the investigation of the accident being completed by the MAIB.

1.2. The investigation was conducted under MAIB Purchase Order No. 8000108390 of 9th Aug 2012 and in accordance with MAIB Specification of Work 04/03/105.

1.3. The scope of the investigation is to review and analyse the structural records for MV SWANLAND, together with the relevant Classification Society Rules, surveys and repairs in order to:

- i. Provide an overview of the vessel's structural design;
- ii. Summarise the history of structural repairs, modifications and surveys;
- iii. Assess the effect (if any) of the structural repairs and modifications on the loss of the vessel.
- iv. Draw any appropriate conclusions on the most likely cause(s) of the structural failure and subsequent loss of the vessel;
- v. Assess the likely condition of the vessel, in particular in way of the cargo hold and double bottom beneath the hold in vicinity of the midships area;
- vi. Assess the vessel's structural design in terms of its fitness for purpose.

1.4. This report describes the review of the available evidence and provides conclusions as appropriate on the elements of the investigation described in 1.3 above.

2 SOURCES OF INFORMATION

2.1 The MAIB provided a Blu-Ray disc of data and information for this investigation, containing the following information:

- Narrative of the accident;
- Vessel drawings and structural plans;
- Relevant Classification Society Rules;
- Classification Society survey records, reports and other associated documents;
- Ship operator's records of dry-dockings and repairs;
- Port State Control inspection records;
- Photos from various sources;
- Weather data for the period in question;
- Information relating to the cargoes carried;
- Condition survey reports carried out for insurance purposes;

2.2 Unless specifically referenced to a Reference at the end of this report, all information, data or evidence quoted in this report is provided by the MAIB. Where appropriate, specific references from the evidence provided by the MAIB are highlighted.

2.3 Specific references are identified in the text of this report with the relevant reference number in square brackets, e.g. [1].

3 BACKGROUND

3.1. The Cook Islands registered general cargo vessel MV SWANLAND was lost on 27th November 2011 in heavy weather while on passage from Llanddulas, North Wales to Cowes, Isle of Wight. Only two of her eight crew survived.

3.2. She had sailed from Llanddulas at 10:45 on the 26th November 2011, fully loaded with 2,730 tonnes of Type 1 Limestone. Throughout the voyage on the 26th, the weather conditions deteriorated with conditions at 01:00 on the 27th described as south west gale force 8, gusting to 9 and wave heights of between 4 and 6 metres.

3.3. It is reported that at approximately 02:00, the MV SWANLAND was struck by a large wave forward, following which the bow dipped as the wave moved along the length of the vessel. The bow was then struck by a second large wave and as the bow rose again, the starboard side bulwark (between the forward and aft hatch covers) was observed to fold outboard. At this time, the forward most section of the aft hatch cover lifted and the bow appeared to be higher than normal.

3.4. The general alarm was sounded, at which point another large wave broke over the main deck. The MV SWANLAND was turned around, going hard to port so as to present her stern to the waves. The damage appeared to increase as the vessel turned with the bow rising higher and when beam-on to the seas, large waves broke on top of the hatches and water was seen to have entered the holds where the hatch covers had lifted.

3.5. Water continued to enter the hold and consequently, the vessel rapidly lost freeboard before sinking with the loss of six crew.

3.6. Sonar and Remotely Operated Vehicle (ROV) surveys confirmed that the wreck was lying inverted on the seabed, having sustained a large structural failure in the area of the Load Line mark on both the port and starboard sides of the vessel. The bottom plating was generally intact, but with a large crease running transversely across the vessel between the port and starboard side failures. Due to the wreck being upside down, the main deck plating was not accessible and no physical samples were recovered from the wreck.

3.7. Some localised damage was observed at the vessel's bow area and a large item of debris was observed on the seabed, 145 metres to the North of the wreck.

4. THE VESSEL

4.1. General Characteristics

4.1.1. The principal characteristics of the MV SWANLAND are given below:

Name:	SWANLAND
IMO No.:	7607431
Flag:	Cook Islands
Classification Society:	International Naval Surveys Bureau (INSB)
Owner:	Swanland Shipping
Manager:	Torbulk Ltd
Type:	General Cargo
Year of Build:	1976 (Keel laid)
GT:	1978
Deadweight:	3,100 tonnes
Length Overall:	81.01 m
Length Between Perpendiculars:	74.80 m
Beam:	13.80 m
Draught (summer):	5.36 m
Propulsion:	Single Screw, Diesel
Power (MCR):	1,942 kW

Figures 1(a) and (b) below show the MV SWANLAND on voyage at Point Lynas, Anglesey (March 2008) and alongside at Raynes Jetty, Llanddulas (June 2010) respectively. Figure A.1 of Appendix 1 shows the General Arrangement.

Figure 1(a) – MV Swanland at Point Lynas, March 2008

Figure 1(b) – MV Swanland at Raynes Jetty, June 2010

4.1.2. The MV SWANLAND was built in 1977 as the CAREBEKA IX in the Netherlands. She was renamed SWANLAND in 1996. She was operated around the UK coastline and northern Europe, carrying various dry cargoes in her single hold.

4.1.3. Her accommodation and engine room were located aft, with double bottom tanks beneath the cargo hold. Her single hold was covered by two folding hatch covers (one each forward and aft of a cross beam at Frame 65), each consisting of 10 folding segments.

4.1.4. She had a raised forecastle to provide protection to the main deck and buoyancy in accordance with the classification society rules of the time. Her summer load freeboard was 990mm.

4.1.5. In 2003, she was modified to enable self-discharge operations with the addition of a conveyor system on the port side of the main deck and a moveable carriage on rails either side of the cargo hatch coaming, on which was stowed an excavator for discharging cargo. At sea, the carriage and excavator were stowed forward, immediately aft of the raised forecastle.

4.2 Structural Design

4.2.1. The keel of MV SWANLAND was laid on 27th July 1976 and the vessel was built according to the rules of Lloyd's Register. The exact rules which were applied to the vessel have not been fully confirmed, but based on the keel laying date, it is reasonable to assume that the Lloyds Register of Shipping Rules and Regulations for the Construction and Classification of Steel Ships, 1976 (LR 1976 Rules) were applicable.

4.2.2. However, since the vessel's length is less than 90m, according to Chapter D of the LR 1976 Rules (page 34), the Rules for Hull Construction of Steel Ships Under 90m in Length, 1976 (LR Small Ship Rules 1976) are applicable.

4.2.3. It is possible that she was built to the LR 1976 Rules, as there is generally some flexibility for such changes (at Owner's request). However, since this would generally involve additional Classification fees and construction costs, it ought to be considered unlikely that she was built to the LR 1976 Rules.

4.2.4. Accordingly, for the purpose of this investigation, we have therefore assumed the LR Small Ship Rules 1976 were applicable.

4.2.5. MV SWANLAND was of all steel construction and was transversely framed with a series of flanged plate frames. The single cargo hold measuring approximately 52.6 metres by 13.0 metres was accessed through a large cargo hatch opening either side of a central cross-beam at frame 65 (see General Arrangement drawing in Appendix A).

4.2.6. At either end of the hold was a short longitudinal bulkhead situated on the centre-line at frames 24-31 and 99-106 (Figure 2). Within the hold, all of the frames were exposed apart from three frames in way of frames 64-66, which were plated in and of deeper scantlings.

Figure 2 – Photo of MV SWANLAND Hold, Showing Longitudinal Bulkhead at Fr24-31

4.2.7. The frames alternated between deep and intermediate frames (alternate frames being half the depth of the others) and frames 46-48 and 82-84 were additionally strengthened with deep frames at frames 47 and 83, the positions of which correspond to the mid-point of each cargo hatch opening. Figure 3 below shows the cross-deck beam at Fr 65 and the additional deep frames at Fr46-48, 64-66 and 82-84, which are different to the others having increased scantlings in way of the connection to the deck-head above (see also Sections 5.1.10 and 5.1.11). At frames 64-66, the frames were also plated over, as detailed in Section 5.1.10. Examination of the drawings also shows that these frames had a fuller connection to the double bottom structure at the side, with structural continuity in way of the plated in flanges extending below the tank top plating.

4.2.8. The bottom structure was of an enclosed "double bottom" type with longitudinal and transverse floors, providing additional strength and rigidity in the vessel's bottom area.

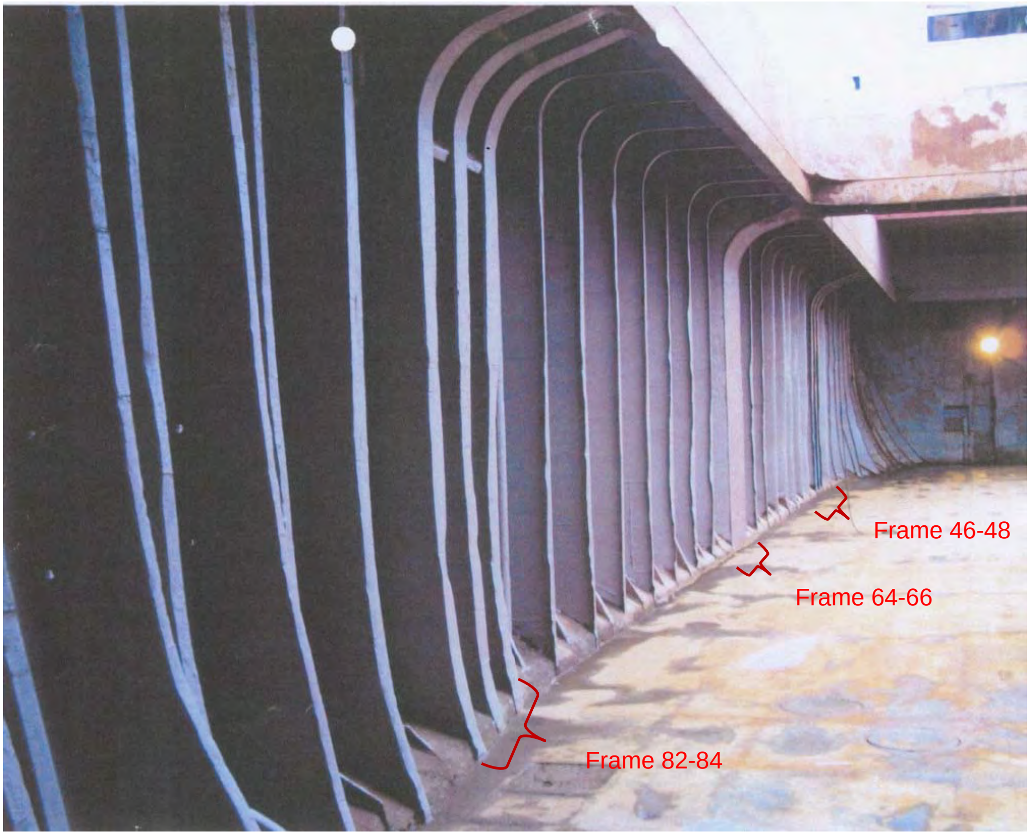

Figure 3 – Photo of MV SWANLAND Hold, Showing Transverse Framing System

4.3 Ship Classification and Registry

4.3.1. As stated in para. 4.2.1, MV SWANLAND was built to Lloyd's Register (LR) rules and hence was entered into LR for her classification upon entering service. Through her life, she was entered into the following classification societies:

1976 - 1987: Lloyd's Register;
1987 - 1997: Bureau Veritas;
1997 - 2009: Lloyd's Register;
2009 - 2011: International Naval Surveys Bureau (INSB).

4.3.2. Lloyd's Register and Bureau Veritas are both leading and founding members of the International Association of Classification Societies Ltd (IACS), the association which comprises the 13 leading classification societies for shipping[1]. INSB is not an IACS member.

[1] A full explanation of IACS can be found at http://www.iacs.org.uk/explained/default.aspx.

4.3.3. Both the full 1976 LR Rules and the LR Small Ship Rules 1976 stipulated that an approved manual for loading be developed to provide guidance on the applicable safe sequence and distribution of loading to ensure that shear forces and bending moments were within the agreed permissible limits in accordance with the vessel's required structural design.

4.3.4. IACS produces so-called 'Unified Requirements' on certain aspects of ship Classification, designed to provide consistency across all IACS members. A Unified Requirement may simplistically be considered as an 'umbrella' requirement to which individual Classification Societies Rules will adhere to. The IACS Unified Requirement (UR) concerning loading manuals[2] relevant at the time of construction of MV SWANLAND states that "*Ships exceeding 150m in length are to be equipped with loading guidance facilities (calculation sheets, instruments etc)......All Ships, regardless of length, for approved uneven cargo or ballast distributions..... are to be supplied with information to facilitate rapid assessment of stresses in the hull*". Subsequent revisions of IACS UR S1 also confirm the requirement for an approved loading manual for a vessel of MV SWANLAND's size and type, noting that these subsequent revisions (1983, 1995 and later) state that for ships contracted before 1st July 1998, the relevant revisions at the time of contracting shall apply. For MV SWANLAND, this would therefore be Revision 1 of 1971.

4.3.5. The 2008 INSB Rules also required the provision of both loading calculations (Part I, Chapter 2, section 3.4.1) and a Loading Manual (Part I, Ch 2, section 3.7.1, if applicable). For the transfer of the vessel to INSB Class, INSB also required verification of that "loading guidance and stability data are onboard ready for use" at each annual survey (Part I, Ch 3, section 1.2.5). However, there is no reference in the 2008 INSB Rules as to application of this requirement for a 'Loading Manual' only 'if applicable'. Section 5.5 refers to this in more detail.

4.3.6. The minimum longitudinal strength requirement was set out in Section 3 of the LR Small Ship Rules 1976 (page 9), which stipulated the minimum section modulus at deck and keel according to an empirical formula utilising the maximum Still Water Bending Moment (determined from the light-ship weight distribution, buoyancy and cargo loading along the length). No explicit mention is made of Wave Bending Moments in LR Small Ship Rules 1976, compared to the 1976 LR Rules (i.e. for vessels greater than 90m length), which provides a requirement explicitly determined from the Still Water and Wave Bending Moments.

4.3.7. MV SWANLAND's country of registration (flag state) through her life was as follows:

1977 - 1988: Netherlands (entered service);
1988 - 1990: Malta;
1990 - 1996: Cyprus;
1996 - 2009: Barbados (changed name to SWANLAND);
2009 - 2011: Cook Islands (together with change of classification to INSB).

[2] UR S1: Requirements for Loading Conditions, Loading Manuals and Loading Instruments, Rev 1. 1971.

4.3.8. Hence at the time of the accident, MV SWANLAND was registered to the Cook Islands flag and classified by INSB.

4.3.9. In accordance with the relevant Classification Society rules, MV SWANLAND was surveyed annually (Annual and Intermediate Surveys) and underwent a special survey every 5 years. Due to the age of the vessel and previously surveyed poor condition of the ship in way of critical areas (e.g. double bottom sea water ballast tanks), the scope of the Intermediate Surveys (2^{nd} or 3^{rd} survey after a Special Survey) should have been increased to provide full internal inspection of all salt water ballast tanks and cargo hold spaces. Accordingly the inspection and testing of these areas should have been effectively the same as a Special Survey and should have included ultra-sonic thickness measurements (UTM). This is set out in the INSB Rules (Part I, Ch 3, Section 2).

4.3.10. The 2009 survey at Kaliningrad was classified by INSB as an Intermediate and Dry-Docking survey. Since MV SWANLAND's classification was transferred to INSB at this time, she underwent an initial survey for entry and thickness measurements survey. The next special survey was due in 2012.

4.3.11. In accordance with the Classification Society rules, as a vessel ages, so the requirements for the stringency of the surveys increase, requiring increased inspection of structural members, examination of an increased number of critical areas and greater density of thickness measurements. Depending on the results of annual or intermediate surveys, the classification society may impose additional requirements on each subsequent annual or intermediate survey, such as thickness measurements of particular areas of structure if corrosion is a problem for example, in order to maintain the required minimum standards for vessel safety.

4.3.12. In the case of MV SWANLAND, Lloyd's Register had imposed a 'Memoranda of Class'[3] on her annual surveys for additional inspections and thickness measurements where required, for a number of areas of the hull structure due to wastage of structural material. Specifically, this was for all double bottom water ballast tanks (since 22/03/2005, Great Yarmouth), and areas of the side shell frames) port (fr 59-62) and starboard (fr 35-53, 65-77) since 30/10/2006, (Klaipeda), various structural elements in the Aft and Fore peak tanks (since 12/06/2006, Liverpool). Following entry into the classification of INSB, an additional requirement only for inspection of the vessel's ballast tanks at each annual survey was imposed.

4.3.13. Section 5.2 provides an assessment of the vessel's structure based on the classification survey records and the owner's own records.

4.3.14. In accordance with the Paris MOU protocol[4], MV SWANLAND was inspected by Port State Control officers 46 times between February 1998 and October 2011.

[3] A 'Memoranda of Class' in this context defines "recurring survey requirements, such as annual survey of specified spaces, ..., which have the de-facto effect of conditions of class" (IACS Document 'Classification Societies; What? Why? How?' http://www.iacs.org.uk/document/public/explained/Class_WhatWhy&How.PDF).

[4] The Paris MOU sets out the requirements for Port State Control inspections by participating maritime administrations (flag states) http://www.parismou.org/.

During this time, she was detained two times and since 2009, 41 deficiencies were registered. It is not known how many of these were outstanding, if any, for rectification at the time of the accident.

4.4 Repairs and Modifications

4.4.1. Based on the available records, MV SWANLAND underwent dry-dockings / repair periods as described below in Table 1. For full descriptions of the abbreviations and numbering system, please see the Glossary.

4.4.2. Some information is available for periods prior to 1997 but it is relatively sparse and it should be noted that the information available for the repairs prior to 2009 is limited. Thickness measurement reports exist for the 2005, 2006 and 2009 repair periods, but it is understood that any previous thickness measurements reports were lost with the vessel.

Date of Repair Period	Age at Time of Repair (from entry in service)	Location / Survey Type	Summary of Significant Structural Repairs
1987	10	Papenburg / Special Survey	Bottom plating extensively renewed after grounding, stbd side fr's 28 – 81, 95-105/ Port side 32 – 81, 95-105, shell plate F strake fr 68-79. Corroded seam & butt welds in forebody veed out and rewelded. Doubler plate at FPT stbd repaired. Replaced heavily corroded tank top plate at stbd fr9 on bulkhead + horiz. stringers. Long'l CL bulkhead part renewed, connecting deck beams, brackets & stiffeners. Local stevedore damage in holds repaired
1988	11	Vlissingen / Annual Survey	Side shell buckled plate fr 97-105. Aft peak – welds at upper side stringer cracked P/S.
1992	15	Pireaus / Special Survey	Keel fr's 29-88 and assoc'd internal cropped & renewed. Strakes A, B, C P/S 31-88 & internals cropped & renewed. Tank top CL 1st, 2nd plate P/S fr31-84 and assoc'd internals renewed. Stevedore damage to frames / brackets repaired in hold. Condition of SW ballast tanks to be examined annually.
1993	16	Unknown / Annual Survey	Shell damage stbd side fr 81 – 94, iwo fwd cargo hold, crop & renew web frame fr 94.
1994	17	Unknown / Intermediate Survey	Var. Side frames & brackets partly buckled /damaged. Keel plate and 1st bottom plate and assoc'd internals buckled & renewed (1 DBT P fr 86-94). Bottom plate & internals iwo of #2 P FO Tank buckled and renewed (fr 60-86)
1997	20	Hull / Special Survey	Repair of hold frames, aft shell plating, bulwarks, transom, forward main deck, Aft Peak Tank, Forepeak Tank, hatch coamings,

			bulwark fractures, Forecastle bulkhead fracture
2000	23	Leith / Intermediate Survey	Shell plating frames and deck stringers aft, P/S side shell plating, P/S shell frames, Aft Peak bulkhead, hatch coamings, hatch covers, existing weld repairs, fore peak plating, bulwark fractures, renew shell plating fr25-30 and 35-40. Doubler plate iwo fwd hold access.
2002	25	Bijela / Special Survey	Shell plating Port, 1st – 4th strake, shell plating stbd, 1st – 4th, 6th strakes, bottom longitudinal inserts, hold frames web, flanges and brackets (total 32 stbd side, 43 port), repair of fillet weld crack on hold frame web, deck plating iwo hatch coaming 1 and 2, under-deck stiffeners, fwd deck plate and stiffeners iwo hatch coaming/fo'cstle, wt bulkhead at fr 116, DB ballast tank frames (no 2 and 3 P/S, DB long'l bulkhead iwo DB tanks 1-2 renewal, bottom plating and long'l (fr 7-9)
2003	26	Reimerswaal / Occasional Survey	Self discharge equipment added, deep web frame scantlings modified, hold frames renewed (total 26 fr's P, 22 fr's S), deck fr's renewed (total 2 P, 6 S), inserts replaced in 5 fr's P, 4 S, hatch coaming crack repaired
2004	27	Rotterdam / Occasional Survey	Thickness measurements taken (no report available), repairs to aft peak tank
2005	28	Great Yarmouth / Intermediate Survey	Hatch cover lids, runners and guides, fwd tank top, bulkhead and stingers, frames. Aft bulkhead repairs, hold frames, DB tanks P fwd stiffeners, insert plate P fwd, main deck aft beam renewal, centre, main hatch beam girder repair, UTM report advises "stiffening added to frames to compensate for thickness".
2006	29	Leipaja / Special Survey	UTM completed, hatch coaming repairs, hatch lids renewed, DB structure #1-4 P/S/CL extensive repairs incl. longitudinal, lower frames, bottom framework, deck longitudinal, tanktop plate, CL bulkhead, bottom plate (CL), FO tank repairs no's 2 and 3 P/S, renewal of shell plate stbd, bottom & side (15 locations), bulwark repairs, hold frames repair / replace (total 58 locations P, 31 S). Repair cracks both sides (5 locations, total length 3960mm). Repair hold stringers P/S (x 8), Aft hold bulkhead steel replacements, forecastle deck plating & framework iwo windlass replaced, Aft Peak tank steel and framing renewal, Fore peak tank bulkhead/frames, plating renewed,
2009	32	Kaliningrad / Intermediate & Initial.	Main deck at fwd superstructure bulkhead, & iwo forepeak. Hold frames on CL (6 locations), Port (17), Stbd (37), cargo hold shell plate, stbd side fr 23 – 37, complete renewal of CL

			bulkhead in hold aft. Repair cracked bottom longitudinal (13 locations), hatch coamings, bulwarks, outer shell plating at bottom stbd (21 locations), Stbd fwd side shell (x 9), Port fwd side shell (x9). Bilge keel P/S. Repair hold frames P (x 4) / S (x17), side shell plating P fwd & stiffeners, fwd bulkhead fr 106, Under-deck stiffeners, side frames P (x 3), Port outer plating fr 24-35 iwo bulkhead – repair pit corrosion, Trans. bulkhead at fr 24-31, repair damaged hold frames P (x2), S (x10), main deck plate at Fr25-30, 100-102.
2010-11	33-34	N/A	No evidence of any repairs conducted.

Table 1 – Summary of Major Repair Periods

4.4.3. As can be seen from Table 1, MV SWANLAND underwent extensive repairs throughout her service life with repeated repairs to the following areas. These were repeatedly identified and reported during her Classification Hull Surveys and Conditions of Class were imposed requiring repairs to be effected:

- Cargo hold transverse frames (webs and faces) and associated plating due to 'mechanical' damage and wastage of material;
- Side shell plating damage;
- Bottom plating and associated stiffeners / structure due to grounding damages and / or buckling;
- Cracks to bottom longitudinals in double bottom;
- Deck plating and under-deck stiffeners;
- Forward and aft cargo hold transverse bulkheads;
- Tank top plate due to heavy corrosion;
- Hatch coamings and bulwarks;
- Cracked and corroded welds;
- Localised cracking.

4.4.4. Figures A.2 (a) – (l) in Appendix A present this schematically in profile and tank-top plan views (A.2(a) – (i)) and sections at frames 56, 58 and 60 (A.2 (k) – (l)) for each repair period from 2009 to 1997 and prior years.

4.5 Cargoes Carried

4.5.1. Records exist and have been provided for the cargoes carried and voyage details for the period from 2003 to the accident voyage. It is understood that prior to 2003, MV SWANLAND was freight managed by another company, Torbulk Ltd being her freight managers from 2003 and technical managers from 1996.

4.5.2. In this period, MV SWANLAND carried a range of bulk cargoes, ranging from agricultural products such as wheat and barley, to aggregates such as limestone, sand or gravel and by-products from industrial processes such as various types of furnace ashes and slag.

4.5.3. Included within the cargoes carried are a number of potentially corrosive cargoes including Furnace Bottom Ash (FBA), Potash, Clinker and Salt. Also, of note is that a number of the cargoes carried are abrasive materials including HTCR, Type-1 Limestone[5], asphalt and limestone.

4.5.4. Figure 4 above shows the number of days that each cargo type was carried in the calendar years 2009 – 2011 for which the most complete records are available.

4.5.5. In 2009, the cargoes were primarily Wheat, Type-1, Asphalt, Aggregate and Salt. Wheat is a benign cargo with regard to corrosion or abrasion, although it has dangers with regard to cargo shifting and vessel stability. The other primary cargoes carried are all either abrasive or potentially corrosive.

4.5.6. In 2010, the cargoes were primarily Wheat, Barley, Type-1 and Salt with a greater spread of other cargoes. The number of days for which salt was carried (52) was almost double that of the previous and subsequent year, coinciding with the bad winter experienced in 2010 in the UK and increased demand for road gritting salt by local councils[6]. Salt is a potentially corrosive cargo as defined by the IMSBC Code[7]. Type-1 and a number of other cargoes carried are all abrasive cargoes.

4.5.7. In 2011, a wider range of cargoes was carried, although primarily Aggregate, Limestone, Wheat and Salt. Again, wheat is benign as far as direct ship structural matters are concerned, but the other cargoes are abrasive and in the case of salt, corrosive under the right circumstances.

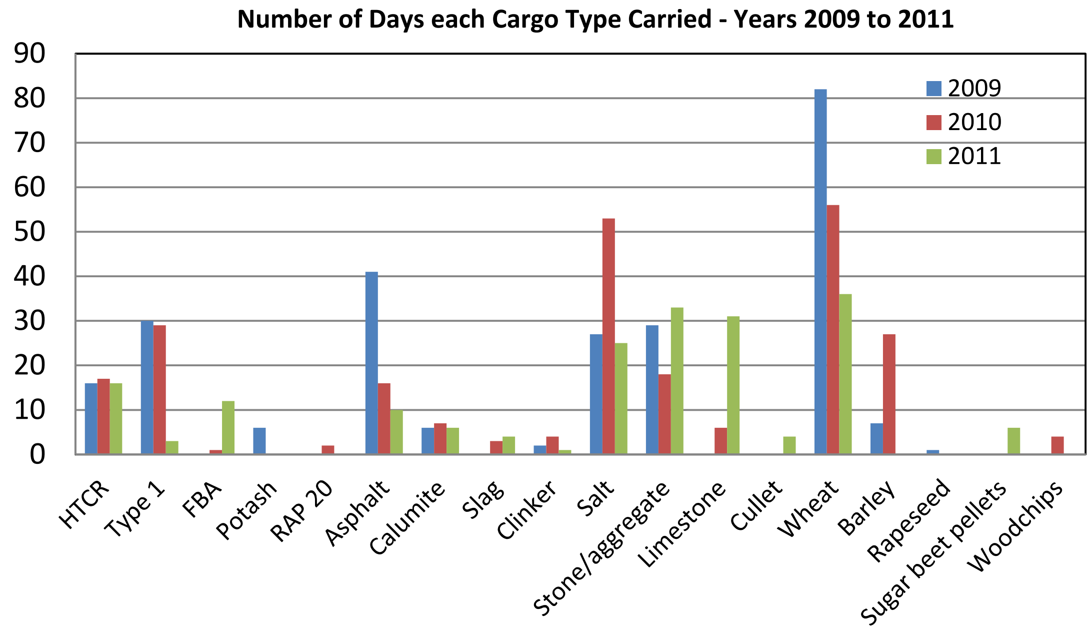

Figure 4 –Days Each Cargo Type Carried by MV SWANLAND, 2009-2011[8]

[5] HTCR is High Temperature Crushed Rock. Type-1 is a type of aggregate typically used in road construction.

[6] See http://en.wikipedia.org/wiki/Winter_of_2010%E2%80%932011_in_Great_Britain_and_Ireland, http://www.metoffice.gov.uk/climate/uk/2011/winter.html, http://www.guardian.co.uk/uk/2010/jan/10/sub-zero-grit-supplies-snow.

[7] International Maritime Solid Bulk Cargoes (IMSBC) Code.

[8] FBA is Furnace Bottom Ash, also a by-product of coal burning and is often used as a construction material , RAP 20 is Reclaimed Asphalt Pavement and is used in road construction.

5. ANALYSIS AND REVIEW OF THE STRUCTURAL HISTORY OF MV SWANLAND

5.1. Structural Design

5.1.1. In accordance with the MAIB Specification of Work, we have examined the structural design of the MV SWANLAND with regard to:

i. The appropriateness of the vessel's original structural design including the framing system;

ii. How common this particular structural design is for dry cargo vessels of this size and type;

iii. The reason(s) for the plated-in frames at frame numbers 64-66 in way of the cargo hold;

iv. The reason(s) for the additional strengthening at frame numbers 46-48 and 82-84 in way of the cargo hold;

5.1.2. There are two principal types of framing system used in ship design: transverse framing and longitudinal framing. Ship designs, in principle, could be exclusively one or the other, but more usually incorporate both systems for different parts of the vessels' structure.

5.1.3. A transverse framing system is one where the outer shell plating is supported only by vertically aligned frames, as illustrated in Figure 5(a) for side shell structure. A longitudinal framing system is one where the outer shell plating is supported predominantly by longitudinal frames as shown in Figure 5(b). A longitudinally framed structure, though, will often have transverse frames as well, although these will be at a much greater separation than in a purely transversely framed ship. As these transverse frames have to pick up the load from the longitudinals, they will generally be deeper than the frames of a transversely framed structure.

5.1.4. A ship's shell plating and its associated framing (i.e. its stiffening system) generally serve several purposes at once, the significance of each being dependent upon the position of the structure within the hull. These purposes, or functions, are:

- To keep the water out;
- To provide structural rigidity against transverse loads on the outside (hydrostatic water pressure, wave impact pressure, normal contact loads from tugs, etc.) and cargo loads on the inside;
- To contribute to the ship's overall strength to withstand longitudinal bending moments, shear forces, torsional moments, and racking loads.

5.1.5. There is nothing inherently right or wrong about either framing system. However, for a specific application or area in a vessel it is likely that one system will be more efficient than the other – i.e. will support the same loads with less weight of structure. This, however, may have to be balanced against structural complexity and ease of construction.

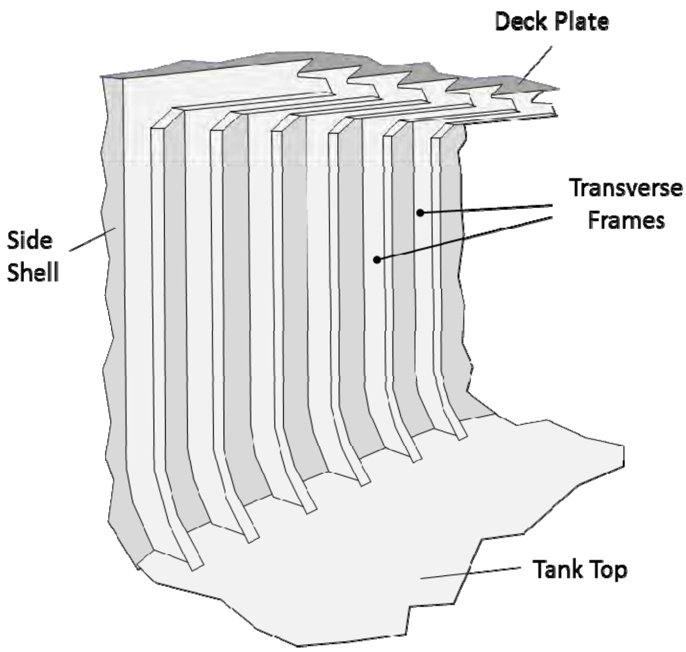

Figure 5(a) - Transverse Framing on a Side-Shell

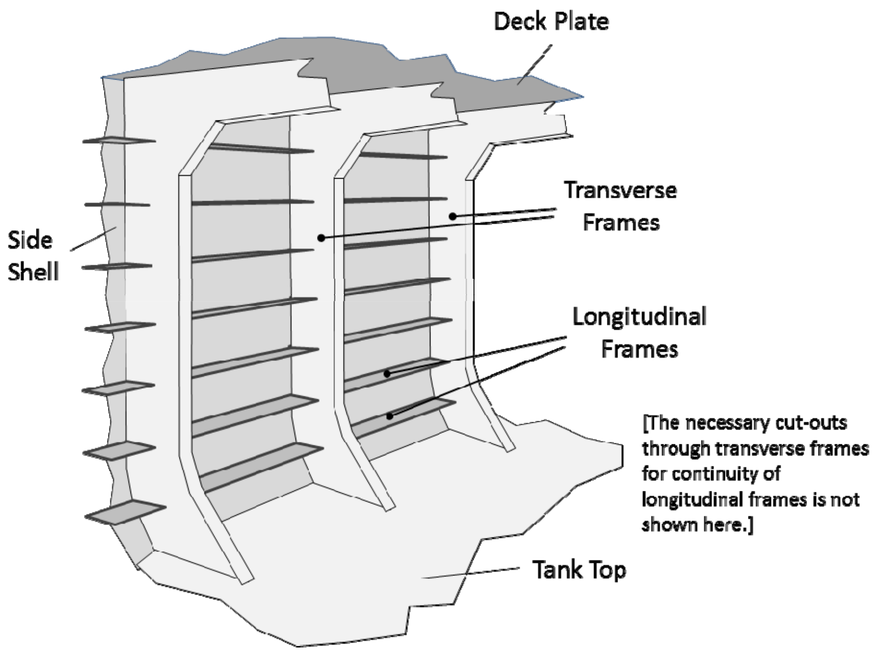

Figure 5(b) - Longitudinal Framing on a Side-Shell

5.1.6. By studying the structural drawings of the MV SWANLAND in the mid-body area, it can be seen that the bottom structure is an enclosed “double-bottom” structure with longitudinal and transverse floors, rather than an open framed system. This is entirely usual and appropriate for coastal vessels which sometimes have to take the ground in drying-out berths during their service and therefore need additional rigidity and strength in the bottom area. A double-bottom structure additionally, and importantly, adds some level of protection against uncontrolled flooding of the one or two holds of such vessels should a breach occur through bottom contact.

5.1.7. The structural drawings and photographs available show that the side shell in way of the hold is transversely framed. This is very common for this type and size of vessel. Even with large hatch openings and relatively narrow main deck at the sides, the overall bending moments on ships of this size are such that they can normally be absorbed by plating contributions to the ship's midship section modulus, without having to gain more longitudinal structure through the use of longitudinal frames on the side shell. Transverse framing in a side shell is easier to construct, and although through calculation it might be less efficient than an equivalent longitudinally framed system, it can have the advantage of less encroachment into the "free" or unobstructed hold space.

5.1.8. The particular implementation of transverse framing in the MV SWANLAND was a series of flanged plate frames, with alternate frames being half the depth of the others. With this arrangement, the deeper frames would have carried the bulk of the transverse pressure loading on the side, transmitting this load to the bottom and deck structures. The smaller frames were likely included to prevent shear buckling of the plating occurring between the larger frames as a result of overall hull-girder shear forces, as well as to increase the "effective width" of the shell plating's contribution to the larger frames' strength by stabilising the plating mid-span between main frames.

5.1.9. Breaking the general pattern of alternately sized open frames, the three frames 64-66 in way of the cross-deck beam between hatch openings at the mid-length of the single hold were of equal (large) size and plated-in to form a vertical box section. The structural drawings show that there was a fuller connection of these three frames to the double bottom structure at the side, with structural continuity in way of the plated-in flanges extending below the tanktop plating. The combination of these boxed frames and the cross-deck beam formed a portal frame that was purposefully "built-in" to the tank top structure. The scantlings of this portal frame would have been chosen to provide strength in the midship area against racking loads (a tendency for the main deck to move laterally with respect to the tank-top), a job that a transverse bulkhead would otherwise do. The original web thickness of these 3 frames is 10mm compared to 8mm for all other frames between fr46-84. All other frames are 7mm, except fr 30-31 and fr 99-100 which are also 8mm.

5.1.10. The plating in of the three frames at numbers 64-66, although creating a strong 'portal' frame, would have had an added effect of creating an enclosed space inside the 'box' within which it is possible that corrosion could develop, due to the inaccessibility of the internal structure for maintenance and the potential development of an atmosphere internally conducive to corrosion. Access holes are identified on the relevant structural drawing, but it would have been difficult to access for any meaningful maintenance.

5.1.11. The structural drawings further show that at two other locations – frames 46-48 and 82-84 – the frames are similarly of equal (large) size and similarly built-in to the tank-top structure in a more rigid way than the other side shell frames, but the flanges of the three frames are not plated-in. These locations correspond to the mid-length of the hatch openings. It appears that these additional cantilever-like supports projecting from the tank-top would have assisted the boxed frames at 64-66 in supporting the narrow main deck strips against lateral movement generally. The arrangement of these higher strength frames is illustrated in Figure 6.

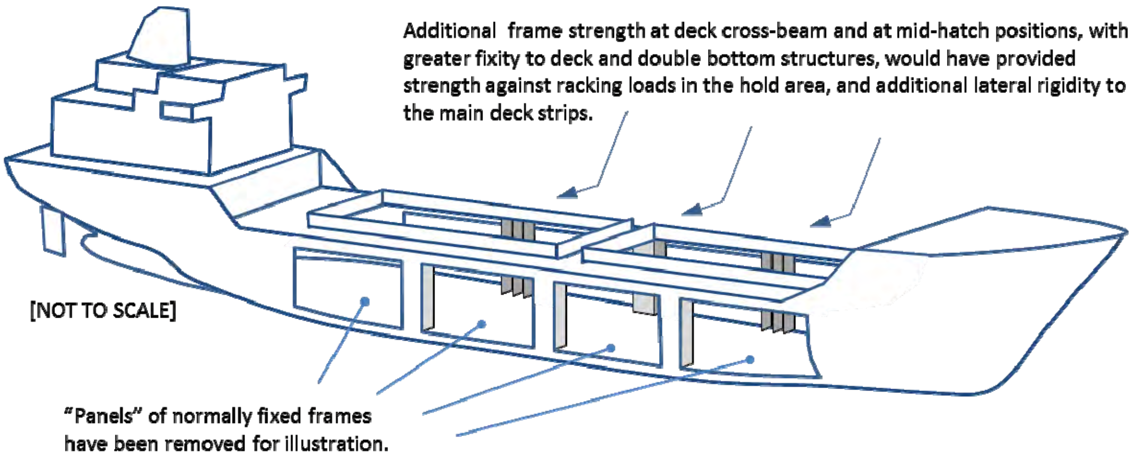

Figure 6 - Arrangement of Higher Strength Frames

5.1.12. In 2003, with the addition of the conveyor and hopper system to enable self-discharge, a moveable carriage was added to the main deck on which an excavator was situated. The carriage was moveable up and down the length of the hold on a rail located either side of the Port and Starboard longitudinal hatch coaming, approximately 300mm outboard of the coaming and slightly raised off the deck plate (see Figure 7 below). The date of the photograph in Figure 7 is not known, but the build up of scale and loose material can clearly be seen underneath the rail and in between the hatch coaming stays. As such areas become blocked or clogged, they can create water traps and over time, areas of localised corrosion. It is also notable that the welds joining the rail to the supports on the main deck are new, suggesting that the rail has torn away from the deck supports at some point, or that the previous welds had failed.

Figure 7 - Excavator Carriage Rail

5.1.13. Further, it can be expected that the vessel would have experienced water on deck during rough weather. Her available freeboard when fully loaded in compliance with the required Classification Society rules was 990mm.

5.1.14. It was reported that prior to the sinking of the vessel, waves were breaking over the deck, once the vessel was not head on to the waves. In normal operation, any such water on deck may have become trapped around the various constructions on deck such as the excavator rail. This would lead to corrosion problems unless the water is properly freed from the deck. It is notable that MV SWANLAND had freeing ports running the full length of the main deck within the bulwarks. See Figure 1(a) which demonstrates the low freeboard in rough weather.

5.2. Effect of Repairs and Modifications

5.2.1. As presented in Section 4.4 and Table 1, MV SWANLAND was subject to extensive repairs over her service life. She was classified as a 'General Cargo', but based on the record of cargoes carried since 2009 and previous intermittent records she was primarily operating as a dry bulk carrier on coastal trades.

5.2.2. The problems with dry bulk carriers with regard to maintenance, corrosion and structural failures are well known (Reference 1) and hence the extent and nature of the repairs is somewhat to be expected. As with all dry-bulk carriers, the cargo can only be discharged mechanically with the assistance of cranes, bucket grabs, excavators and similar devices. MV SWANLAND was fitted in 2003 with a dedicated excavator which was used to lift cargo from the hold into the hopper on the port side main deck, from which the cargo could be discharged via the conveyor system. A 'Bobcat' wheeled loader was used in the hold to move cargo into suitable piles for the excavator to pick up. Prior to 2003, MV SWANLAND would have discharged cargo by use of shore cranes and grabs or excavators.

5.2.3. As with any mechanical system of picking up and moving cargo in the hold, the grabs can impact the vessel's structure causing mechanical damage such as dents, localised buckling of stiffener webs and faces, dishing of plating (especially tank top). An added effect of this 'contact' damage is that protective coatings are quickly damaged and lost, therefore exposing the bare metal.

5.2.4. Loading dry bulk cargoes can also cause problems with mechanical damage to the vessel structure. With abrasive cargoes and those with higher unit / particle size such as limestone, damage may also occur due to impact and abrasion during loading. Careful loading is therefore required for such cargoes (e.g. no free-fall drops) to avoid or minimise damage to the vessel's hold structure.

5.2.5. In this context, it is common in our experience, for bulk carriers (or vessels carrying dry bulk cargoes) to require regular and often substantial maintenance work on the vessel's structure including periodic renewal of structure. The type of operation or trade that the vessel is engaged in can often affect the required level of maintenance. For example, an iron ore carrier engaged in primarily long trans-continental voyages will be subjected to loading and discharging approximately once every 35 – 40 days. Conversely, a vessel such as the MV SWANLAND who was engaged in short (often 1 – 2 days) voyages around the UK and Northern Europe will be subjected to loading and discharge much more regularly and so the propensity for build-up of this kind of mechanical damage increases.

5.2.6. With these shorter voyage durations and short port turnarounds, the opportunities for the required level of hold preparation (e.g. cleaning and coating) are significantly reduced. Based on the records available for cargoes carried, it appears that MV SWANLAND rarely operated on alternate loaded / ballast voyages as she was carrying varying cargoes between different ports, often within 1 day of discharge of the previous cargo. For example, in 2011, a sequence of cargoes was as follows in Table 2:

Load Date	Discharge Date	Cargo	Load Port	Discharge Port
09/02/11	11/02/11	Granulated Asphalt	Dordecht	Ipswich
11/02/11	13/02/11	Cement Clinker	Dunkirk	Purfleet
16/02/11	23/02/11	Wheat	Boston	Warrenpoint
24/02/11	26/02/11	Salt	Kilroot	Ellesmere Port
26/02/11	04/03/11	Limestone	Raynes Jetty	Cowes

Table 2 – Example Sequence of Cargoes

5.2.7. By way of further example, for a period in the winter of 2010, MV SWANLAND was engaged in carrying rock salt from Kilroot to Liverpool / Ellesmere Port coinciding with the heavy snowfall and icy conditions at the time. The duration of each voyage was approximately 1 day and at a time when the cargo was in heavy demand.

5.2.8. Consequently, it is likely in our opinion, that the nature of the trade that MV SWANLAND was engaged in did not lend itself to full and proper hold cleaning and coating. This would have been exacerbated by the mechanical damage incurred during loading and discharging and resulted in regular and significant damage and corrosion to the vessel’s structure, as borne out by the summary of repairs in Table 1.

5.2.9. The overall effect is therefore one that means that the primary structure of MV SWANLAND was likely in a weakened state for much of her operational life. Periodically or whenever component parts of the structure became critical, repairs would ensure some strength is regained, however because older structure that is perhaps not as heavily damaged still exists around the new structure it is unlikely that the original overall strength is ever regained.

5.2.10. For example, replacing a segment of tank-top plate adjacent to one that has corroded but is still within the accepted limits, creates a relative weak point and potentially enables corrosion to develop adjacent to the seam due to the plate thickness differences (unless suitably faired). So, even though substantial parts of the vessel have been gradually repaired or replaced, its overall strength is still only as good as its weaker points. Figure 8 shows how the structural reliability of a vessel can degrade over time (Reference 2) following the cumulative effect of repairs over time. The variable R(t) shown in the graph is a reliability function describing the ability of the ship's primary structure to resist the forces placed upon with the influence of corrosion and cracks.

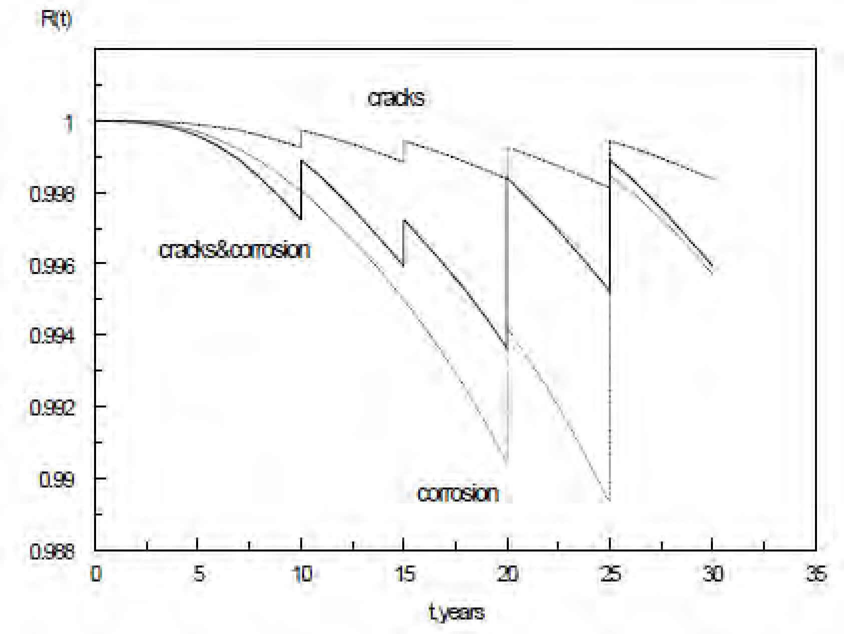

Figure 8–Loss of Structural Reliability with time after Cumulative Repairs

5.2.11. A large number of repairs were made to the bottom structure of the vessel. These repairs appear to have been required for two principal reasons. Firstly, the MV SWANLAND had grounded a number of times and the 'set-up' bottom plates and buckled stiffeners were therefore necessarily replaced. Secondly and perhaps most importantly, the assumed original coating in the Double Bottom (DB) tanks used for water ballast had broken down and consequently the associated bottom structure was reducing in structural capacity through corrosion. This is first referred to in the 1992 survey at Piraeus (BV classed), with a requirement for annual inspection of the ballast tanks. Subsequently, in 2000 at the LR survey in Grangemouth the coatings were rated as 'FAIR', suggesting a reinstatement of coatings. However since 2000, no new coatings are believed to have been applied and LR required annual inspection of the tanks at each survey due to concerns over heavy corrosion. The amount of repairs required is therefore self-evident with ongoing use as sea-water ballast over a number of years.

5.2.12. In 1992, when the vessel was 15 years old, ultrasonic thickness measurements (UTM) were taken at the Special Survey (No.3) whilst under Bureau Veritas (BV) Classification. In general the thickness reductions reported are not significant (5% or less), which in our experience, may be considered normal and within expected ranges for a well-maintained ship of her age at the time. Around this time, the vessel had experienced a grounding, requiring extensive bottom renewals (fr's 25-89, keel, 1st, 2nd and 3rd strakes, P/S) with new plating 10mm thick (1mm thicker than the original). It would be common practice in way of these bottom and double bottom plates that all of the attached longitudinal members, frames, brackets, girders and floors were also renewed.

5.2.13. At the same time the entire tank top plating (fr's 32-82 excl. shear strakes) was renewed with original thickness plates of 17mm. The cargo hold was de-rusted by High Pressure (HP) jet and fully coated.

5.2.14. Given the extensive repairs, all in the presence of the BV surveyor, it would be reasonable to assume that the repairs were satisfactory and that after the 1992 dry-docking the vessel was in a sound structural condition.

5.2.15. In 1997, at the special survey carried out in Hull, UK under BV classification, all of the structural tanks and spaces were reported to be internally inspected and pressure tested. Reviewing the Class records and bearing in mind that 5 years earlier in 1992 almost all of the double bottom structure in 0.5L in way of the cargo hold was renewed and that no steel repairs of note were carried out, we would consider that vessel would still be in a sound structural condition.

5.2.16. In 2000 at the survey in Grangemouth under LR classification, the vessel satisfactorily underwent a docking survey when sea water ballast tanks were examined and coatings rated as "FAIR". Prior to this, the references to structural defects, wastages or cracks are minimal, so considering the evaluation as "FAIR" of the coating condition by the LR surveyor, it would be reasonable to assume that the overhaul thickness of vessel's steelwork would still be in a satisfactory condition.

5.2.17. In the LR Enhanced Survey Programme (ESP) for Bulk and Ore Carriers (Reference 3) a "FAIR" coating condition is described as "*Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for POOR condition".* We consider that upon being given a "FAIR" rating a plan should be immediately implemented for coating improvement in the water ballast tanks.

5.2.18. In January 2002, the LR Class survey found the cross deck plating near to midships, between the hatches with substantial diminution. At the time, a 10 metre by 1.2 metre section of deck plate was cropped out and renewed. This is an area of high stress and given the design of the vessel and large single hold, an area that had to provide the resistance to transverse and racking loads.

5.2.19. At April 2002, corroded longitudinals were found with substantial thickness diminution. A year later the hatch covers cross joint seal retaining bars were heavily corroded and were cropped out and renewed accordingly.

5.2.20. Also in April 2002, a condition survey was carried out in Bari, Italy on behalf of the owner's Protection & Indemnity (P&I) club, The Shipowners' Mutual Protection and Indemnity Association. The condition survey is required annually by the P&I Club and is designed to establish the basic risk profile of the vessel from an insurance perspective. It is notable that following review of the condition survey report, the P&I Club attached their Standard Warranty Clause to the policy for MV SWANLAND. This means that, in the event that a claim is made that arises wholly or in part from any of the listed defects in the condition survey report, the P&I Club will not pay the claim. This demonstrates that the P&I Club would have had significant concerns about the condition of the vessel.

5.2.21. The structural condition of MV SWANLAND at this survey was found to be 'poor' and the P&I Club made a strong recommendation for a maintenance programme to be implemented. There was no evidence of a Planned Maintenance System and substantial diminution was noted in the structure. The attending surveyor stated that 'excessive corrosion' existed in the main deck and hold frames, and that the general condition was 'poor'.

5.2.22. In September 2002, a further condition survey was carried out on behalf of the Hull & Machinery insurers of MV SWANLAND at Amsterdam. The attending surveyor noted that the condition of the coatings was generally 'poor' (especially in the cargo hold spaces). The cargo hold side frames were noted as 'serviceable and repaired regularly'. The main deck structure was reported to have slight corrosion and the tank top plating was reported as set-in between frames. No inspections were made of the ballast tanks.

5.2.23. In March 2003, the vessel was fitted with rail, carriage, hopper and conveyor for self cargo discharging. At that time, already some substantial diminution was found in the DB floors. A year earlier in 2002, an ISM audit raised a major non conformity as the maintenance and inspection recording regime onboard did not include obvious faults sighted during the 2002 audit such as numerous cracks found in the port and starboard bulwark stanchions. The Class surveyor also found various internal members within the aft peak tank with substantial diminution, including doubler plates fitted along with other defects. Deck beams at fr's 27, 75, 77, 87, 89; upper and lower brackets from fr's 25 to 89, various web frames from fr 27 to 100 all inside the cargo holds were extensively repaired by inserts. In many cases this was due to wastage.

5.2.24. The next annual condition survey on behalf of the P&I Club of MV SWANLAND was conducted at Ipswich in April 2003, after the modification to fit the self discharging conveyor system and the associated repairs carried out at the same time. The attending surveyor noted that the vessel was generally in a satisfactory condition and that the vessel's primary structure was generally free of wastage and corrosion. However the survey report goes on to say that the hatch comings had 'large areas of rust breaking through, but were free of corrosion'. No inspections were made of the cargo hold or ballast tanks.

5.2.25. It is clear that in April 2002, the attending surveyor and the P&I Club had serious reservations about the structural condition of MV SWANLAND and it should be highlighted that this survey took place after the repairs undertaken at Bijela in March 2002. The subsequent P&I condition survey in April 2003 was after the conversion and repairs undertaken at Reimerswaal in March 2003. In this case, the condition was found to be generally satisfactory. At the Hull & Machinery condition survey in September 2002, evidence of corrosion and mechanical damage was noted and the condition of the coatings was reported as 'poor', but no adverse comment was made about the vessel's sea-worthiness at the time.

5.2.26. There is some contradiction in the available condition survey reports (no survey reports have been made available for years after 2003), which in our experience is not uncommon. Condition surveys for insurance purposes can often be performed quickly when the vessel is completing cargo operations (for example) and as such they naturally can only provide an overview of the condition of the ship, its management and operation. They cannot and do not provide a detailed structural condition assessment in the way that a UTM survey does and because they are conducted by different surveyors, there can be an element of subjectivity to their outcomes. Accordingly, it is difficult to draw firm conclusions from the available condition surveys, but they do provide evidence of a poor structural condition of MV SWANLAND at various times.

5.2.27. At the Intermediate survey in March 2005 at Great Yarmouth, it was noted that all water ballast tanks were to be 'examined internally and gauged as necessary at each annual survey'.

5.2.28. In June 2006 at the time of Special Survey, various internal members inside the fore peak tank were found with substantial corrosion. Inside WBT DB No.4 port and starboard the longitudinal bulkheads were renewed between fr's 24-33 due to wastage and holes found. The same occurred in the WBT DB No.1 port and No.2 starboard between fr's 96-104. Other ballast tanks, cargo hold and deck structure was reported to have experienced repairs and/or to be wasted thus to be specially examined/gauged and dealt with as necessary. The wasted and hold plates were as reported widely spread along the structure including the cargo hold hatch covers.

5.2.29. In October 2006 substantial corrosion was noted in the port and starboard side shell in way of wind and water strakes connected with the cargo hold. The LR surveyor required these areas (as described in Section 4.3.12) to be examined and gauged annually, although the subject areas were considered to remain within allowable limits. The ballast tanks were internally examined and reported with "FAIR" structure and "POOR" coating. Substantial corrosion was noted in the following areas as stated in the 2006 UTM Report:

- Starboard side shell plate 1st strake A5-A7 fr 52–72 and B4-1, B5 fr 28 – 33, 39-50, plus various small dents in bow section, above waterline;
- Portside side shell 1st strake, A4, A5-2 fr 35 – 65 and A9-2 fr 97-104, plus keel strake fr 97-106, various small dented areas forward.
- Numerous side shell frames inside the cargo hold were found damaged and noted wasted. On the Port side, damage /wastage was noted at frames 26, 30, 31, 40, 42, 54, 56, 70, 82, 83, 92, 100 and 104 and marked as requiring repair. In particular this included damage / wastage to the 'base' areas of the frame at the connection to the tank top inside the cargo hold, lower half of the frames and in some cases (fr's 30, 54, 56, 70, 104) this included up to ~80% of the frame requiring repair. On the starboard side, damage/wastage was noted at frames 28, 31, 32, 34, 40, 42, 52, 54, 56, 58, 60, 72, 74, 76, 80, 83, 88, 90, 92, 96, 97, 104 and marked as requiring repair. Again, these frames had experienced damage to the 'base' areas in way of the tank top, lower and top sections of the frame and up to ~80% of the frame (fr's 54, 56, 58, 60, 72, 80, 96). It is notable

that the majority of the damage/wastage noted was to the deeper (and hence more exposed) even numbered frames.

- Double bottom transverse frames at fr's 36, 40 48, 52, 56, 64, 72, 76. Smaller and more localised areas of damage/wastage were also noted on other frames.
- Double bottom longitudinal girders number 1 at fr 83-106, port and starboard, number 2 port at fr 24-40 and 83-96, starboard at fr 24-32, 37-40 and 83-102.
- Tank top plating at fr's 86-94 port and starboard.
- Main deck bulwark stays portside found thin in connection to the upper deck plating.
- Transverse cargo hatch coamings at fr 31, 64 and 99 (requiring complete replacement) and localised damage at fr 66.
- All hatch covers and linings in hold number 1 and 2. This is mostly to the hatch cover lining and the areas in way of the transverse 'fold' between panels.

5.2.30. During the Annual Survey in March 2007, wasted sections of frames and associated stringers inside the aft peak tank were found in way of the longitudinal bulkhead, which was subject to repairs by cropping and inserts. On the same survey, ballast line leaks were noted in DB No.4 tank which is indicative of corrosion in the ballast line system. Damage was also observed to a number of the side shell frames in the cargo hold, which were subsequently repaired.

5.2.31. At the Annual Survey in June 2008 at Great Yarmouth, the repairs were confirmed for the renewal of six side frames (47, 48, 70, 86, 91, 94) on the port side inside the cargo hold and also thirteen web frames on starboard side (33, 44, 50, 52, 58, 68, 72, 76, 80, 84, 86, 88, 92). At the same time, main deck bulwark stays (port) were found cracked in connection with upper deck. These damages are reported to have been caused due to wastage.

5.2.32. In June 2008 at Ipswich, the vessel tanks were again inspected and confirmed the earlier recommendation of 2005, that the tanks were to be internally examined and gauged (UTM) as found necessary by the attending surveyor at each annual survey. The coating was stated to 'remain in poor condition'.

5.2.33. It was reported that the vessel grounded on sand on 8th April 2009 whilst departing Boston, UK. Upon soundings, it was confirmed that no tanks had been ruptured, but the internal examination by the LR Surveyor revealed several cracks associated with general wastage in the bottom longitudinal members, as follows:

- DB No.2 Stbd 1st and 2nd longitudinal at frame #64;
- DB No.2 Port 1st and 2nd longitudinal at frame #79;
- DB No.3 Stbd 1st and 2nd and 3rd longitudinal at frame #55 (near midships);
- DB No.4 Stbd 1st longitudinal at frame #37;

5.2.34. Although the structure was considered by Class to remain efficient, as a consequence, a condition of class was imposed with a very restricted window for repairs. The Owners reportedly then decided to bring forward the next scheduled dry docking, at Kaliningrad. This then coincided with the change of Classification Society and Flag state to INSB and Cooks Islands respectively.

5.2.35. The cracks in longitudinal members connected to the bottom shell in regions close to the midships are of high significance. As soon as a crack reaches the shell plating it propagates rapidly due to the high bending moments imposed in that region, eventually creating a serious structural failure. The fact that the cracks were reported to be due to wear and tear and not misalignments or localised stresses increases the concern as any other cracks not evident at the time of this survey may soon have appeared subsequently and quickly become serious. Figure 8 shows examples (not of MV SWANLAND) of cracks in longitudinal stiffeners in way of the bottom shell plating.

Figure 8 - Examples of Cracks in Bottom Longitudinal Members (Not MV SWANLAND)

5.3. Corrosion / Diminution

5.3.1. It is not the purpose of this report to provide a full explanation of corrosion and its effects on ship structural strength. It is sufficient to say that corrosion in structures operating in the marine environment is inevitable to a greater or lesser extent and that it is to be prevented as far as practically possible. Various methods are available to the ship-owner to protect a ship and its structure from the effects of the varying forms of corrosion, but by far the most common is painting or coating of a structure to provide a protective layer over the bare structure. It should then be self-evident that prevention of corrosion can only occur as long as that protective layer is intact and maintained

5.3.2. In theory, if correctly coated and the coating is well maintained, there should be no corrosion and hence no loss of material. Loss of material is the important factor in trying to retain structural strength as with any structural member, it is the amount of material present and its position on that member that is the critical factor in the strength of the member.

5.3.3. The rate of corrosion that a ship suffers depends on many variables including location of the structural member, the localised atmosphere, moisture, cargo carried (chemical composition and propensity to reactions), air temperature, material type and protection system (e.g. anodes, coatings). The prediction of actual corrosion rates in a particular case is therefore very difficult and near impossible with any certainty. In the case of the MV SWANLAND, we have very little evidence other than general factors relevant to corrosion issues and hence it is simply not possible to be definitive with regard to the types and rate of corrosion that may have occurred in order to develop a complete picture of the condition of the ship at the time of its loss.

5.3.4. Classification Societies have developed models for predicting corrosion rates for the application of setting diminution limits on hull structures. However, such models generally only apply to so-called 'general corrosion' and not pitting, grooving or edge corrosion types (Reference 4).

5.3.5. A literature search on corrosion rates for particular scenarios was carried out and resulted in some figures that can be used to provide guidance on potential corrosion rates for MV SWANLAND but cannot be taken with any certainty due to the number of variables and lack of evidence involved.

5.3.6. It is known that MV SWANLAND carried a number of cargoes that are potentially corrosive such as salt, or abrasive such as various aggregates (see Section 3.5). The periods in which salt was carried are of particular interest because of the nature of the voyages and external circumstances at the time. It is known that salt was carried for 105 voyage days between 2009 and 2011(calendar years) with a peak of 53 days in 2010. These voyages were of short duration (approx. 1 day) between Northern Ireland and Liverpool (or similar). Based on the demand from local councils for salt and the repeated short journeys in a period of bad weather and snowy conditions, it is likely that significant moisture was present in the cargo hold over a prolonged period. This would increase the likelihood of corrosion to the hold structure, which would be further exacerbated with mechanical damage or lack of coating to the structure.

5.3.7. Figure 9 below shows two photographs showing the conditions at the time with rain and snow and residual cargo on the vessel's deck structure. It is likely that similar residual cargo and moisture existed in the hold enabling a period of potentially accelerated corrosion of the vessel's structure.

Figure 9 – Operating Conditions during Period of Carrying Salt.

5.3.8. Hence, examining the potential corrosion rates with 'Class' general corrosion rates and specific data for road salt, we find the following:

- DNV data (Ref. 4) suggests typical material loss rates between 0.09 and 0.15 mm/year for different parts of the structure;

- Gardiner and Melchers (Ref. 5) suggest figures of 0.23 – 0.4 mm/year (but this is specific to different cargo types, not salt);
- Houska (Ref. 6) suggests that in high corrosive environments (e.g. with high moisture levels) salt corrosion may result in wastage up to 2.19 mm/year.

5.3.9. Hence, applying this data to the diminution data in the 2009 UTM report, an estimate of potential diminution at the time of the sinking can be made. If we take a plate of 7mm original thickness (say) and a diminution reading in 2009 of 1.05mm (15%), then add the general corrosion rate over the period 2009 – 2011 (from standard Classification Society data (Ref. 4) plus the salt specific corrosion from Houska (Ref. 6) for the relevant duration of salt carrying voyages (105 days), the percentage material loss in that time increases to 30%. Since the classification society limits for diminution are 25% or 30%[9] for a vessel such as MV SWANLAND, the plate would potentially have needed to be replaced before 2011 under the Classification Society rules (INSB), based on the assumed corrosion rates applied between June 2009 and November 2011. This does not include any allowance for grooving or pitting corrosion which could create localised areas of substantial material loss and relates to plate in way of the cargo hold.

5.3.10. Further examination of the original scantlings, diminutions recorded at the 2009 UTM and the potential change in thickness by 2011 due to corrosion shows that all recorded diminutions over 15% have the potential to have become substantial[10] (i.e. greater than 75% of the diminution limit) . This would activate the requirement for further UTM (Part I, Ch. 3, 11.1.5 of the 2008 INSB Rules) and remedial actions to repair and/ or renew. We are not aware of any evidence that this requirement was activated.

5.3.11. Corrosion rates for the cargo hold structure may be further increased by the constant abrasion due to cargo operations. Since the corrosion process requires the chemical reaction to take place at the metal surface, the corrosion rate tends to slow as layers of scale or rust build up. Consequently if that layer of scale is removed, the bare metal is exposed again and the chemical reaction is able to take place in full contact with the metal surface so increasing the rate of corrosion.

[9] INSB Rules and Regulations for the Classification and Construction of Steel Ships, Part I, Chapter 3, Section 11, Table C

[10] 'Substantial' corrosion is defined by INSB (INSB 2008 Rules, Part I, Ch.5, 1.2.1) as 'an extent of corrosion with wastage in excess of 75% of the allowable margin, but within acceptable limits'. Note that this is defined in the section concerning bulk carriers, but the term 'substantial' is used throughout in the same context. IACS UR Z7.1 also defines substantial corrosion in the same manner, specifically in relation to general dry cargo ships.

5.3.12. The 2009 UTM report shows substantial renewals were made in the following areas (Figure A.3 (a) – (d) presents this schematically):

- In way of the bottom plating, (fr72-80, 24-56, stbd side);
- Main deck plate forward, main deck aft of aft hatch;
- Hold centre-line partial bulkhead aft;
- Transverse hatch coaming stays at fr66;
- Hold transverse frames at fr 33, 35, 38, 48, 74, 76, 83 - 93, 95, 96, 98, 99-104 stbd side and 58, 68, 74, 78, 96, 98 port side;
- Areas of DBT transverse plate at fr 28, 32, 72, 76 stbd, 32, 36, 90, 92, port, bottom girder, fr 24-28.

5.3.13. Additionally, the following structural members have been identified as areas of over 15% diminution according to the 2009 UTM report (Figure A.3 (a) – (d) presents this schematically):

- Bottom plating, stbd, fwd A8, A8a, B8a, C9a, stbd aft bottom plate B3, B4a C4a, port aft bottom plating A3, B3, B4a, B4, C3, D4;
- Starboard side shell D6, E6, F6, D7a, D7, port side shell D6, F6, D7, D7a, E7, port bottom / side shell plate fwd at A8, B8, B8a, C8, C9, D8, D9;
- Hatch coamings (longitudinal) port; fr’s 46-60, top rail iwo fr 62, 75.
- Cargo hold frames stbd side at fr 33, 48, 74, port at fr 58, 68
- Main deck fwd, C12 stbd, C11, A5 port. Main deck iwo midships, cross deck plate A2, port side deck plate C1, C3, C4, C5, stbd deck plate A1a, C1, C4, C5.
- Inner bottom, stbd aft C2, C3;
- Transverse WT bulkhead at fr 9, vert. stiffener #7 P/S, Transverse WT bulkhead at Fr 106, vertical stiffener 5, 6, 7 P/S;
- Tank top plate at fr 44, 68, 80 stbd and fr44, 80 port;
- DB longitudinal girder port fr19.
- Centreline plate in FPT plate C1, C2, B1, B2, A1, E1. Stringer I in FPT plate A1 stbd, A1, A1a, A2, A3, A3a, A3b port, FPT frames at fr 106, 108, 109, 110, 111 bottom plate, webs and faces positions 1, 2, 3.
- Centreline plate in APT A1, APT fr at fr 5-8 positions 3, 4, 5.
- WT transverse bulkheads in DB; at fr 40, plate B port, fr 60, plate B1, B2 stbd, fr 82, plates B1 P/S.

5.3.14. The 2009 UTM report states that the tank top plating original thickness is 14mm. This is incorrect and should be 17mm. We believe that the UTM surveyor has taken the 14mm value from the structural drawings of Hull no. 352 for the MV SWANLAND’s sister vessel, MV CAREBEKA VIII, built in 1976, which shows a tank top plating thickness of 14mm. MV SWANLAND was hull no. 360 as proven by various certificates for the vessel such as the Lloyd’s Register Load Line Certificate of 1997 and the approved Trim & Stability Book of 1988.

5.3.15. This had the effect of significantly under-estimating the diminution of the tank top plating in 2009. Had the correct value been used, then virtually all of the tank top plating would have been identified as having greater than 15% diminution. Twenty two plates would have been identified as having greater than 22.5% diminution (i.e. greater than 75% of the relevant Class limit) and would therefore have required additional inspection and UTM (as per INSB 2008 Rules, Part I, Ch. 3, 11.1.5). These plates are highlighted in Figure A.3(d) in Appendix A with a thick border[11].

5.3.16. One plate (C2 starboard at fr32-40) would have had a measured diminution of 33.5% and therefore should have been replaced, having a diminution greater than the 30% allowed by the INSB 2008 Rules (Part I, Ch.3, Section 11, Table C).

5.3.17. Table D of the INSB 2008 Rules (Part I, Ch.3, Section 11) concerns the overall (average) diminution of the measured transverse section. The average measured diminutions for the Bottom Area are within the INSB limits with or without the tank-top plating included.

5.3.18. The corrected measured diminutions for the tank-top are in our opinion, not unexpected given the lack of coating, the mechanical impact and abrasion that would occur and the cargo types carried, all enabling an increased rate of corrosion compared to a well coated and maintained structure.

5.3.19. Figure A.3(a) – (d) in Appendix B shows the areas listed above in Section 5.3.13 on the Shell Expansion drawing, taken from the 2009 UTM report. In relation to the longitudinal strength of the vessel, it can clearly be seen areas of significant loss of material existed at:

- Side Shell plating, standard side in way of fr 53 – 83, but especially between fr 53 – 67;
- Side shell plating, port side in way of fr 53 – 84;
- Main deck plating port and starboard between fr 23 – 62;
- Various transverse frames in cargo hold, port and starboard;
- Bottom plating, starboard side in way of fr85-95;
- Bottom plating, port side between Fr 25 – 40 and fr84 - 100;
- Main deck plating, forward, port side at fr 101-105;
- Main deck plating, cross deck at fr 65;
- Tank top plating;
- DB longitudinal girder at fr 80;
- Watertight transverse bulkheads at Fr 40, 60 and 82 port and starboard;
- Hatch coamings (longitudinal), port side;

5.3.20. The loss of material (greater than 15% of original thickness) in 2009 was within INSB limits for diminution. However, given the potential corrosion rates (as per Section 5.38 and 5.39) the diminution would likely have been substantially increased by 2011 and potentially have been seriously detrimental to the longitudinal strength of MV SWANLAND. This would have resulted in a significantly reduced Midships Section Modulus and since this is the primary measure of longitudinal strength a significantly reduced resistance to bending moments induced by waves.

[11] Figure A.3 (d) presents the tank top based on the higher maximum diminution of 30% as a conservative approach, due to the interpretation of the INSB rules required. The result is still that significant parts of the tank top plating would likely have required additional UTM in 2009 and likely renewal by November 2011.

5.3.21. Figure 10 below presents a schematic comparison of the Midships Section Modulus (Frame 58) at the time of build, in 2009 (post dry-dock) and at the time of the incident. The Section Modulus has been calculated based on the scantlings from the 'as-built' approved drawings and is assumed to be 100% at the time of build. From this, diminution of relevant plates and stiffeners is applied to determine an approximate section modulus value after the 2009 dry-docking[12] and an estimation of the value at the time of the accident (November 2011). The November 2011 section modulus value is determined using the 2009 UTM data and extrapolating this forward using Classification Society corrosion allowances for general corrosion (Ref. 4) and cargo specific data where it can be applied with reasonable certainty (Ref. 6). With regard to cargo specific corrosion, this was only applied for the periods carrying salt cargoes, where we can make reasonable assumptions on the conditions in which it was carried. No allowance was made for grooving or pitting corrosion from any other sources.

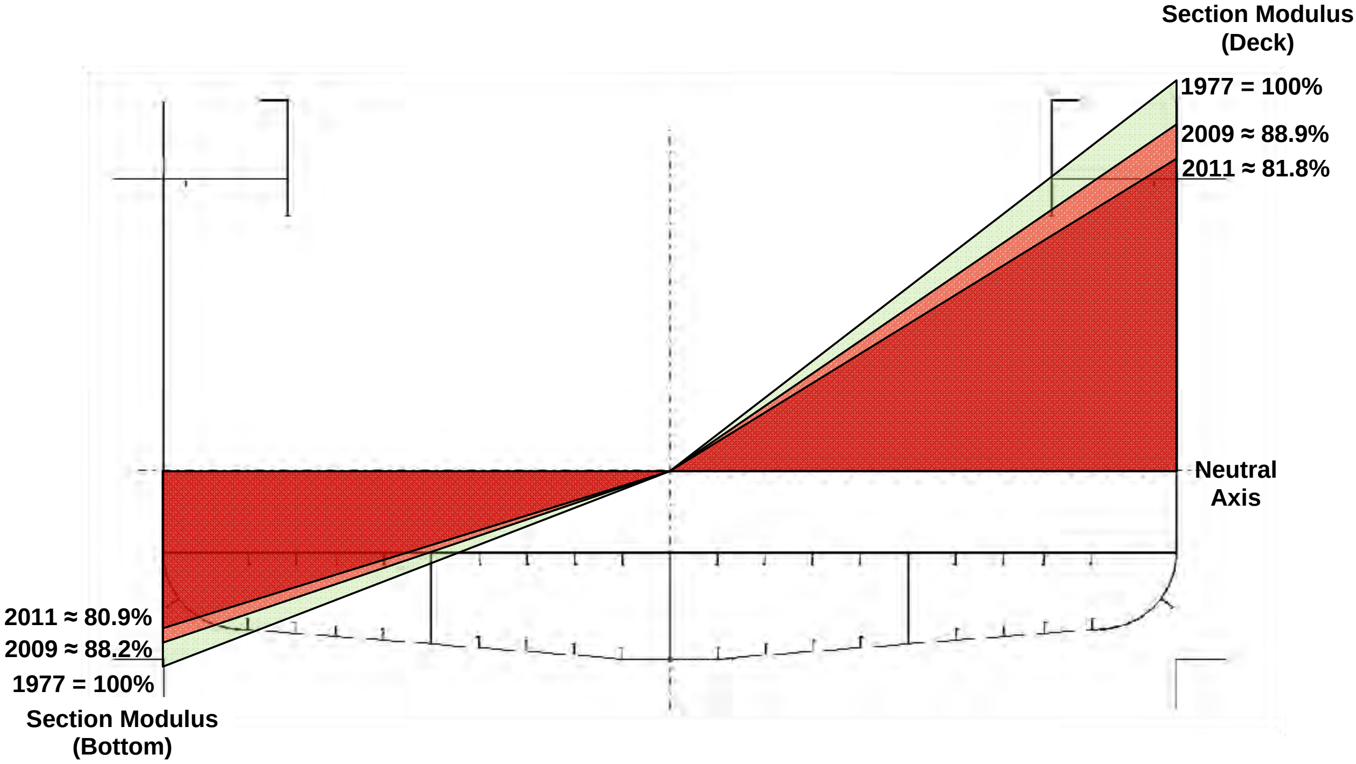

Figure 10 – Calculated Midship Section Modulus at Build, 2009 (post-repair) and at Time of Loss (frame 58)

5.3.22. It can be seen from the results presented in Figure 10 that we estimate that the Midship Section Modulus of MV SWANLAND was reduced by nearly 20% from the original value. Figure A.4 in Appendix A sets out the diminution values applied to each area of structure. It is notable that the diminution values for the Double Bottom stiffeners have large differences in the diminutions between the 2009 post-repair condition and the estimated condition at November 2011. This is based upon an estimation of the corrosion rate due to the use of sea water ballast and an un-

12 This was based on the 2009 UTM report, but since the midships section (frame 58) was not subject to any renewals, the measured thicknesses can reasonably be assumed to apply to the post repair condition.

coated structure (assuming the original coating had broken down as previously described).

5.3.23. Having a length of less than 90 metres, MV SWANLAND was categorised as a ‘Category 3’ vessel by INSB. Category 1 and 2 vessels are subject to a requirement that the in-service Section Modulus should not be less than 90% of the ‘as new’ Rules value (Part I, Ch. 3, Section 11, Table D of the INSB 2008 Rules). There is no requirement for Category 3 vessels to maintain a minimum Section Modulus relative to the ‘as new’ condition.

5.4. Classification and Regulatory Issues – In Service

5.4.1. A review of the Lloyd’s Register classification history shows that the shipboard safety management system was identified as having failures, which is further backed up by the high number of Port State Control deficiencies against the vessel’s general condition. A number of these deficiencies relate to the structural condition and maintenance of areas such as personnel access (gangways) to the vessel and similar. It can be inferred from this, that the overall implementation and management of these tasks in the context of safety management was not sufficient.

5.4.2. Port State Control inspections in Orpington (Aug 2010) and Shoreham (May 2011) listed deficiencies including damaged gangway, railings, corroded / cracking decks, and incorrect following of procedures. It is understood that the deficiency relating to ‘corroded / cracking decks’ relates to the rails for the excavator carriage.

5.4.3. As described in Section 4.2, it is clear that by 2002, substantial areas of localised corrosion were evident and by June 2008 the vessel’s structure was already subject to substantial corrosion in most of her primary and secondary structural members. The most relevant deficiencies listed with regard to the vessel’s structural integrity were the poor condition of the hull, main deck and closing appliances. Further, it was noted that in October 2006 by LR, that ‘doubler plate’ had been fitted on the side shell without record of repair and no evidence that Class was informed. In the same remarks, various side shell frames that were in poor condition and damaged were not recorded in the vessel’s ISM documentation or any ship staff inspection records. Also worthy of note is that the crew was not able to satisfactorily conduct the demonstrations of basic/emergency shipboard operations.

5.4.4. The records from Lloyd’s Register have numerous references to corrosion, holes and wastages in the vessels structure. In 2009, after transfer of Class to INSB, there appears to be a ‘stop’ to this type of information and even some clear contradictions.

5.4.5. The INSB survey reports for 2009 and 2010 simply refer to the condition of the water ballast tanks as “GOOD”. From our experience, “GOOD” in terms of structural condition is used for new and / or very well maintained structures. With regard to the vessel’s structure we do not believe that this can be the case, as described above. Further, the coating in the ballast tanks was repeatedly described as “POOR” by the owners of the MV SWANLAND in their 2009 dry-dock report and as uncoated and due for annual inspection by INSB, yet by 2010, the INSB survey report refers to it as “FAIR”.

5.4.6. There is no record of any new coatings applied to the ballast tanks in the period between these two inspections and hence this is, in our view, a clear contradiction of the condition by two Class societies (one IACS, one non-IACS) and the owner’s own assessment in 2009. Accordingly, without evidence of any new coatings, the reasons for the reported condition following the 2009 surveys are unclear.

5.4.7. MV SWANLAND was classified as a “General Cargo” type ship since her build. The cargoes she carried were in the main, dry bulk as far as the available information allows us to determine. Due to the serious and known issues with bulk carriers, corrosion and the more onerous requirements for structural inspection and maintenance, officially classified dry bulk carriers are subject to an Enhanced Survey Programme (ESP) that is designed to address this issue by providing a more comprehensive survey and inspection programme to assist in maintaining the vessel to a safe standard (ref. 3). Given the cargoes being carried, the age and known condition of the ship, we consider that subjecting MV SWANLAND to a similar level of inspection and survey would have assisted in maintaining the safe structural condition of the vessel.

5.4.8. It is not within the scope of this report to provide a full description of the ESP requirements and how they compare with the survey regime for general cargo ships. References 3, 11 and 12 document this in detail. However, the general principle is to provide a survey regime with increased focus and attention to key areas of bulk carrier structures that are well known to suffer damage and wastage. The survey regime is based on two key criteria; the condition of the coating and the extent of structural corrosion and provides for the full documentation of the inspected areas (themselves increased from the normal survey regime) and the associated acceptance criteria. Further, the ESP regime provides a significantly enhanced focus on structures that are found to be substantially wasted or corroded (i.e. wastage of between 75% and 100% of the allowable diminution).

5.4.9. The 2008 INSB Rules did not require MV SWANLAND to be subjected to Close-up surveys, being classified as a General Cargo ship. A Close-up survey is defined as a close visual inspection by the surveyor, usually within a distance of an arm’s length and is applied when substantial corrosion and / or structural defects are found. Typically, this would involve the surveyor making use of ladders and / or staging to access areas out of reach.

5.4.10. According to IACS (UR Z, Section 7), as a minimum, General Cargo ships should be subjected to Close-up surveys for the lower hold frames, side brackets and lower parts of cargo hold bulkheads. For Bulk Carriers (which, in our opinion, MV SWANLAND was operating as), the requirements are more onerous and extend to include all hold frames, all transverse bulkheads, all deck plating inside the line of openings, all inner bottom plating.

5.4.11. In our experience, it is quite possible to observe ship's structures with no visible scale or obvious signs of corrosion, but with local wastage beyond the acceptable limits. Therefore, we consider that based on the cargoes carried, previously reported structural condition, ship's age and type of vessel (all of which is documented), it would have been prudent to subject MV SWANLAND to Close-up surveys of the cargo hold structure. Since the upper hold frames, brackets and under-side of the deck plating and associated stiffeners were approximately 5 metres above the tank-top plating, it would not be possible to visually inspect these areas without a Close-up survey.

5.5. Classification and Regulatory Issues – Design and Construction

5.5.1. The LR 1976 Small Ship Rules require that a loading manual be developed and approved[13]. It would therefore be required that a copy of the approved loading manual should be retained on the vessel and a copy kept in the owners' office.

5.5.2. Further, the IACS Unified Requirement S1 concerning the provision of loading manuals and guidance (rev. 1, 1971) would have required that MV SWANLAND be provided with an appropriate loading manual. We consider that due to her single hold and multiple double bottom ballast tanks, she would have had the possibility to experience uneven cargo or ballast distributions and thus a loading manual would be required. At the time of the vessel's build, there is a record of a request being made by Lloyd's Register Headquarters for a copy of the loading manual to be forwarded by the local surveyors in the Netherlands. However, no records are available to confirm whether this loading manual was provided or approved. Later revisions of UR S1 further confirm the requirement for vessels of the size and type of MV SWANLAND to be provided with an approved loading manual.

5.5.3. Under the INSB 2008 Rules for the Transfer of Class (Part I, Ch 2, section 3.3 – 3.7), the minimum technical documentation to be provided included loading calculations (Section 3.4.1 (j)) and a loading manual, if applicable (section 3.7.1 (b)). No statement regarding when provision of the loading manual is applicable is made with the INSB 2008 Rules.

5.5.4. The INSB 2001 Rules (Part I, Ch. 2, section 2.2.3.3.1.3) similarly require that loading calculations are to be provided and a loading manual where the length of the vessel is greater than 120 metres for General Cargo vessels. Accordingly, we consider that the INSB Rules did not require a full loading manual, but as a minimum, details of the load cases and calculations, Bending Moment calculations and related instructions and documentation should have been provided. No record of such documentation is available.

5.5.5. Under the INSB Rules (Part I, Ch 3, section 1.2.5), the loading guidance and stability data should be inspected at the annual in-service survey. This was confirmed as sighted in 2010 but there is no record of it in either 2009 or 2011.

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[13] Lloyds Register of Shipping Rules for the Construction of Steel Ships under 90m in Length, 1976. Para. 110 and Chapter D para. #306 pg 10.

5.5.6. No record of loading calculations, loading guidance or similar approved documentation has been provided either by the owners, managers or has been made available by the vessel's Class Society.

5.5.7. The issues of loading dry bulk cargoes such as requirements for cargo distribution in respect of structural strength and trimming of the cargo and the potential catastrophic consequences are well established (Ref. 8 & 9). It would therefore be imperative that the crew and loading supervisors / stevedores were aware of the vessel's approved loading plans in order to load the vessel properly, safely and in compliance with her abilities / limitations. For a vessel involved in a trade such as that which the MV SWANLAND was, in our experience, it can happen that experience is applied by the crew instead of the available approved guidance (or manual) and hence complacency is possible, especially given the amount of different cargoes that were carried in the last period before the accident.

5.5.8. The LR Small Ship Rules 1976 did not explicitly require the determination of Wave Bending Moments in the requirement for minimum section modulus and it appears that this is contained within the empirical formulae for the minimum section modulus. In our experience, this approach is common in Classification Society Rules as they are designed for ease of use by vessel designers. Since the LR Small Ship Rules 1976 provide a simpler methodology for hull structure design compared to the 1976 LR Rules, this approach is to be expected. However, in 1976, the rules concerning longitudinal strength might be considered as being in their relative infancy with regard to a full understanding of the physical processes in hull bending and wave climates to be experienced (compared to the current day). Hence it is possible that the rules to which the vessel was designed were unable to reflect the operational conditions to which MV SWANLAND was more recently subjected.

5.5.9. No calculations concerning the original structural design of MV SWANLAND, such as design bending moments and shear force calculations, tank top loading assessments and deck plate thickness are available.

5.6. Other Similar Cases

5.6.1. The issues described above that have occurred in the case of the MV SWANLAND are not new issues in our opinion when considered in the general sense. Since the 1960's the marine industry has been aware of the problems associated with the carriage of bulk cargoes and considered the increase in failures of bulk carrier hulls over the following years, leading to the IMO led Formal Safety Assessment for Bulk Carriers (Ref. 10) and ultimately to revised regulations relating to the design, construction and operation of Bulk Carriers and the Common Structural Rules for Bulk Carriers[14].

[14] IACS: Common Structural Rules for Bulk Carriers, July 2012. First edition released in January 2006.

5.6.2. To demonstrate the on-going nature of the problem, Table 3 below presents a list of similar cases for which the following factors were identified as key causal factors:

- Corrosion of key hull structure, resulting in the reduction of local and global hull strength;
- A record of poor maintenance by the Owners;
- A lack of adequate control by the vessel's Classification Society in ensuring compliance with the Rules or "Class-hopping"[15].

5.6.3. Similar problems have been put forward in the well known cases for the Tankers ERIKA, PRESTIGE and CASTOR.

5.6.4. The data presented in Table 3 is amalgamated from a selection of sources including

- Global Integrated Shipping Information System (GISIS);http://gisis.imo.org;
- Center for Tankship Excellence Casualty Database (includes bulk carrier data); www.c4tx.org;
- EQUASIS; www.equasis.org
- Paris MOU Database; http://www.parismou.org/ and Tokyo MOU Database; www.tokyo-mou.org.
- Braemar's own database of casualties for which we have been involved on behalf of various interests;
- IMO Formal Safety Assessment on Bulk Carriers (Ref. 10)

5.6.5. The data in Table 3 is for Bulk Carriers and Combined Bulk / Cargo vessels. The MV SWANLAND was classified as a General Cargo vessel but was primarily carrying dry bulk cargoes and hence it is most appropriate in our opinion to compare her loss with those of vessels with similar cargoes.

[15] This is where a vessel may be transferred to a different Classification Society in or to gain the benefit of more relaxed Rules.

Vessel	Date of Casualty	Casualty Type	Key Causal Factors Cited		
			Corrosion	Owner care	Class Control
Marine Electric	1983	Hull Failure / Sinking	Y	Y	Y
Alexandre P	1990	Hull Failure / Sinking	Y	Y	Y
Azalea	1990	Hull Failure / Sinking	Y		
Pythia	1990	Hull Failure	Y		
Pankar Indomitable	1991	Hull Failure	Y		
Atlas Pride	1991	Hull Failure	Y	Y	Y
Trave Ore	1992	Hull Failure	Y	Y	Y
Protoklitos 4	1993	Hull Failure / Sinking	Y		
San Marco	1993	Hull Failure	Y	Y	Y
Alpha Star	1993	Hull Failure	Y	Y	Y
Kamari	1994	Hull Failure/ Sinking	Y	Y	Y
Iron Antonis	1994	Hull Failure / Sinking	Y	Y	Y
Trade Daring	1994	Hull Failure	Y		
Bluenorth	1996	Hull Failure	Y		
Giga 2	1996	Hull Failure	Y	Y	Y
Leros Strength	1997	Hull Failure / Sinking	Y	Y	Y
Flare	1998	Hull Failure / Sinking	Y	Y	Y
Cape Providence	1999	Hull Failure	Y		
Iolcos Mariner	1999	Hull Failure	Y		
Lassia	1999	Hull Failure	Y		
Leader I	2000	Hull Failure / Sinking	Y	Y	Y
Eurobulker X	2000	Hull Failure / Sinking	Y	Y	Y
Setsuyo Star	2006	Hull Failure	Y	Y	Y
Golden Glory	2007	Hull Failure	Y	Y	Y
Pine Trader	2009	Hull failure	Y	Y	Y
Ioannis NK	2009	Hull failure / Sinking	Y		

Table 3 – Vessels (Bulk Carriers + Combination Cargo) suffering Serious Casualties

6. THE STRUCTURAL FAILURE AND SUBSEQUENT LOSS OF MV SWANLAND

6.1. The repairs made to the structure of MV SWANLAND would have increased her structural capacity compared to that before the repairs. However, over time the vessel had become a 'patchwork' of renewed plates and stiffeners with older or original plates in between. Consequently there would have been some variation in thickness and hence discontinuities. This could have created problems such as water traps at the joins, increasing the likelihood of grooving and/or corrosion.

6.2. It also creates strong points next to weak points, so as load is applied to the structure, the stresses may be transferred to the weak points and so may lead to failure.

6.3. In general the repairs made are reasonable for the damage reported, but it would have been preferable to have taken a more holistic approach to the structural capacity, so rather than simply replace those plates or stiffeners that have exceeded class diminution limits or are clearly damaged, a preferable approach would be to review surrounding areas at the same time to ensure that after renewal it is not creating a strong point immediately next to a weak one. That is, a repair strategy should be developed to provide optimum repair and maintenance to retain the vessel's reacquired structural strength.

6.4. However, the main issue is what was not done. It is clear that Lloyd's Register had serious concerns about the lack of coating in the ballast tanks. It may be considered that maintenance of the ballast tanks is one of the most important areas of keeping the ship structurally sound. To not coat the tanks internally will allow corrosion to prosper and inevitably the structure will eventually fail. It is not possible to say with certainty what the condition of the ballast tank structure was at the time of the loss, but it would be reasonable to expect it to be poor. Figure 11[16] below presents photographs included in the owner's own dry-docking report from 2009, which (allowing for the poor reproduction of the photographs) shows that the structure within the double bottom tanks is in a poor condition pre repair. This can be assumed to be indicative of the condition after a period without repairs (the last significant repairs to the double bottom structure were in 2006).

6.5. Similarly, there were large areas of plating on the side shell and main deck that had significant wastage, within INSB limits, but sufficiently large areas that would warrant a plan for replacement and further preventative measures in our opinion. It is our opinion that these were the critical areas with regard to the cause of the structural failure and subsequent loss of the vessel. By 2011, it is likely that general corrosion and potentially accelerated corrosion due to specific cargoes and a lack of hold maintenance would have further reduced the side shell and deck plate thickness.

[16] It is believed that these photographs are of the condition pre-repair, although it should be noted that no location references are provided in the Owner's dry-dock report.

Figure 11 – Various Photos of Double Bottom Tanks Showing Heavy Corrosion and Wastage (2009, exact locations unknown)

6.6. As per section 5.1, based on the size of the vessel, it is likely that the side shell and main deck plating alone made significant contributions to the midship section modulus and hence the longitudinal strength of the vessel. It would therefore be critical to maintain the integrity of these regions. This would be especially true for the main deck plating in the way of the cargo hold hatches due to the low width and hence sensitivity to loss of plate thickness as regards contribution to the section modulus and buckling resistance. As shown in Figure A.3(a) – (d) in Appendix A, there were clearly areas of side shell and deck plating that had experienced substantial reductions in thickness and consequentially the midship section modulus was reduced.

6.7. As per Section 5.5, it is our interpretation that at the minimum, approved loading calculations were required and this would be even more essential given the age and condition of the ship and need to ensure loading with Shear Forces and Bending Moments within permissible limits. Any poorly distributed load would amplify the problem by increasing the shear forces and bending moments that the already corroded deck structure and WBT tanks had to withstand. No copies of approved loading calculations, appropriate loading guidance and associated documents required for entry to INSB classification are available.

6.8. The vessel initially took a large wave at the bow. Given the limited fetch of the Irish Sea and wind against tide conditions (Ref. 7) resulting in steep waves, it is likely that the wavelength was similar to the vessel length. Consequently, the vessel would, being fully loaded, be in a sagging condition. As this large wave moved down the ship to midships, then the vessel would thus enter a hogging condition. With the impact of the second large wave at the bow, the vessel would return to a sagging condition and it is likely that it was at this point that the structural failure occurred. There is evidence that the bow rose up relative to the main deck and the starboard bulwarks folded outwards, hence it can be concluded that she buckled globally in the sagging condition. It is our opinion that the main deck plate would likely have buckled in compression initially, due to decreased buckling resistance under compressive loads as a result of reduced plate thickness.

6.9. As the second large wave then passed down the ship towards midships, the vessel would then be in the hogging condition, such that the deck plate would be in tension with the weight of the bow and stern sections trying to tear the two parts apart. The fracture occurred in way of the Load Line marks at frame 58, close to a join between two deck plates at frame 61 (C5/C6). The fracture would likely have propagated rapidly down the side shell, allowing massive water ingress to occur and the vessel would then sink rapidly.

6.10. Since a large amount of bottom plating was renewed in 2009, it is reasonable to consider that the structure remained efficient, which would be consistent with the bottom plate remaining intact, as it did, albeit creased due to the folding before sinking in the hogging condition.

7. CONCLUSIONS

7.1. General

7.1.1. The MV SWANLAND sank in heavy weather on the 27th November 2011 whilst on route to Cowes from Llandulas carrying 2,730 tonnes of Type 1 Limestone. Six of her eight crew were lost.

7.1.2. The vessel was struck by a combination of large waves of wavelength similar to the length of the vessel, resulting in the bow appearing to rise (relative to the rest of the ship), the hatch covers lifting and the starboard bulwark folding outwards. Subsequently, as the vessel was turned, water would have entered the holds due to large waves breaking onto the deck when beam-on to the seas.

7.1.3. Available ROV footage confirms that the vessel experienced a large structural failure in way of the Load Line marks on the port and starboard side of the vessel. The wreck lies upside down and hence it was confirmed that the bottom plating was generally intact but with a heavy transverse crease running between the fractures on the port and starboard side.

7.2. Structural Design

7.2.1. MV SWANLAND was constructed with a transverse framing system, alternating between deep and half frames. Additional deep frames were provided at midships and the mid-point of each hatch opening. A cross-deck beam was also situated at midships to provide a complete ‘portal’ frame. These deep frames would have been required to resist transverse and racking loads that the vessel would otherwise have been susceptible to due to the single open cargo hold. In all respects, her structural design was, in our opinion, normal for a vessel of her size, type and trade and therefore was not a significant factor in the loss of the vessel.

7.2.2. However, her design of having a single cargo hold and two hatch covers forward and aft of a small cross-deck beam resulted in large openings at main deck level and consequently relatively little main deck plating in the midship section to contribute to the overall hull girder strength. This meant that the deck plating either side of the hatch opening at midships (frame 58) and the under-deck longitudinal stiffening was critical to the maintenance of sufficient strength in the deck to resist hull bending moments. Adequate maintenance of these areas would have been of paramount importance to ensure sufficient strength of the deck structure.

7.2.3. It is believed that MV SWANLAND was constructed according to the LR Small Ship Rules 1976, although it has not been possible to fully confirm this. These Rules provided for minimum longitudinal strength requirements based on empirical formulae (as was and is common practice) according to a simpler methodology than the equivalent ‘large’ ship rules (for vessels greater than 90 metres in length). Due to the relative infancy of the technical development of Class Society rules at this time, we consider it possible that the LR Small Ship Rules 1976 may not have provided a minimum longitudinal strength representative of the operational conditions to which MV SWANLAND was subsequently subjected in her later service life.

7.2.4. The addition of the self-discharging conveyor system in 2003 did not in itself provide any detrimental effect to the structural capacity of the vessel. On the contrary, it required the scantlings of the transverse frames to be increased and thus it likely had an overall beneficial effect in structural strength terms. However, the installation of the rails on either side of the hatch coamings created a water 'trap' between the stays and hence an area where corrosion would have been able to develop and propagate unless a diligent approach to cleaning and maintenance was applied. See Figure 12 below which demonstrates the problem of water and dirt trapped between the stays.

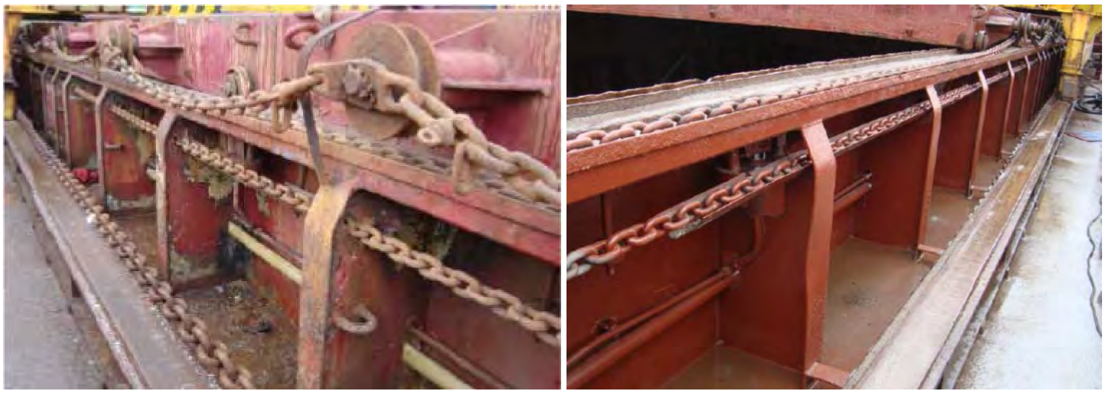

Figure 12 – Water and Dirt Trap Area between Hatch Coaming Stays

7.3. Classification, Registry, Surveys and Repairs

7.3.1. As is common, MV SWANLAND was entered into various different classification societies and registered under different maritime administrations during her service life. Of note is the transfer to INSB in 2009, which is the first time she was entered with a non-IACS classification society. At the same time, she was transferred to the Cook Islands flag state, which was on the Paris MOU Grey list of flag states at the time (and close to the Black list limit)[17]. Her registry and Classification remained the same until the time of the accident.

7.3.2. MV SWANLAND was subjected to a full survey and inspection regime, including Special Surveys every 5 years and Annual / Intermediate Surveys in the intervening times. Due to the age of the vessel and existing Memoranda of Class with regard to the double bottom tanks, the scope of the Intermediate surveys was effectively the same as Special Surveys, to include ultra-sonic thickness measurements. The 2009 survey completed by INSB at the time of transfer from Lloyd's Register was classified as an Intermediate and Dry-Docking Survey.

7.3.3. MV SWANLAND was regularly inspected by Port State Control officers. Since 2009, she had been detained for serious deficiencies two times and had 41 defects registered, including a number for structural damage and / or corrosion. The PSC

[17] The 'Grey' List, together with the While and Black Lists are published under the Paris Memorandum of Understanding on Port State Control (Paris MOU) to summarise the overall risk factor for a particular flag state; Black being poor quality flags with high detention records, White representing 'quality' flags with a low detention record and Grey representing average performance.

inspection reports do not document the defect in any detail and it is not known how many of these defects were outstanding at the time of the accident.

7.3.4. MV SWANLAND underwent a considerable amount of structural repairs during her life, including virtually all of her cargo hold and double-bottom structure at various times. For a vessel of her age, type and trade, this is not an unexpected situation. However of particular note are regular repairs to the cargo hold transverse frames due to wastage and mechanical damage, side shell plating, cracks in bottom longitudinals, deck plating and under-deck stiffeners, tank top plating due to heavy corrosion, cracked and corroded welds and various localised cracks.

7.3.5. Examining the nature of the voyages that MV SWANLAND was engaged in, it is our opinion that full and proper hold cleaning, coating and maintenance would have been difficult to have carried out due to time constraints. Based on the record of cargoes carried, she rarely operated on ballast voyages and carried varying cargoes between ports often within 1 day of discharge of the previous cargo. Combined with mechanical damage due to the discharge method (grabs and excavators), there would potentially have been regular and significant damage and / or corrosion to the vessel's cargo hold structure.

7.3.6. We therefore consider that the MV SWANLAND was likely to have been in a weakened structural condition for much of her latter service life. Periodic repairs would have regained structural strength but because these appear to have been 'piecemeal' and re-active, the overall effect would have been that the original structural strength would potentially never have been regained.

7.3.7. Based on the available survey records from Bureau Veritas (1987-1997) and Lloyd's Register (1976-1987, 1997-2009), we believe that up until 2000 the vessel's structure was generally in a sound condition, following extensive steel renewals and an apparently diligent and extensive survey regime. In 2000, the Double Bottom tanks are first reported by Lloyd's Register to be in a FAIR condition and extensive and repeated reports of repairs to the vessel's primary structure (cargo hold, main deck area, side shell, tank top and double bottom structure) are given, including cracking of bottom longitudinals. In October 2006, a serious ISM non-conformity was reported by LR, relating to the non-reporting of structural defects and repairs carried out without notification of the Classification Society.

7.3.8. Following the Lloyd's Register survey in 2000, there are repeated reports of the poor condition of the double bottom structure in way of the seawater ballast tanks. It is assumed that the original coating in these tanks had broken down and these were therefore free to corrode. There are no references from this survey to the time of the accident of any plans to re-coat, or of actual coating of the double bottom ballast tanks. We would consider that upon the report of FAIR condition for this structure, it would have been prudent to implement a plan for improving the condition of the ballast tanks.

7.4. Corrosion of the Vessel's Primary Structure

7.4.1. Records exist for the cargoes carried by MV SWANLAND from 2003. From this time, she was primarily engaged in carrying dry bulk cargoes including a number of potentially corrosive cargoes such as Furnace Ash, Potash, Clinker and Salt. She also carried abrasive cargoes such as Limestone, Asphalt and various aggregates.

7.4.2. Between the beginning of 2009 and the time of the accident, she carried road salt for a total of 105 days, often in periods of poor weather. Of particular note is a period of carrying exclusively road salt in the winter of 2010 at a time when local authorities in England had high demand for road salt due to the heavy snow and icy conditions. It is our opinion, that this period of operation (plus the other equivalent periods in 2009 and 2011) would likely have resulted in significant corrosion to the vessel's structure due to the moisture likely to have been present in the cargo, residual moisture (from snow / ice) in the vessel and a probable lack of hold cleaning and preparation due to the short voyage, turnaround times and high demand.

7.4.3. Based on considerations of predicted corrosion rates and applying Classification Society rates for 'general' corrosion together with specific rates available for salt corrosion, we believe that it is possible for the relevant parts of the vessel's structure (Cargo hold plating, tank top, transverse web frames, underside of main deck structure) to have been corroded close to the Classification Society limits for diminution by 2011. Any structure identified as having diminution over 15% at 2009 has the potential to have reached diminutions greater than 75% of the INSB limits (i.e. 22.5% of original) by 2011, thus requiring further thickness measurements testing and therefore, further possible renewals as appropriate. This result does not account for corrosion due to any other cargoes, abrasion due to mechanical impact and / or damage or pitting / grooving corrosion that may occur through other sources and hence we believe this to be a reasonable and conservative conclusion.

7.4.4. Extensive areas of the vessel's primary structure have been identified from the 2009 UTM and Survey reports as having diminutions greater than 15% of the original thickness (see Figure A.3 in Appendix A). Significant material loss had occurred on the bottom plating, side shell plating, main-deck plating, tank top plating (virtually in its entirety), Double Bottom longitudinal, traverse water-tight bulkheads and various transverse web frames in the cargo hold.

7.4.5. The 2009 UTM report included a serious miscalculation of the tank top diminutions as it used the wrong original plate thickness (14mm instead of 17mm), based on a construction drawing for MV SWANLAND's sister vessel, CAREBEKA VIII, thereby significantly under calculating the percentage diminution from the measured values.

7.4.6. A detailed examination of the condition of the midships section area (fr58) in 2009 (post-repair) and the estimated condition in November 2011 has been carried out. From this, we believe that the Midships Section Modulus would likely have been reduced by nearly 20% from the original 'as-built' value by November 2011. In 2009 (post-repair), the reduction compared to the 'as-built' value was 11.5%.

7.5. Management of Structural Integrity

7.5.1. Based on examination of the Classification survey history and Port State Control records, it is clear that there were a high number of structural defects, deficiencies and failures in the Safety Management System. As well as the general poor condition noted in various inspections and reports, there is evidence of repairs being carried out without notifying the Classification Society and of repairs and known areas of damage to key structural members not being recorded in the ISM records.

7.5.2. Poor management and maintenance of the vessel's structure was also highlighted by the P&I insurers of the MV SWANLAND in 2002, following the vessel's annual condition survey. This noted the lack of a Planned Maintenance System and a strong recommendation was issued to the Managers for a maintenance programme to be implemented for the hull structure. The ISM Code (Section 10) requires that inspections are held regularly and any non-conformity be reported and documented.

7.5.3. Prior to 2009, there are numerous reports in the survey records of corrosion, defects, structural damage and repairs carried out. From 2009, after transfer of Classification to INSB, there is very little information on the actual condition of the vessel's structure in the INSB survey reports. The reports from INSB are, in our opinion, cursory in content and do not detail the condition of individual structural members or areas of structure. They only provide a simple grading of the structure, such as in the 2009 survey report, the report on the Double Bottom ballast tanks is limited to a statement of "*Uncoated all Ballast Tanks. In Good Condition*".

7.5.4. It is our understanding the INSB 2008 Rules did not require MV SWANLAND to be subjected to Close-up surveys. We consider that based on the cargoes carried, previously reported structural condition, age and type of vessel (all of which is documented), it would have been prudent to subject MV SWANLAND to Close-up surveys of the cargo hold structure. This may have assisted in maintaining adequate structural integrity.

7.5.5. Further, there are clear contradictions in the rating of key structural members (double bottom water ballast tanks) by the INSB surveyor in 2010 and the previous survey in 2009 and the owner's own assessment of the condition of the tanks, despite no improvements having been made.

7.5.6. As described in Sections 4.3.12 and 5.2.29, MV SWANLAND was issued with a Memoranda of Class requiring the double bottom ballast tanks to be inspected at each survey and thickness gauged "to the surveyor's satisfaction'. At the 2009 dry-docking, significant repairs to the ballast tank structure were undertaken, although the ballast tanks were rated as "IN GOOD CONDITION" and "UNCOATED" in the INSB survey report. Following the repairs in 2009, the ballast tanks were rated to be "IN GOOD CONDITION" with "FAIR COATINGS" by 2010, despite there being no evidence of repairs or coating after the 2009 dry-docking. The available photographs of the tanks before the repairs in 2009, (see Figure 11) clearly show them to be in a very poor condition and we believe that this is indicative of their condition after a period without maintenance. Whilst the bottom structure remained intact during the sinking, the likely wastage would have resulted in a reduction in the Section Modulus of the vessel and in our opinion, indicates a lack of focus and oversight on the management of the condition of the vessel.

7.5.7. It is our interpretation that MV SWANLAND was required to carry 'loading guidance and stability data' (INSB 2008 Rules; Part I, Ch. 3, Section 1.2.5) which would provide guidance on loading weights and distribution to ensure shear forces and bending moments are maintained within permissible limits. No record of such a document has been provided and it appears that no such information either existed (after 2009) or was used onboard, indicating a degree of complacency over the loading of the vessel and its effect on the vessel's structure and stability.

7.5.8. The various repairs carried out are believed to be reasonable for the reported defects, however they appear to be focussing solely on the immediate area of damage and have not considered the adjacent structure. In many cases this was also significantly corroded, albeit within the INSB limits. In our opinion, a rigorous approach to the structural integrity would have included consideration of these areas and plans for condition improvement taking into account the overall strength, not just the localised area requiring immediate repair.

7.5.9. It is our view that significant areas of the vessel's critical structure with regard to hull girder strength had been corroded to the point where she did not have sufficient longitudinal strength to resist the large bending moments and stresses that she would have experienced on the voyage from Llandulas on 26th November 2011.

7.6. Summary

7.6.1. In summary, based on the available evidence provided and our review of the structural history of MV SWANLAND, the major contributing factors to the structural failure were, in our opinion:

(a) Corrosion of the critical areas of the structure of the vessel that provided her longitudinal strength (main deck area, side shell, transverse web frames, tank top, double bottom structure), resulting in a lack of material and strength in the key structural members and thus stresses due to hull girder bending that exceeded the capacity of the structure and resulted in the structural failure of the main deck area.

(b) An apparent lack of focus on the management and maintenance of the structural integrity of the vessel that allowed her primary structure to degrade over time resulting in a critical reduction in longitudinal strength.

(c) An apparent lack of focus by the Classification survey and inspection regime from 2009 onwards that resulted in errors in the survey and grading of the structural condition of the vessel, potentially allowing key areas of vessel structure, that were already requiring attention in 2009, to continue to be corroded to close to the relevant Classification Society limits. Surveys conducted after 2009 do not appear to have identified the likely continuing diminution of the same structural members in order to prevent a critical loss of hull structural strength.

7.6.2. The three primary conclusions listed above are not new issues within the shipping industry. As outlined, in Table 3 of Section 5.6.2, these factors have been indentified numerous times for vessels lost or damaged due to structural failures.

REFERENCES

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2. Safety of Shipping in Coastal Waters; "SAFECO" Final Report Ch II.6 – Effect of Age in Failure of Structure, EU 4th Framework R&D Project.

3. Lloyd's Register Enhanced Survey Programme (ESP) for Bulk and Ore Carriers: Preparation for Special Survey. Revision 12.1, June 2010.

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5. Gardiner CP & Melchers RE: Corrosion Analysis of Bulk Carriers; Part I Operational Parameters influencing Corrosion Rates: Journal of Marine Structures 16 (2003) pg 547.

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10. Report of FSA Study on Bulk Carrier Safety, IMO Maritime Safety Committee, MSC75/5/2, February 2002.

11. IACS Guidelines for Surveys, Assessment and Repair of Hull Structure - Bulk Carriers (Corr.1 - Sept 2007).

12. Guidelines on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers, IMO Resolution A.744(18), As Amended.

GLOSSARY

Abbreviations

The abbreviations used in this report are listed here in order of appearance in the main body.

Ch.:	Chapter
ps / PS / P:	Port
stbd / STBD / S:	Starboard
fr:	Frame number (Frames are numbered forward from 0 at the aft perpendicular)
FPT:	Fore-Peak Tank
Horiz.:	Horizontal
Long'l:	Longitudinal
CL:	Centre-line
Assoc'd:	Associated
SW:	Salt Water
iwo:	in way of
Var.:	Various
DBT:	Double Bottom Tank
FO:	Fuel Oil
DB:	Double Bottom
Fwd:	Forward
UTM:	Ultrasonic Thickness Measurement
Trans.:	Transverse
WT:	Watertight
Vert.:	Vertical
APT:	Aft-Peak Tank
WBT:	Water Ballast Tank
FBA:	Furnace Bottom Ash
RAP:	Reclaimed Asphalt Pavement
ISM:	International Safety Management Code (IMO Resolution A.741(18) as amended)

Plate Numbering System

Figure I below shows how the shell plating is referenced in this report. For ease of reference, it is the same system used in the Classification Society survey reports and UTM reports. Plates are identified as follows:

- Each plate has a two digit reference consisting of a letter and a number e.g. A1.
- Letters are used to identify the plate position around the girth of the hull (strake) for the shell expansion plan (starting with K for keel, then A upwards moving from keel to main deck level) or transversely for the main deck and tank top (starting with A on the centre-line and then B, C etc moving outboard port and starboard).
- Numbers are used to identify the plate position longitudinally from 1 upwards (1 being the furthest aft).

So plate E6 on the side shell identifies the plate at strake E, just above the turn of bilge on the side shell near to midships (frame 58).

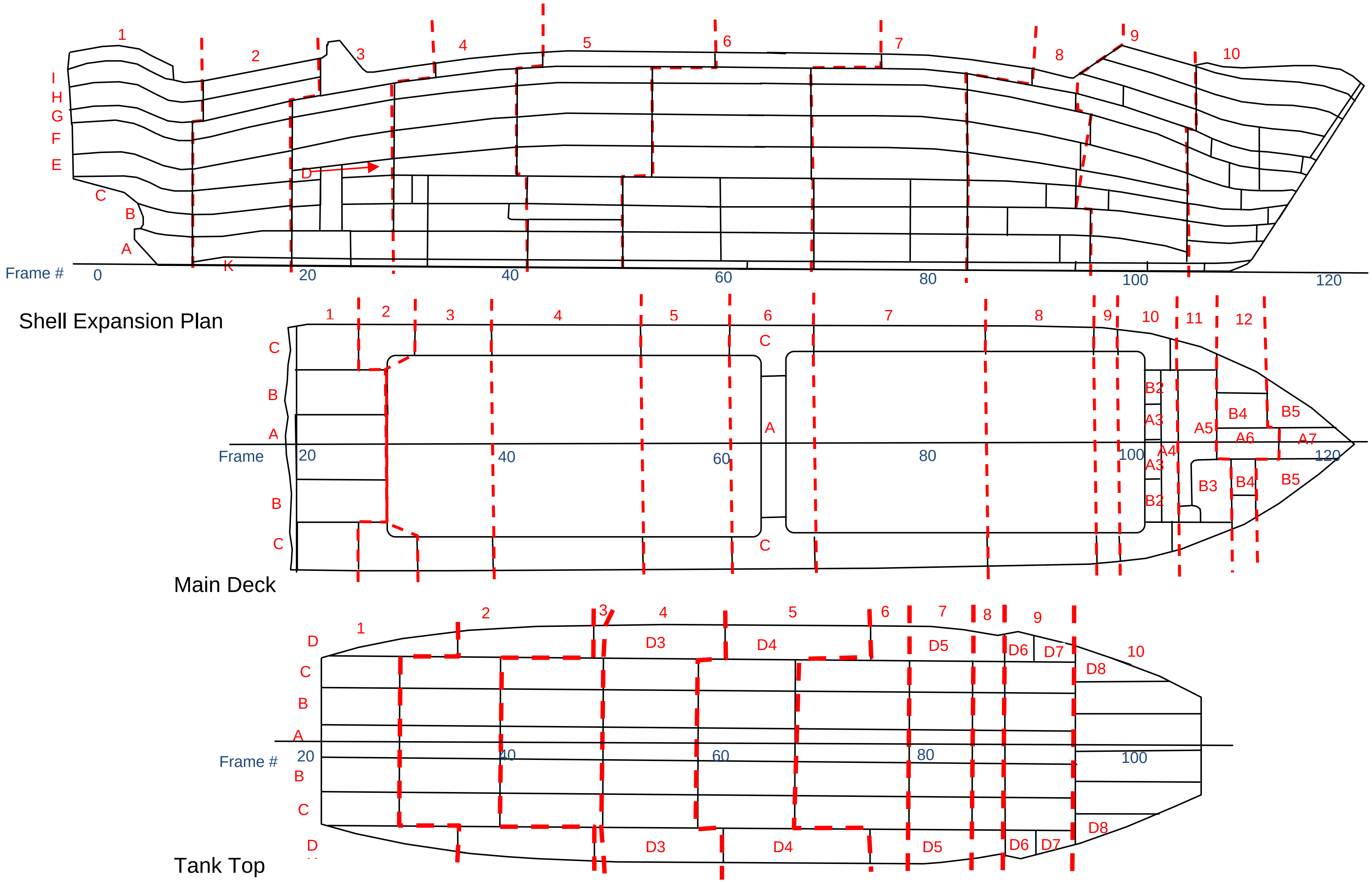


Figure I – Schematic of MV SWANLAND Shell Expansion Numbering Scheme (Not to Scale)

APPENDIX A
FIGURES

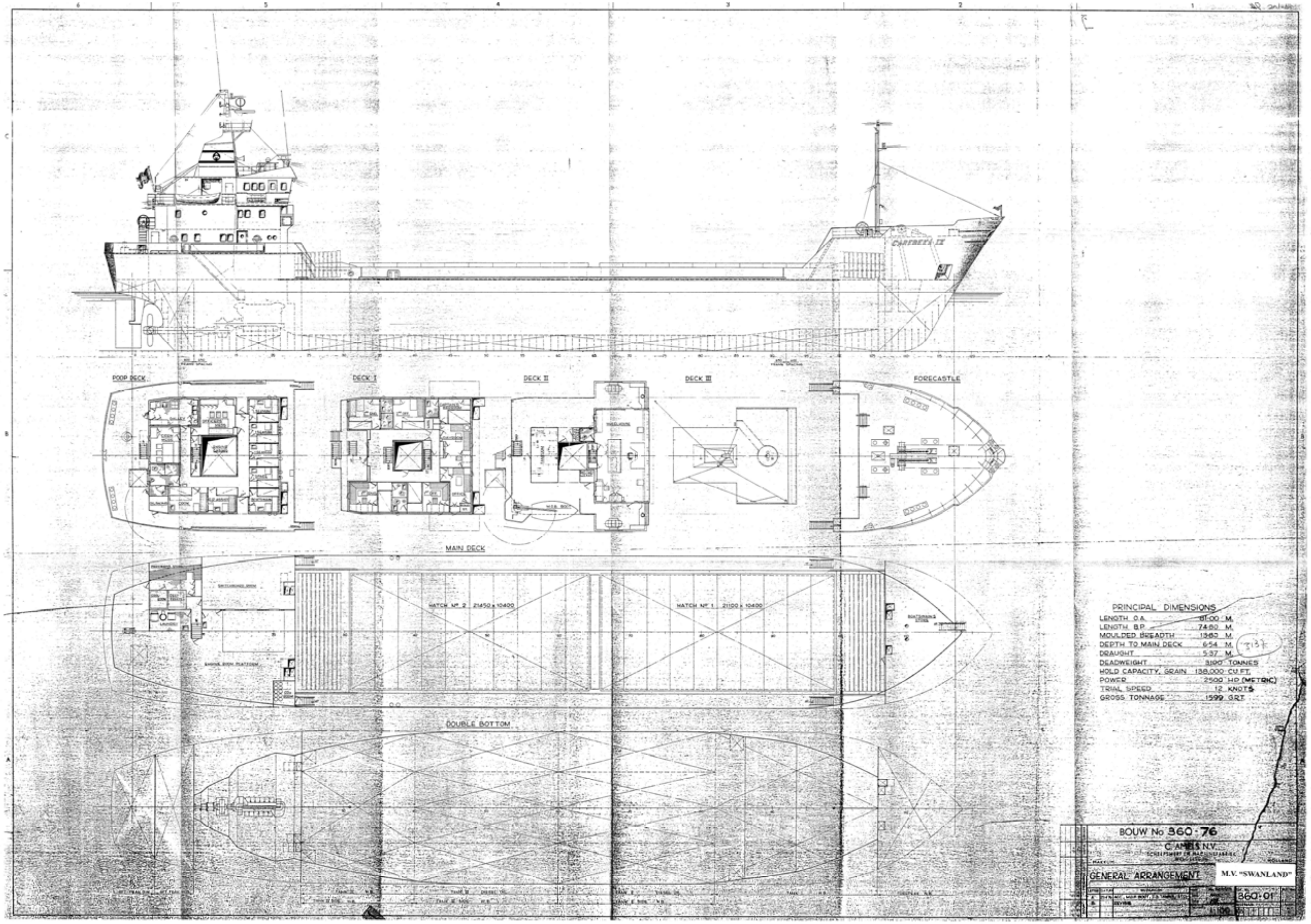


Figure A.1 – MV SWANLAND General Arrangement

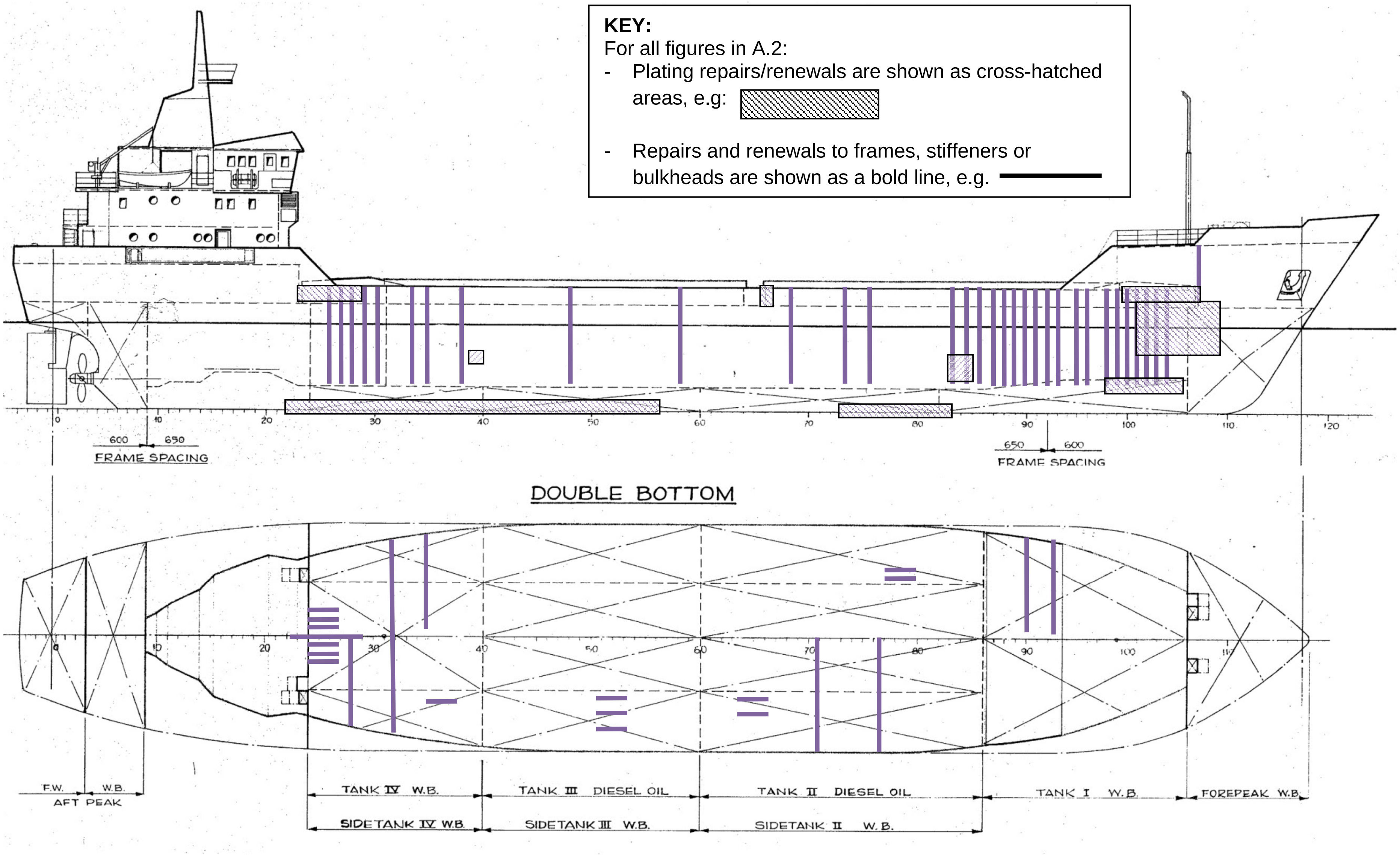


Figure A.2(a) – Areas in way of Cargo Hold and Double Bottom Repaired in 2009 (Kaliningrad)

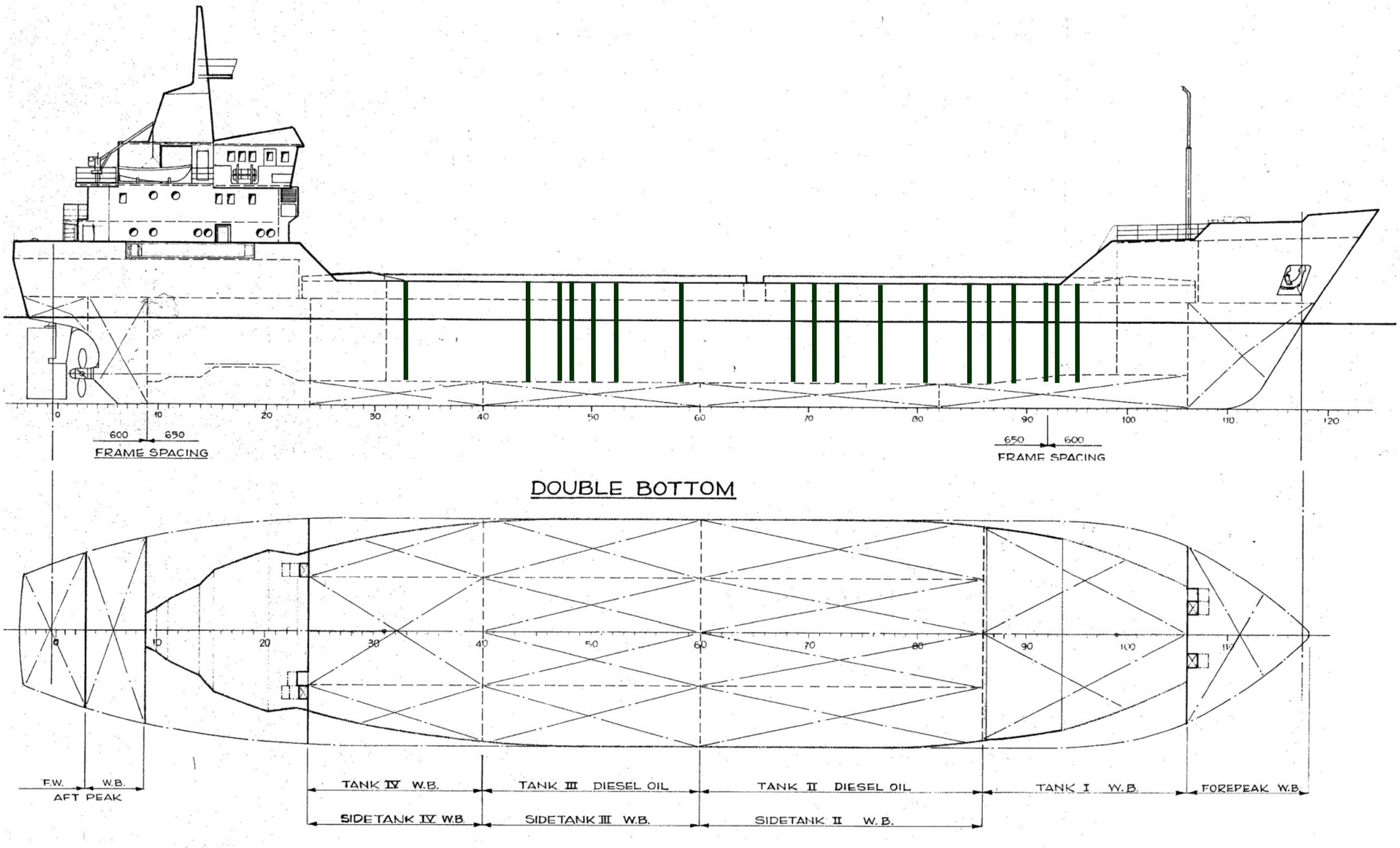


Figure A.2(b) – Areas in way of Cargo Hold and Double Bottom Repaired in 2008 (Great Yarmouth)

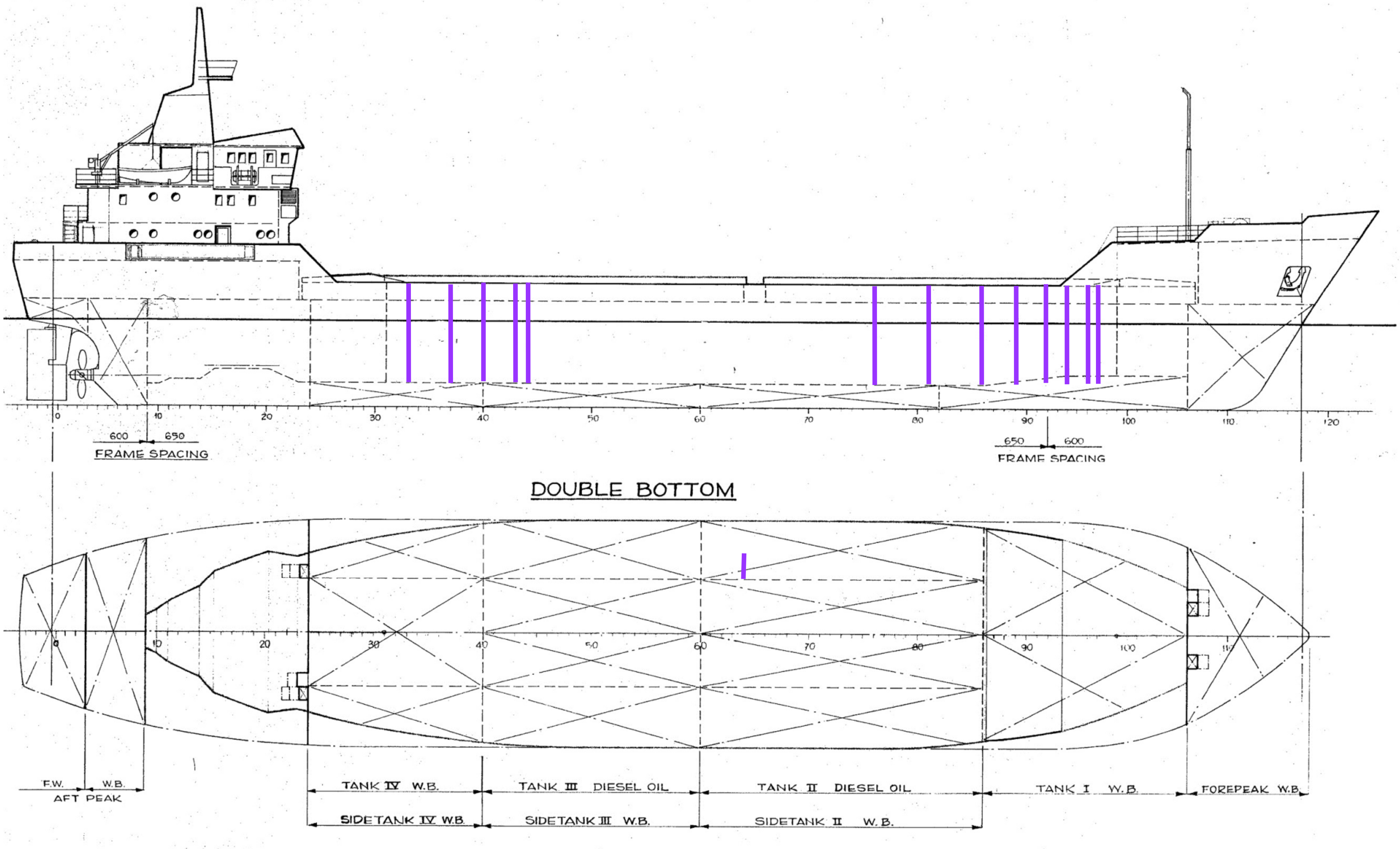


Figure A.2(c) – Areas in way of Cargo Hold and Double Bottom Repaired in 2007 (Warrenpoint)

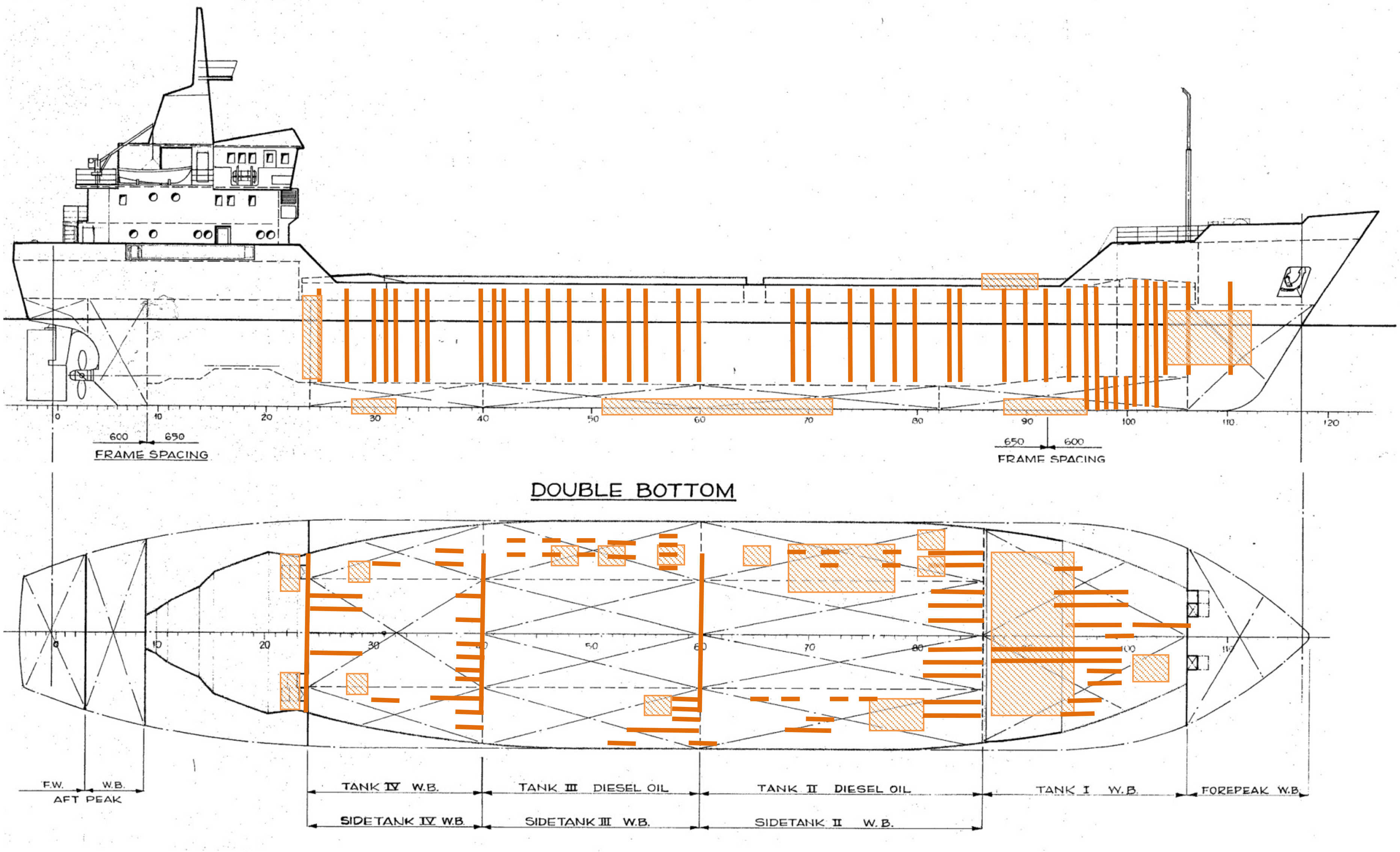


Figure A.2(d) – Areas in way of Cargo Hold and Double Bottom Repaired in 2006 (Leipaja)

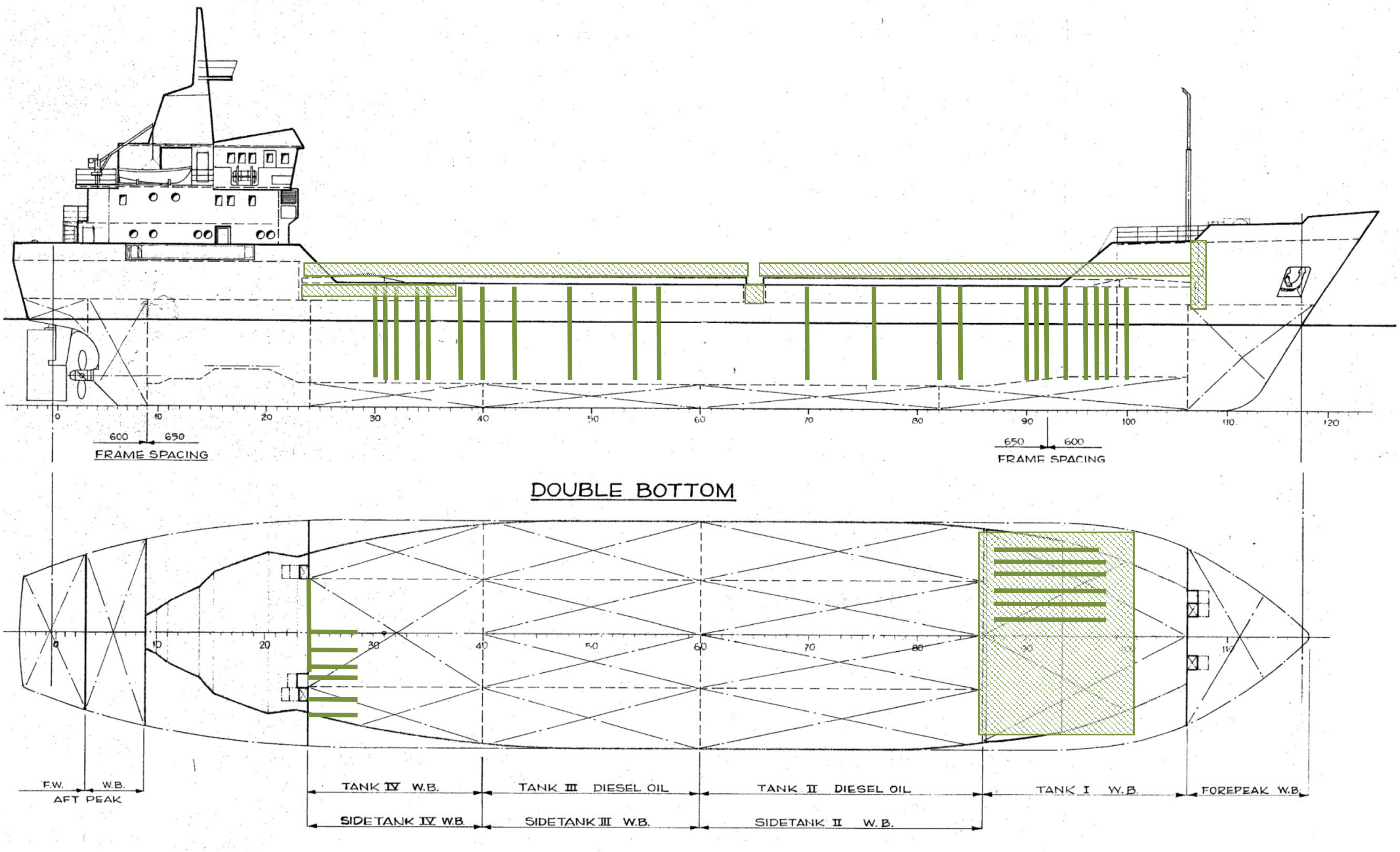


Figure A.2(e) – Areas in way of Cargo Hold and Double Bottom Repaired in 2005 (Great Yarmouth)

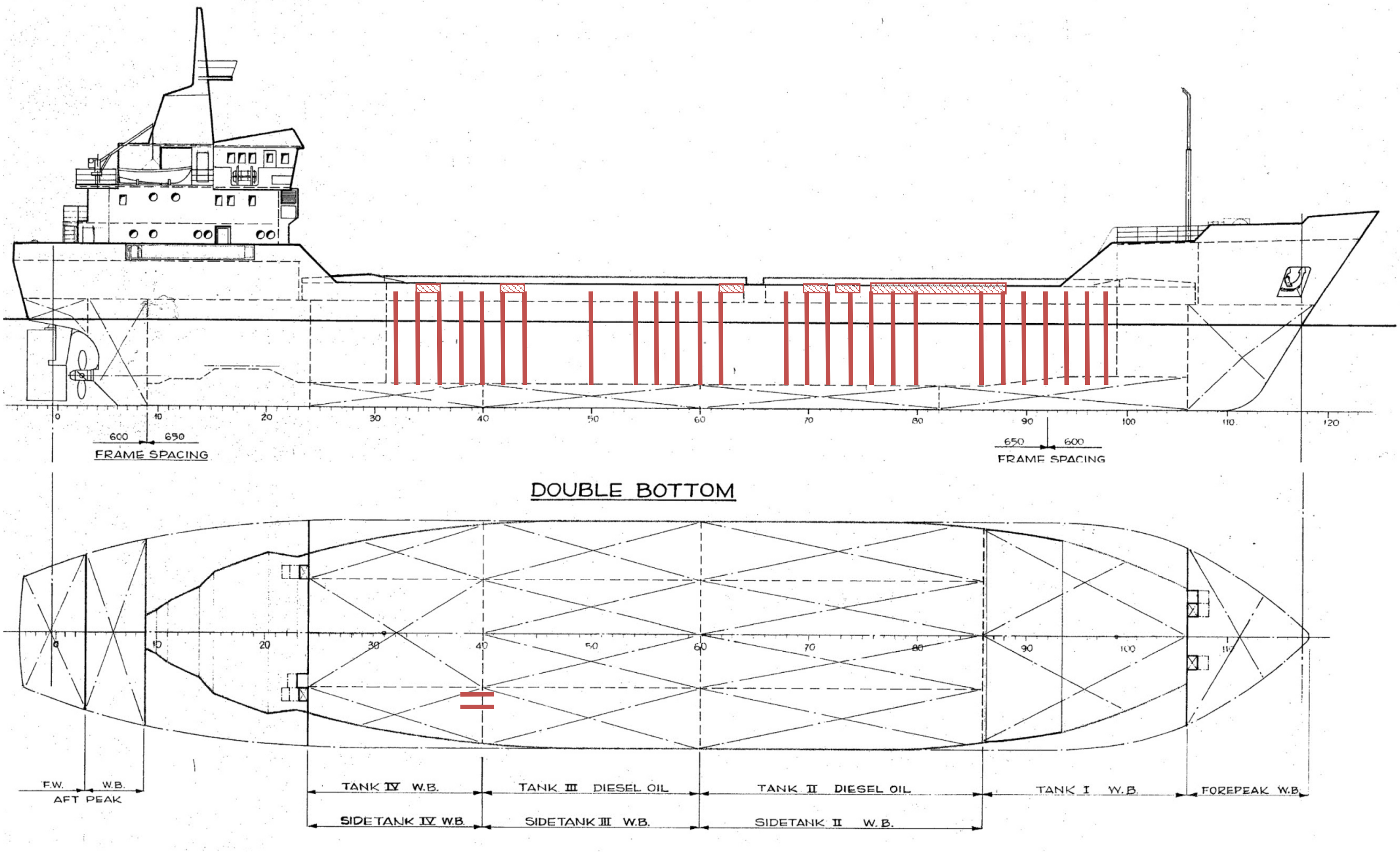


Figure A.2(f) – Areas in way of Cargo Hold and Double Bottom Repaired in 2003 (Reimerswaal) Nb. Only repairs shown, not modifications.

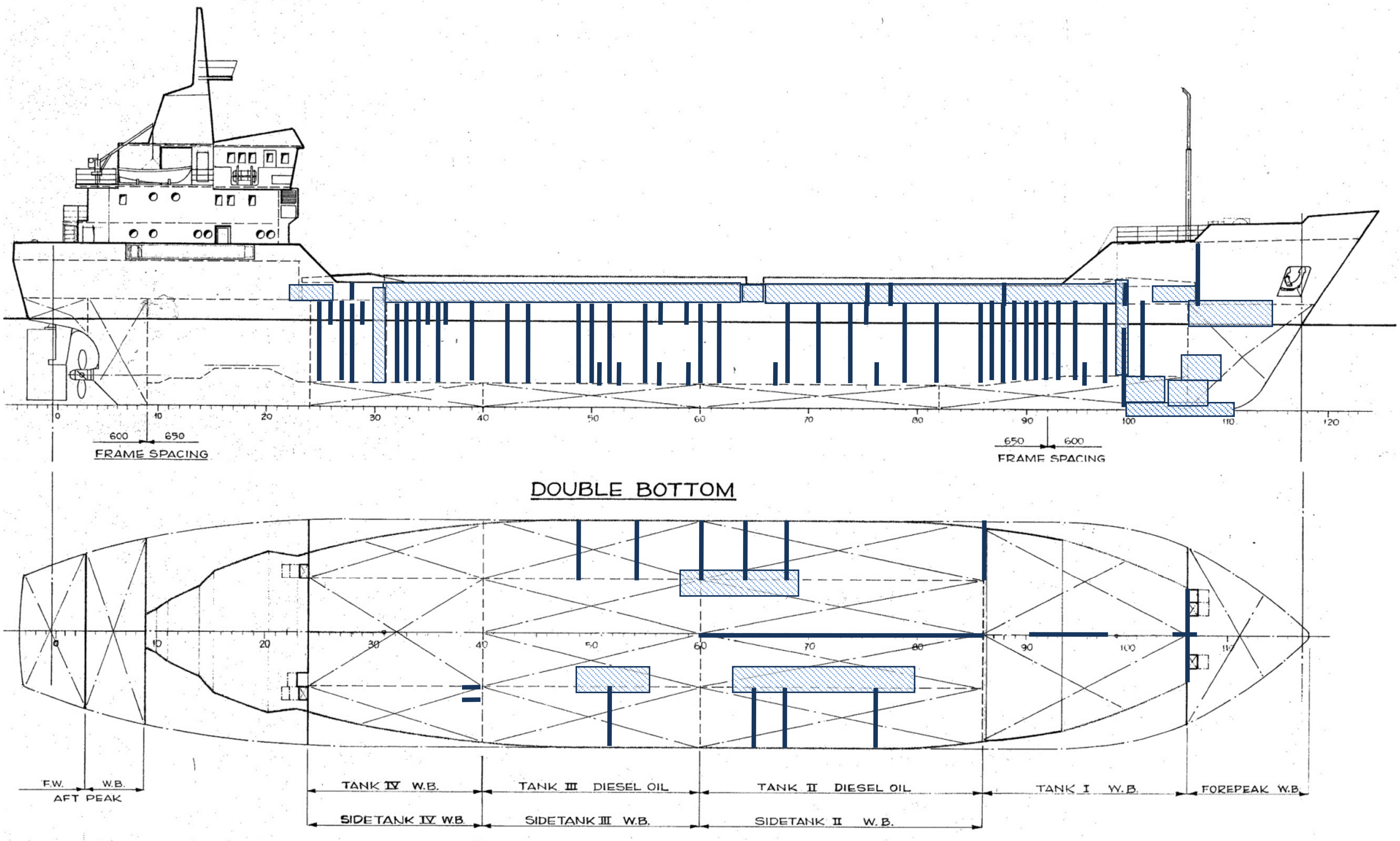


Figure A.2(g) – Areas in way of Cargo Hold and Double Bottom Repaired in 2002 (Bijela)

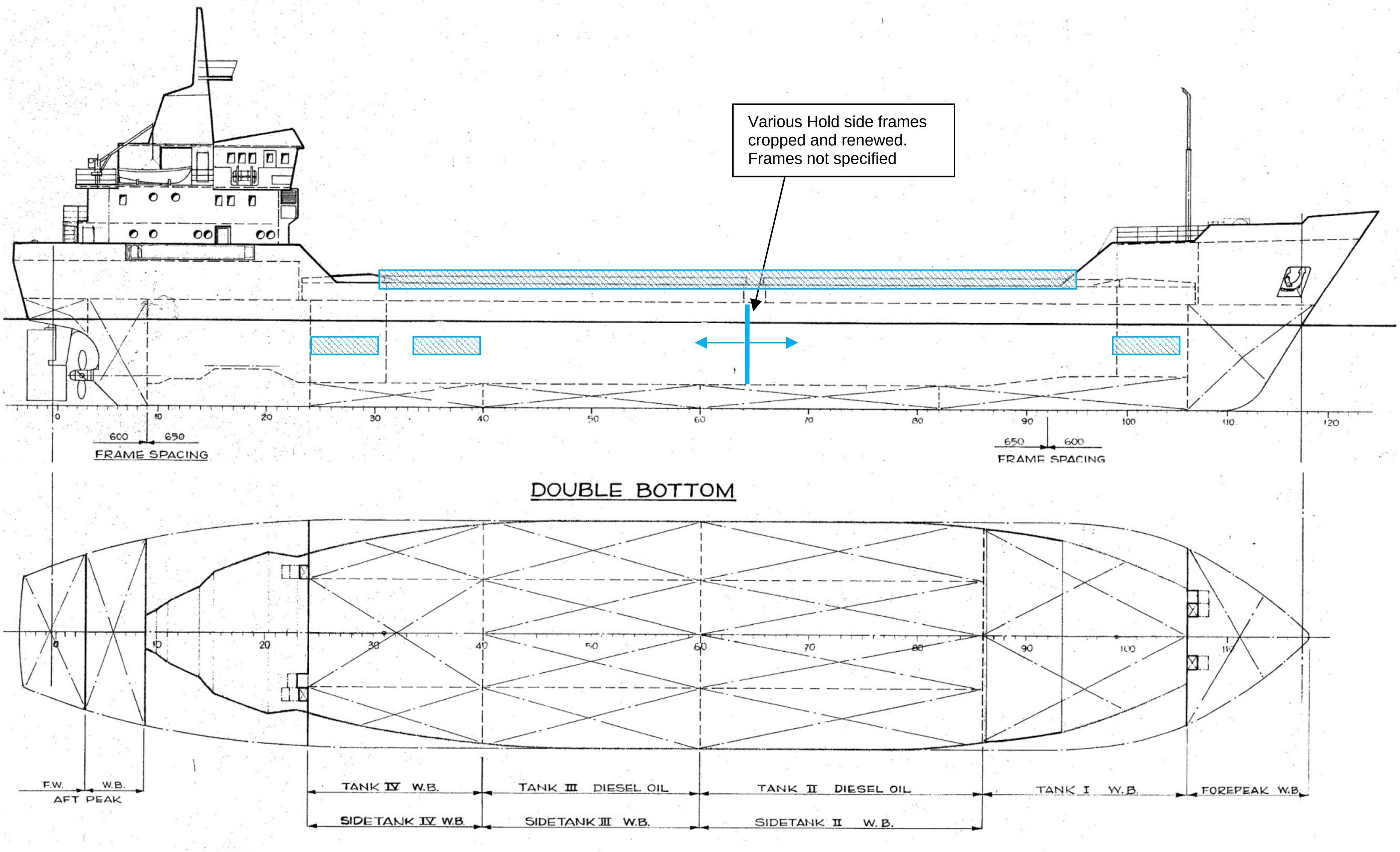


Figure A.2(h) – Areas in way of Cargo Hold and Double Bottom Repaired in 2000 (Leith)

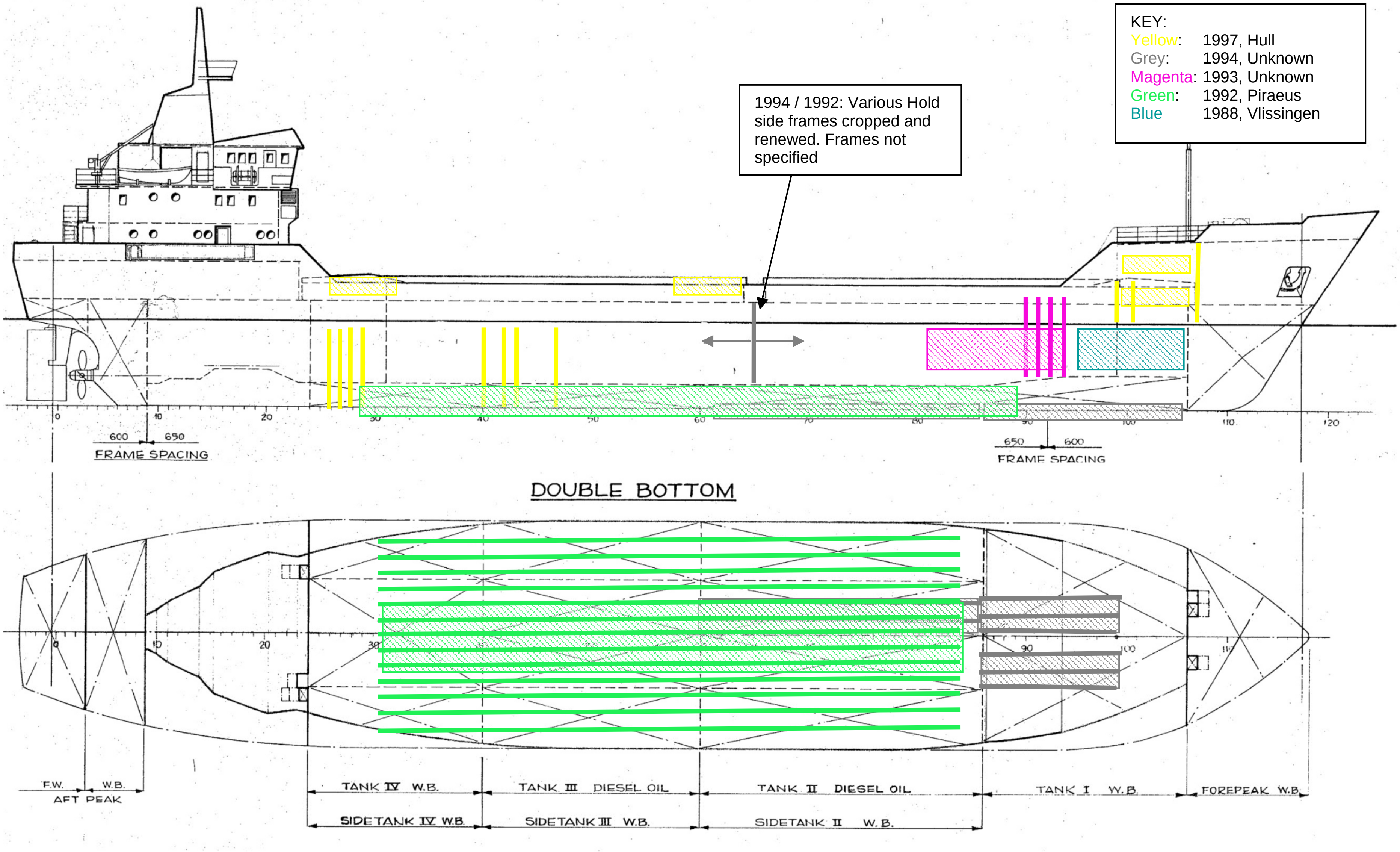


Figure A.2(i) – Areas in way of Cargo Hold and Double Bottom Repaired in 1997 (Hull) and Prior Years to 1988 (1987 excluded as repairs due to grounding)

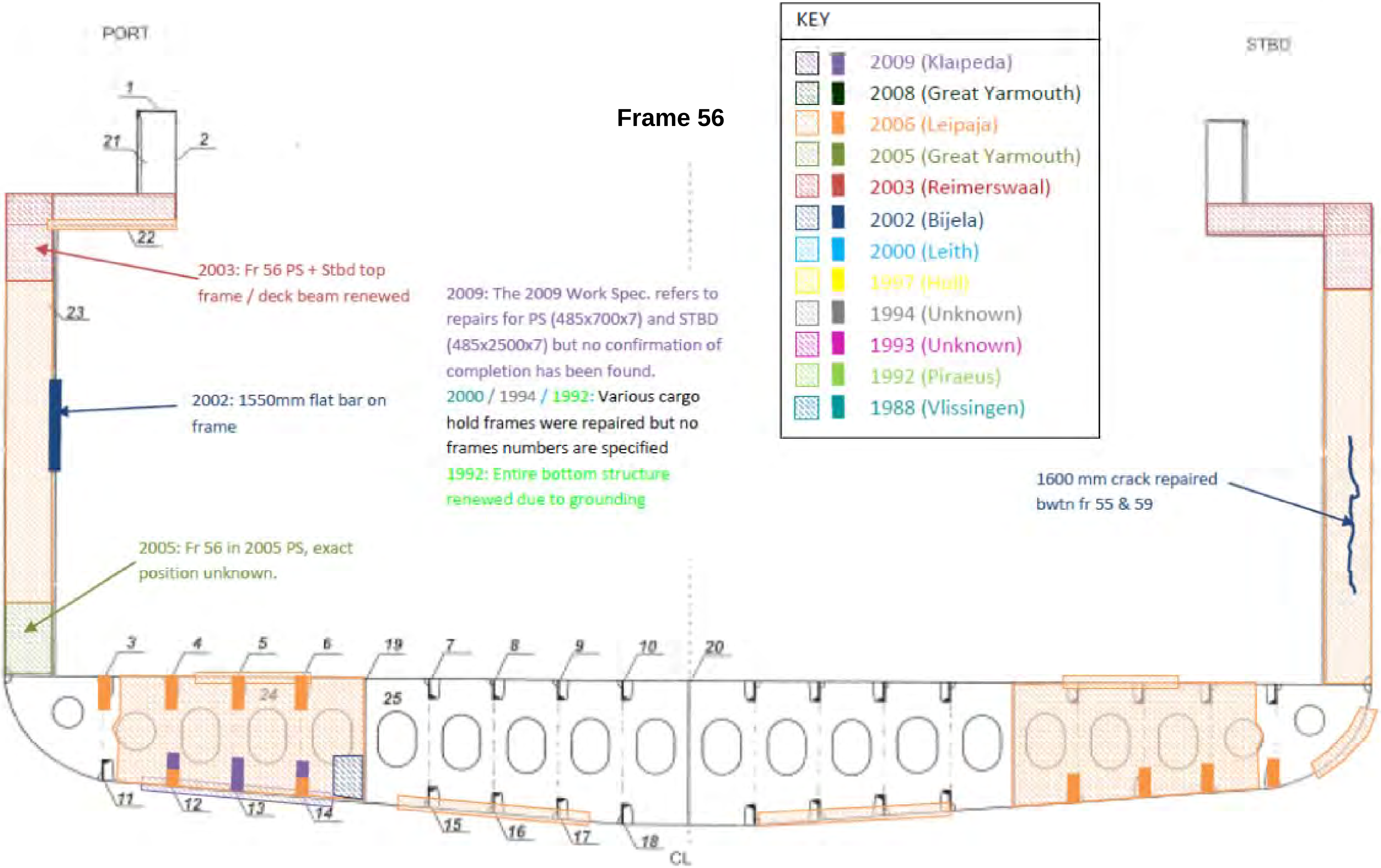


Figure A.2(j) – Areas in way of Frame 56 Repaired between 1988 and 2009

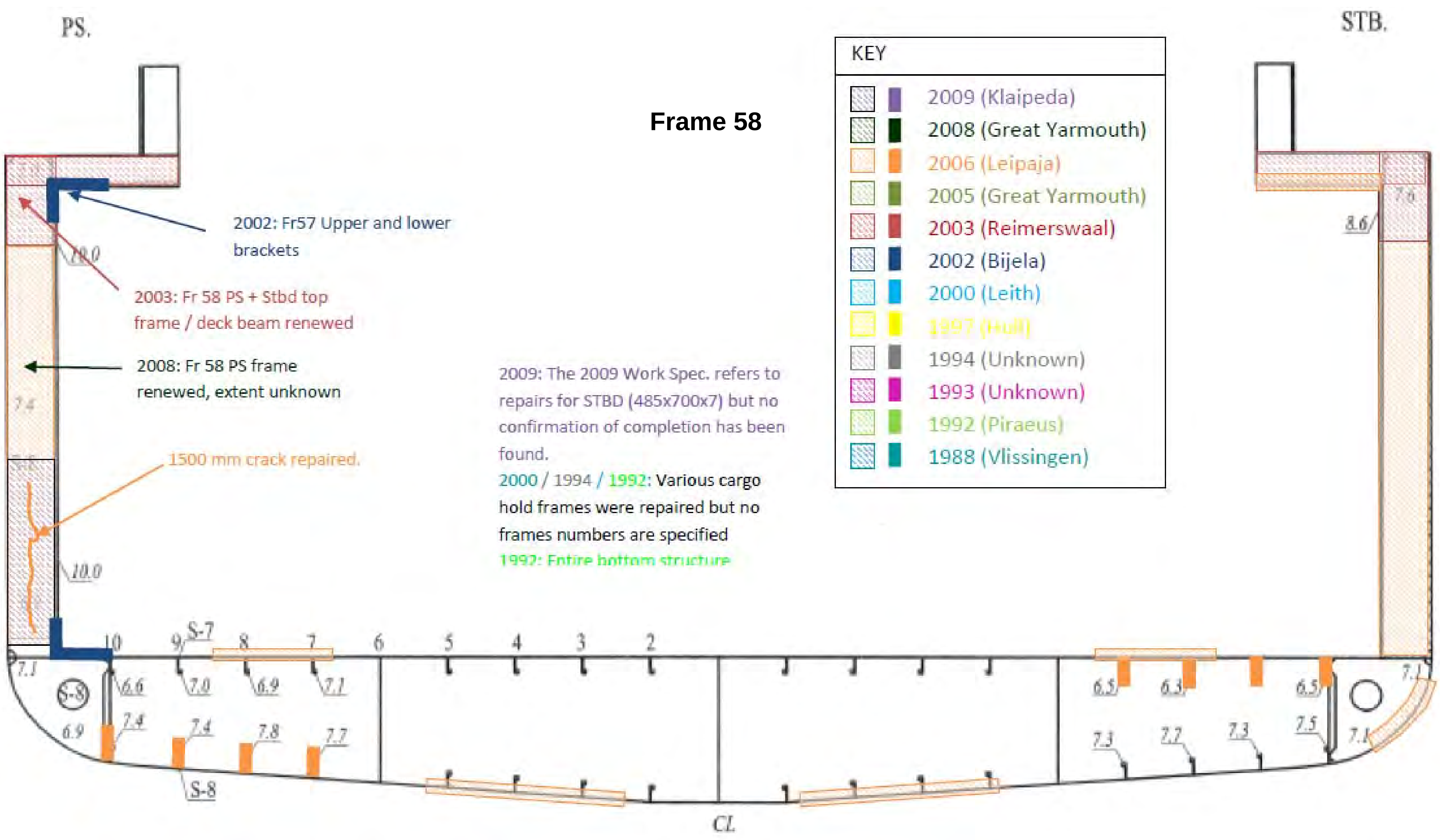


Figure A.2(k) – Areas in way of Midships (frame 58) Repaired between 1988 and 2009

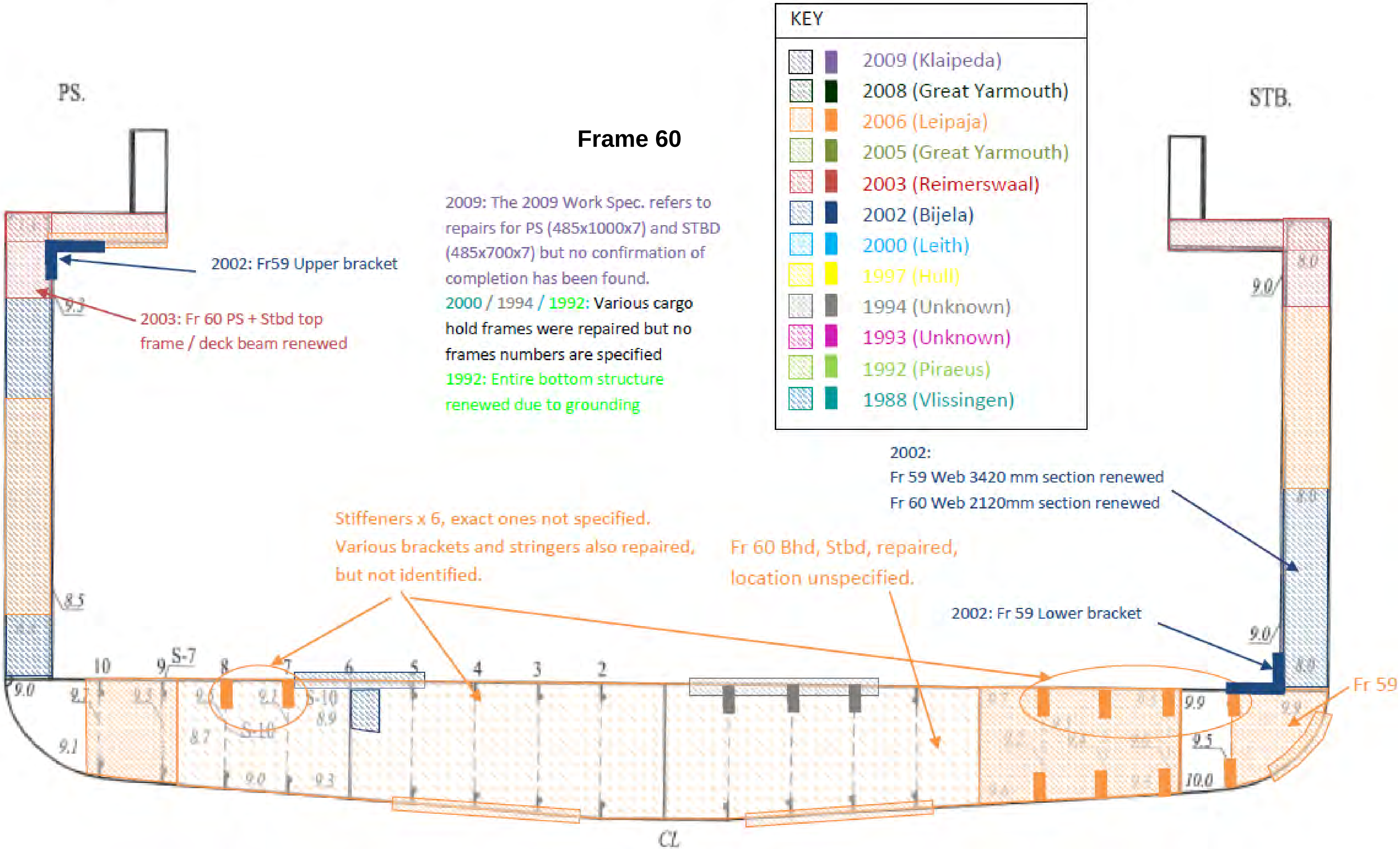


Figure A.2(l) – Areas in way of Frame 60 Repaired between 1988 and 2009

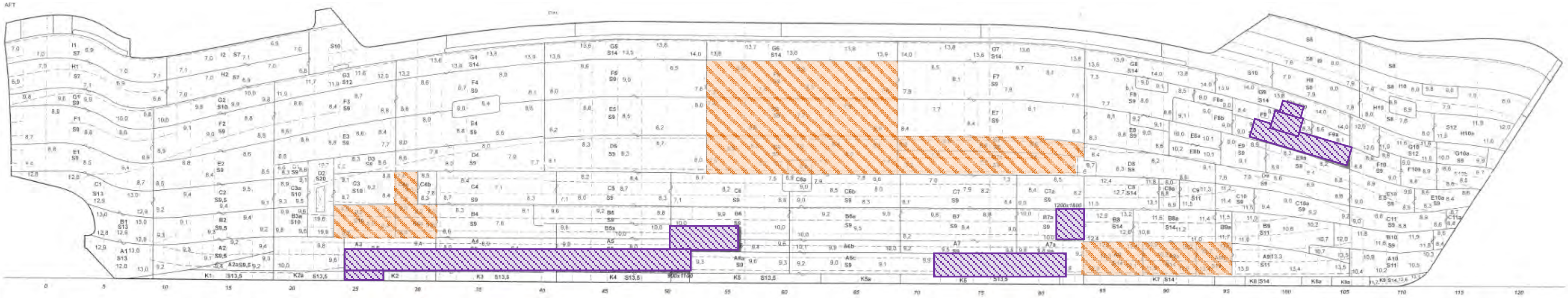


Figure A.3(a) – Side Shell and Bottom Areas Renewed at 2009 Dry-docking and Areas of Diminution Greater than 15% (Starboard)

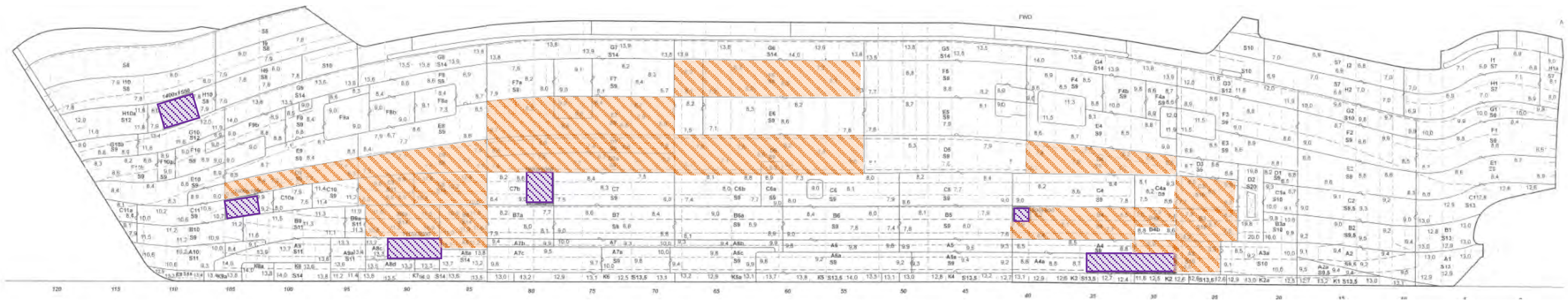


Figure A.3(b) – Side Shell and Bottom Plating Areas Renewed at 2009 Dry-docking and Areas of Diminution Greater than 15% (Port)

KEY:

	Areas of Structure Replaced in 2009.
	Areas of Structure with Diminution Greater than 15%.
	Areas of Structure with Diminution Greater than 75% of Class Limit (22.5%), Requiring Additional UTM and Potential Renewal but not done in 2009.
	Areas of Structure with Diminution Greater than Class Limit (30%), but not replaced in 2009.
	Stiffeners

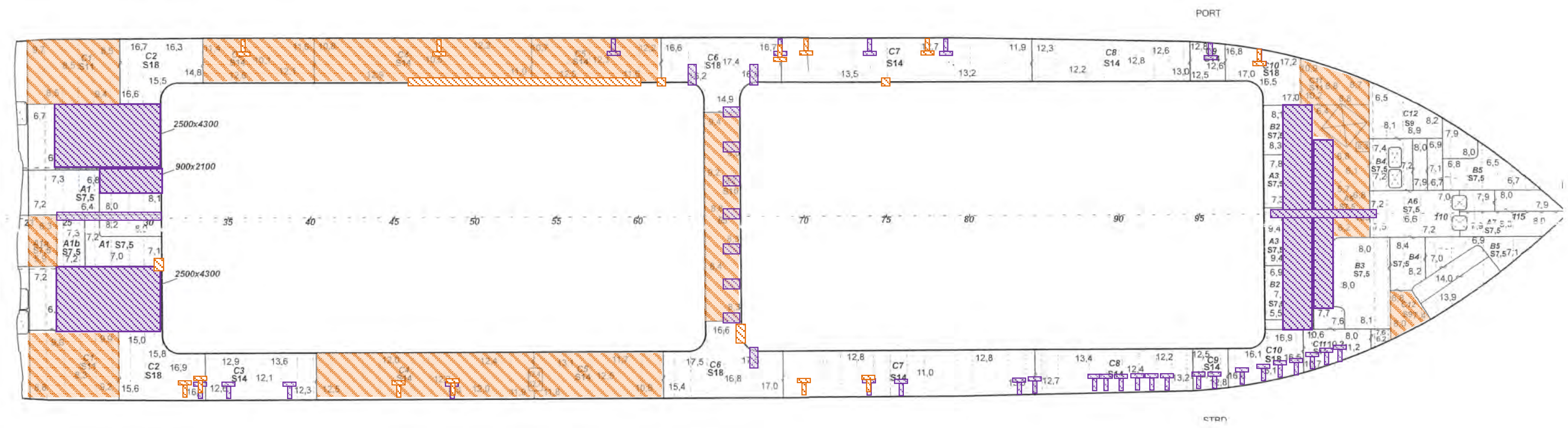


Figure A.3(c) – Main Deck Plating Areas Renewed at 2009 Dry-docking and Areas of Diminution Greater than 15%

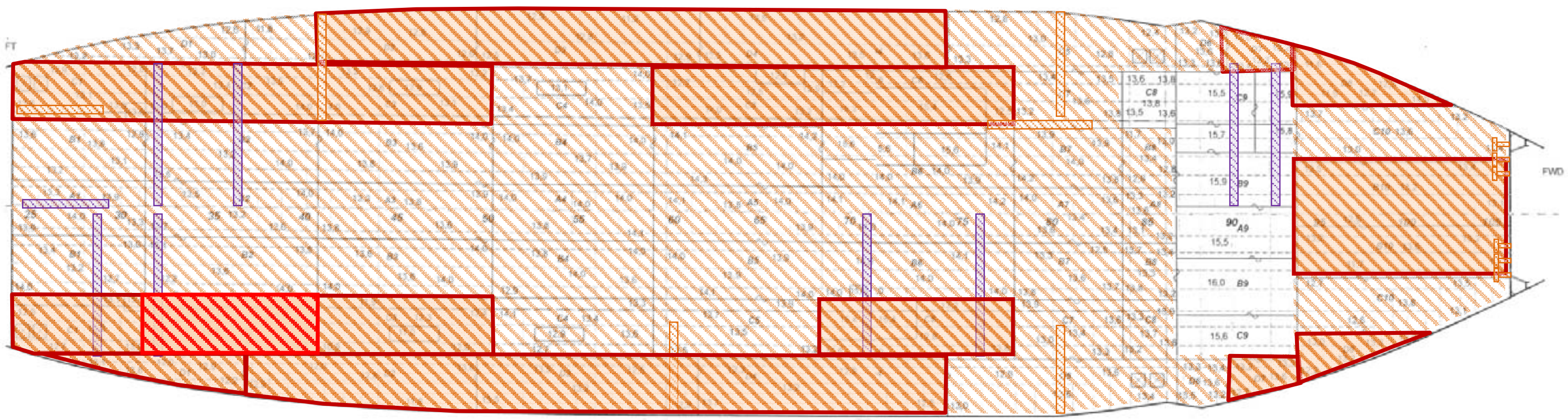


Figure A.3(d) – Tank Top Plating Areas Renewed at 2009 Dry-docking and Areas of Diminution Greater than 15%

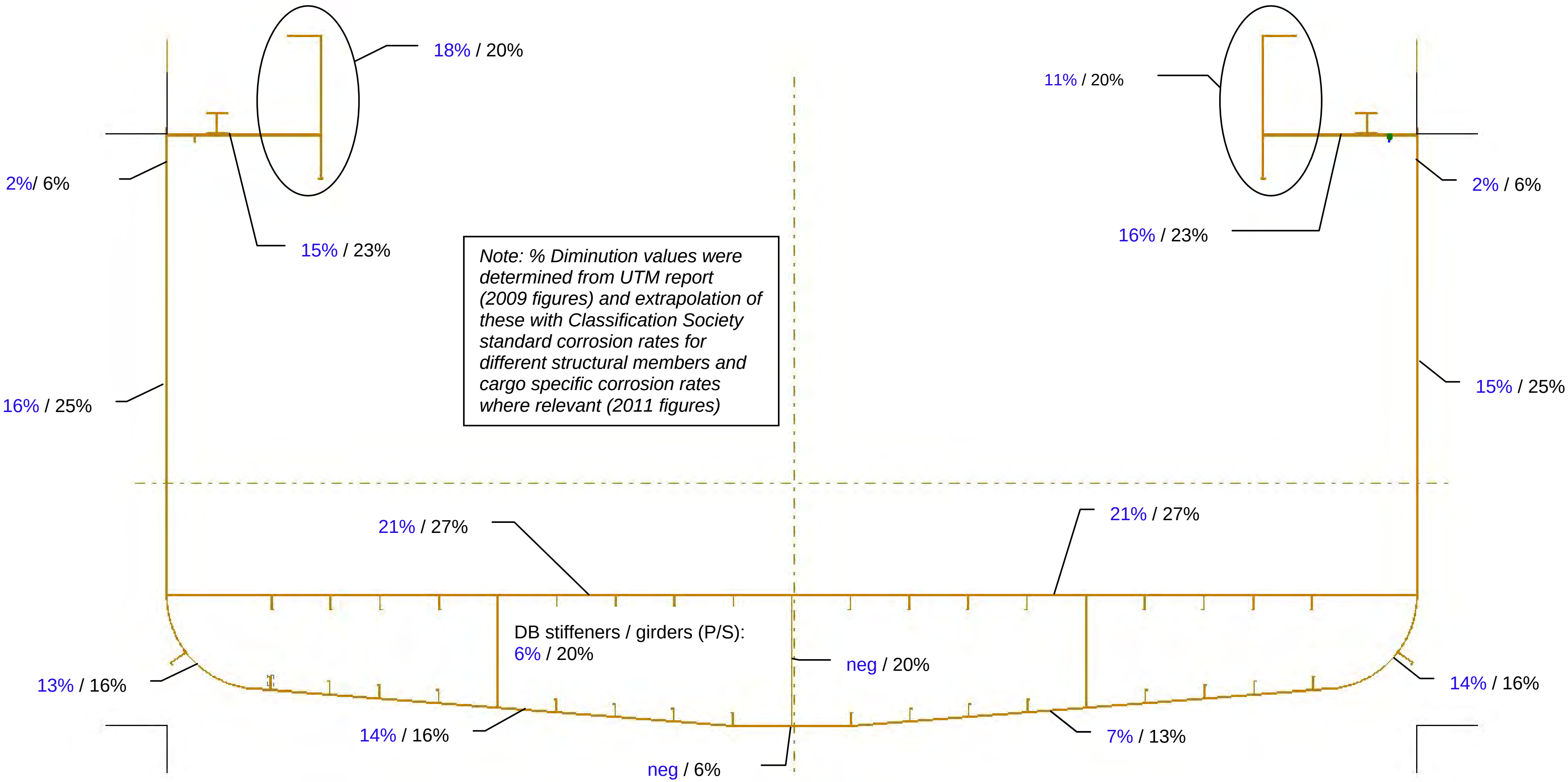


Figure A.4 – Diminution Values Used in Derivation of the Midship Section Modulus (fr 58) at Build, 2009 (post-repair) and at Time of Loss (% at 2009 / % at Nov' 2011)

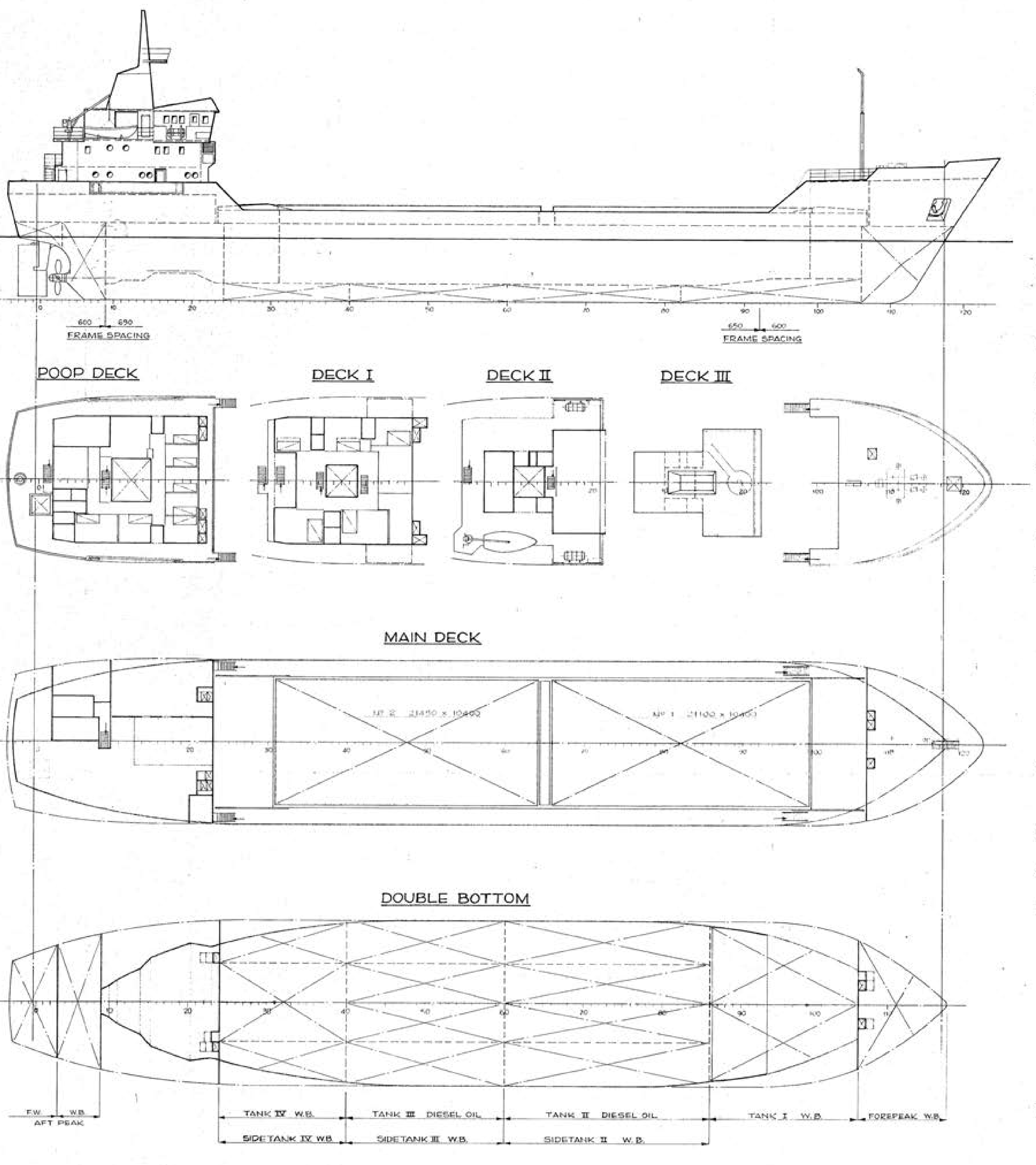
Notes: - The 2009 figures are post-repair, although since very little repairs were undertaken at fr58, there is little difference between the pre-and post-repair condition.

- Although not contributing to longitudinal strength, it is noted that the Port and Starboard side frames at Frame 58 were measured with 53% and 2% diminutions respectively; the former was repaired.

Annex E

MS Carabeka IX Capacity Plan

CAPACITY PLAN



CAREBEKA B.V.
EMMAPLEIN 1
GRONINGEN
HOLLAND
TELEX: 53135
TELEPHONE: 050-183311

M.S. CAREBEKA IX

PRINCIPAL DIMENSIONS:

LENGTH O.A.	81.00 m.
LENGTH B.P.P.	74.80 m.
MOULDED BREADTH	13.80 m.
DEPTH AT MAIN DECK	6.54 m.
DRAUGHT	5.364 m.
DEADWEIGHT	3137 TONNES.
GROSS TONNAGE	1598.31 R.T.
NETT TONNAGE	1080.78 R.T.
SPEED	12 KN.

CLASS L.R.S. 100 A1 L.M.C.

SAILING AREA UNRESTRICTED

NAVIGATIONAL EQUIPMENT:

GYROCOMPASS	SPERRY SR 120
RADAR (2)	ATLAS 4100 + FURUNO FRS 24
NAVIGATOR	SPERRY OMEGA SR 500
ECHO SOUNDER	SPERRY SR 8000
DIRECTION FINDER	RADIO HOLLAND RZ 2051

MAIN ENGINE: 1-NOHAB POLAR TYPE F212-D825.
2640 BHP/825 RPM REDUCED TO 2500 BHP/825 RPM

AUXILIARY ENGINES: 3-VOLVO PENTA TYPE TMD 120 AK
PER ENGINE 231 BHP/1500 RPM

VARIABLE PITCH PROPELLER: J.W.BERG TYPE 800 H/4

HEATING & VENTILATION: INTERNATIONAL HI-PRES

HYDRAULIC FOLDING HATCHES:
MACGREGOR-COMARAIN HOLLAND.
HATCH OPENINGS: 1. 21100 x 10400
2. 21450 x 10400
LOADING (EVENLY DISTRIBUTED) 1735 KG/M²

HOLD CAPACITY, GRAIN: 139 525 cu.ft.
BALE: 129 672 cu.ft.

TANK CAPACITIES (m³)

WATER BALLAST:

TANK I	108.3	x 2
TANK IV	91.8	
SIDETANK II	63.5	x 2
SIDETANK III	47.7	x 2
SIDETANK IV	23.4	x 2
FOREPEAK	108.0	
AFT PEAK	77.0	

FRESH WATER:
AFT PEAK 28.4

DIESEL OIL: TANK II 75.0 x 2
III 57.7 x 2

EQUIPMENT:

HALL ANCHORS	1740 KG.	2 + 1 RESERVE
ANCHOR CHAIN	36 mm.	16 x 15 FATHOMS
TOWING HAWSER	BREAKING STR. 34,500 KG.	190 m.
MOORING HAWSER	" " 15,000 KG.	4 x 110 m.

WINDLASS
ELECTRIC 5.7 TON
CAPSTAN
ELECTRIC 3 TON
} UETERSENER MASCHINENFABRIK HATLAPA

LIFESAVING APPLIANCES:

MAN OVERBOARD BOAT: MULDER & RIJKE.
POLYESTER/FIBREGLASS.
L x B x H: 4.20 x 1.70 x 0.68 m.
WITH JOHNSON OUTBOARD MOTOR.
TYPE 10 BA 74 L

LIFERAFTS: R.F.D. SELF-INFLATING.
TYPE 15 MM, MK. 4.

DRG. Nº 360-58[B]
SCALE 1:200

BUILT 1977 BY

AMELS B.V.
WORKUMERDIJK
MAKKUM
HOLLAND
TELEX: 46188
TELEPHONE: 05158-1441

6.0 / 5.75 / m²

Annex F

Extracts from ‘The LR Rules and Regulations for the Construction and Classification of Steel Ships 1976’ (“full” LR 1976 Rules)

LLOYD'S REGISTER OF SHIPPING

No. 71, Fenchurch Street, E.C.3

LONDON

RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1976

LLOYD'S REGISTER OF SHIPPING

RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1976

71 FENCHURCH STREET, LONDON, EC3M 4BS

Telegraphic Address { *Inland: Committee, London, Telex* / *Overseas: Committee, London, E.C.3*

Telephone: 01-709 9166
Telex No.: 888379

NOTE

Chapter D of these Rules is applicable only to ships of 90 m and over in length.

For ships under 90 m in length, *see* the Rules for the Hull Construction of Steel Ships Under 90 m in Length.

Chapter D

HULL CONSTRUCTION

Section 1

GENERAL

Application

101 This Chapter applies to sea-going ships of normal form aud proportions of 90 m and over in length.

Ships of unusual form or proportions, intended for the carriage of special cargoes, or for special or restricted service, will receive individual consideration on the basis of the general standards of these Rules. (For the carriage of liquefied gases, *see* the *Rules for Ships for Liquefied Gases.*)

102 The scantlings and arrangements in passenger ships will be specially considered in relation to the general design features.

Equivalents

103 Alternative arrangements or fittings which are considered to be equivalent to the Rules will also be accepted.

Definitions

104 Length, L, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of rudder post, or to the centre of the rudder stock if there is uo rudder post. L is not to be less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline.

Amidships is to be taken as the middle of the length, L, measuring from the fore side of the stem.

In ships with unusual stern arrangement the length, L, will be specially considered.

105 Breadth, B, is the greatest moulded breadth, in metres.

106 Depth, D, is measured, in metres, at the middle of the length, L, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Sections.

When a rounded gunwale is arranged, the depth, D, is to be measured to the continuation of the moulded deck line.

107 Draught, d, is the summer draught, in metres, measured from top of keel.

108 Passenger ship is a ship, engaged on international voyages, which carries more than twelve passengers.

109 Other parameters are defined in the appropriate Sections.

Plans to be Submitted

110 Plans covering the following items are to be submitted:—

Midship section.
Longitudinal strength calculations.
Longitudinal section.
Shell plating (indicating extent of flat of bottom forward).
Decks.
Watertight bulkheads.
Pillars and girders.
Deep tanks.
Oil fuel bunkers.
Arrangement of fore body.
Rudder.
Sternframe.
Propeller brackets.
Main engine and thrust seating.
Arrangement of after end.
Superstructure and deckhouse.
Hatchways.
Strengthening for navigation in ice.
Masts and derrick posts.
Scheme of welding.
Particulars for calculation of freeboard.
Loading Manual.
Fire protection, detection and extinction arrangements.

111 *See also* D 4012 and D 8008 for additional requirements.

Direct Calculations

112 The scantlings of structural items may be determined using direct calculations. In such cases, the assumptions made and the calculations are to be submitted for approval.

Ballasting

113 Attention should be given to the amount and distribution of water ballast. It has been found that satisfactory service has been obtained when the draught forward is not less than $0{,}027L$ and the longitudinal radius of gyration of the ballasted ship is less than $0{,}25L$.

Cyclic Loading

114 Where higher tensile steel is used, special attention is to be paid to cyclic loading.

Materials

115 Mild steel is to comply with P 2 and higher tensile steel with P 3.

116 The scantlings of those items for which higher tensile steel is used may be reduced as permitted by other Sections of this Chapter.

For this purpose, a higher tensile steel factor k is to be derived as follows:—

$$k = \frac{245}{Y} \quad \left(k = \frac{25}{Y} \text{ metric}\right)$$

or $k = 0{,}725$ $(k = 0{,}725)$
whichever is the greater,

where Y = specified minimum yield stress, or 0,5 per cent proof stress, in N/mm^2 (kgf/mm^2).

Special consideration will be given to steels where Y is greater than 355 N/mm^2 (36 kgf/mm^2).

For mild steel, k may be taken equal to 1,0.

117 Where higher tensile steel is used extensively in the main hull structure, a suitable descriptive notation will be inserted in the *Register Book*.

118 Aluminium alloy used for superstructures, deckhouses, hatch covers or other structural members is to comply with P 12.

Grades of Steel

119 Steel of a Grade other than A is to be incorporated as required by other Sections of this Chapter.

120 Where higher tensile steel replaces Grades A, B and D mild steel for parts of the structures, then for plates, Grade AH may be used up to and including a thickness of 25,5 mm, and Grade DH is to be used when the thickness of the higher tensile plates exceeds 25,5 mm.

For slab type longitudinals, flame cut from plate, Grade AH may be used up to and including a thickness of 35,5 mm, provided that the carbon equivalent of the steel does not exceed 0,41 per cent, and Grade DH is to be used where the carbon equivalent is greater than 0,41 per cent if the thickness exceeds 20,5 mm.

Grade EH plates are normally to be substituted for Grade E (*but see also* D 414).

For formula for carbon equivalent, *see* D 3219.

Plans for Location of Material

121 To facilitate the ordering of material for repairs, a plan is to be carried in the ship indicating the position and

216 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service.

The following methods of attachment would be acceptable:—

(a) Steel core connected to the structure by continuous welding of adequate section.

(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support.

(c) Approved means of mechanical clamping.

217 Anodes are to be attached to stiffeners or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell.

The two ends are not to be attached to separate members which are capable of relative movement.

Where cores or supports are welded to the main structure, they are to be kept clear of toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web and the welding is to be kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be to the web or at the centreline of the face plate.

Aluminium and Magnesium Anodes

218 Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil but only in locations where the potential energy does not exceed 275 J (28 kgf m). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1 m wide provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, then the height of the anode may be measured above that surface.

Aluminium anodes are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

219 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

External Hull Protection—Impressed Current Systems

220 When the external hull is protected by means of an impressed current system in association with a suitable high duty coating, the ship may be eligible for increased interval between drydockings. *See* B 802.

Plans showing the proposed layout of anodes and reference cells, the wiring diagram and the proposed means of bonding in the rudder and propeller are to be submitted. Where the deferment of drydocking is desired, details of the proposed hull coating are also required.

221 The arrangements for glands where cables pass through the shell are to include a small cofferdam.

Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of about 10 mm in thickness. *See also* M 1623.

Scantling Allowance for Corrosion Control

222 Scantlings in tanks may be reduced in accordance with Table D 2.1 and associated Notes, provided that all surface areas are protected with an approved system of corrosion control. In such cases the notation "(cc)" will be entered in the *Register Book.*

Scantlings in dry compartments may be reduced similarly, but in such cases, only an approved coating system of corrosion control, or equivalent, would be acceptable.

223 Full particulars of the proposed corrosion control system are to be submitted, and the steelwork plans are to show both the Rule and the corrosion control scantlings.

Approved Systems of Corrosion Control

224 Systems of corrosion control installed in association with reduced scantlings and the notation "(cc)" are to comply with (a) or (b) below, as appropriate.

Combinations of these systems or other systems of corrosion control will be specially considered on the basis of providing equivalent protection.

(a) **Coating Systems**

The proposed coating must have been approved by the Society.

The coating is to be compatible with any previously applied primer. *See* 206.

All surface areas in tanks where scantling allowances have been permitted are to be coated.

The painting specification for these areas is to be submitted and is to include the following information:—

(i) Details of the surface preparation.

(ii) Name and type of primer coating (if any).

235 For arrangements in way of refrigerated holds, *see* N 415 and N 416.

Deck Coverings

236 Where plated decks are sheathed with wood or approved composition, reductions in plate thickness may be allowed. *See* D 425.

The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck.

237 Deck coverings are to be of a type which will not readily ignite where used on decks:

(a) forming the crown of machinery or cargo spaces within accommodation spaces of cargo ships,

(b) within accommodation spaces, control stations, stairways and corridors of passenger ships.

Section 3

ASSESSMENT OF LONGITUDINAL STRENGTH

Symbols

301 L = length of ship, in metres,

L_{pp} = the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In ships with unusual stern arrangements, the length L_{pp} will be specially considered.

B = breadth of ship, in metres,

D = depth of ship, in metres,

C_b = moulded block coefficient at load draught but is not to be taken less than 0,50. The block coefficient is to be determined using the length L.

I = the actual inertia, in cm^4, of the hull midship section about the horizontal neutral axis,

y = the vertical distance, in metres, from the neutral axis to the moulded deck line at side, or to the line of top of keel, as appropriate,

$\left(\frac{I}{y}\right)_m$ = the minimum hull midship section modulus, in cm^3, *see* 319,

$\frac{I}{y}$ = the design hull midship section modulus, in cm^3, to deck or bottom as appropriate,

k = higher tensile steel factor, *see* D 116,

M_W = the Rule wave bending moment amidships, in kN m (tonne-f m),

M_S = the design still water bending moment, in kN m (tonne-f m),

F_W = the Rule wave shear force, in kN (tonne-f),

F_S = the design still water shear force, in kN (tonne-f),

V = maximum service speed, in knots, with the ship in the loaded condition,

σ_S = the Rule still water bending stress, in N/mm^2 (kgf/mm^2),

σ_W = the Rule wave bending stress, in N/mm^2 (kgf/mm^2),

σ_C = the Rule combined stress ($\sigma_S+\sigma_W$), in N/mm^2 (kgf/mm^2).

General

302 Longitudinal strength calculations are to be made covering the range of load and ballast conditions proposed for the ship in order to determine the required minimum hull midship section modulus and, where applicable, the shear forces which will be imposed on the hull structure.

303 The requirements of this Section apply to sea-going ships of normal form, proportions and speed unless direct calculation procedures are adopted, in which case the assumptions made and the calculations performed are to be submitted for approval. For ships with restricted service notations, consideration will be given to proposals for a suitably reduced hull section modulus.

304 Individual consideration based on direct calculation procedures will generally be required for ships having one or more of the following characteristics:—

(a) Length L greater than 400 m.

(b) Speed V greater than that defined in Table D 3.1, for the associated block coefficient.

(c) Unusual type or design.

(d) Unusual hull weight distribution.

(e) $\frac{L}{D}$ greater than 17, $\frac{L}{B}$ less than 5, or $\frac{B}{D}$ greater than 2,5.

(f) Large deck openings (*see* 305) or when warping stresses in excess of 14,7 N/mm^2 (1,5 kgf/mm^2) are likely to occur. (*See* 323 and 341).

(g) Openings for side loading in way of both sheerstrake and stringer.

TABLE D 3.1

LENGTH L	C_b	SPEED V
200 m or less	> 0,80 = 0,65 < 0,50	17 20 25
over 200 m	> 0,80 = 0,65 < 0,50	18 23 28

NOTE. Speed for intermediate values of C_b to be obtained by linear interpolation.

305 A ship is regarded as having large deck openings if both the following conditions apply to any one opening:—

(a) $\frac{b}{B_1} > 0,6$

(b) $\frac{l_H}{l_{BH}} > 0,7$

where b = breadth, in metres, of the opening. Where there are multiple openings abreast, these are regarded as a single opening, and b is to be the sum of the individual widths of these openings.

B_1 = extreme breadth, in metres, of deck, including opening, measured at the mid-length of the opening.

l_H = length, in metres, of the opening,

l_{BH} = distance, in metres, between centres of the deck strip at each end of the opening. Where there is no further opening beyond the one under consideration, the point to which l_{BH} is measured will be considered.

See also Fig. D 3.1.

306 For the purpose of longitudinal strength calculations, the ship is to be divided into 21 stations based on the length between perpendiculars, L_{pp}, such that:—

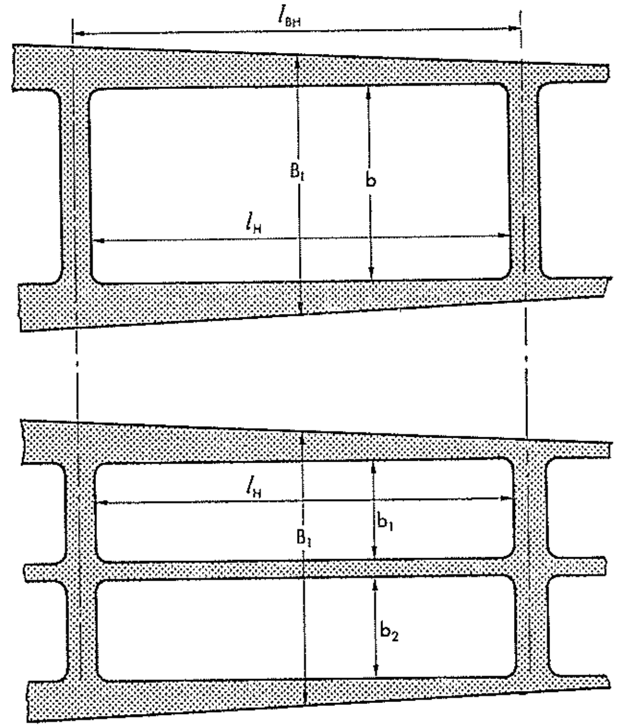
Station 0 is at the aft perpendicular,

Station 10 is at the middle of L_{pp}, and

Station 20 is at the fore perpendicular.

Erections Contributing to Hull Strength

307 Where a long superstructure or deckhouse is fitted extending within the 0,5L amidships, the requirements for longitudinal strength in the hull and erection will be considered in each case.



b = b_1 + b_2

FIG. D 3.1

Direct Calculation Procedures

308 Direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, are to take into account the ship's actual form and weight distribution.

The Society's direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval should normally contain these three elements and produce similar and consistent results when compared with the Society's method.

Information Required

309 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in the Society's standard format where appropriate:—

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

Ships for the carriage of bulk dry cargoes such that the loading (in at least one hold or compartment) is denser than that corresponding to a stowage rate of 1 m^3/tonne.

Type 2

General and miscellaneous cargo ships.
Ships for the carriage of bulk dry cargoes such that the loading in each hold or compartment is less dense than that corresponding to a stowage rate of 1 m^3/tonne.
Liquefied gas carriers.

The stowage rate is defined as the volume of the hold or compartment (excluding the hatchway) divided by the weight of cargo stowed therein.

In general, proposals to use one hold or equivalent compartment as a water ballast tank need not be taken into account in determining ship type.

The requirements for ships of special or unusual design and for the carriage of special cargoes will be individually considered, *see* 304.

TABLE D 3.2

LENGTH L	FACTOR C_1
m	
90	7,840
100	8,040
125	8,473
150	8,913
over 150 and not exceeding 300	$C_1 = 10{,}75 - \left(\frac{300-L}{100}\right)^{1,5}$
over 300 and not exceeding 350	10,75
375	10,69
400	10,63

NOTE. Intermediate values of C_1 to be obtained by linear interpolation.

TABLE D 3.3

POSITION	FACTOR	
	$F_n \leqslant 0{,}20$	$F_n = 0{,}30$
Station 0 (A.P.)	0,00	0,00
2	0,14	0,14
4	0,30	0,30
6	0,58	0,58
8	0,87	0,87
10 (mid-L_{pp})	1,00	1,00
12	0,90	0,95
14	0,68	0,80
16	0,41	0,62
18	0,20	0,33
20 (F.P.)	0,00	0,00

Hull Midship Section Modulus

319 The design hull midship section modulus $\frac{I}{y}$ is not to be less than the greater of the following values:—

(a) $\frac{I}{y} = \left(\frac{I}{y}\right)_m$

where $\left(\frac{I}{y}\right)_m = C_1 L^2 B (C_b + 0{,}7)$ cm^3

and C_1 is defined in Table D 3.2.

(b) $\frac{I}{y} = \frac{M_s + M_w}{\sigma_c} \times 10^3$ cm^3

where M_w, M_s and σ_c are in appropriate units, *see* 301.

Still Water Bending Moments—Special Consideration

320 For sea-going service (*see* Table D 3.4), for any loading condition where the maximum design still water bending moment, M_s, exceeds 0,8 M_w for Type 1 ships or 1,0 M_w for Type 2 ships, the design hull midship section modulus is to be not less than:—

For Type 1 ships

$$\frac{I}{y} = \left(\frac{2}{3\sigma_s}\left(M_s - 0{,}8\,M_w\right) + \frac{1{,}8\,M_w}{\sigma_c}\right) \times 10^3 \text{ cm}^3$$

For Type 2 ships

$$\frac{I}{y} = \left(\frac{2}{3\sigma_s}\left(M_s - M_w\right) + \frac{2\,M_w}{\sigma_c}\right) \times 10^3 \text{ cm}^3$$

where M_w, M_s, σ_s and σ_c are in appropriate units, *see* 301.

(b) Bonjean data, in the form of tables or curves, for at least 21 stations along the hull. A lines plan and table of offsets may also be required when the hull form has to be considered.

(c) Details of the lightweight and its distribution. Where available, the actual lightweight and distribution is to be used. Where, however, it is proposed to use an assumed distribution, and this differs from the Society's standard, data in support of the assumptions may be required.

(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions specified in 310. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water bending moments and shear forces.

310 The main loading conditions to be examined are to include the following:—

(a) For tankers.

- (i) The homogeneous load condition (excluding dry and clean ballast tanks) and ballast or part-loaded conditions for both departure or arrival.
- (ii) Any specified non-uniform distributions of loading.
- (iii) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

(b) Other types of ship.

- (i) The homogeneous and, if applicable, non-homogeneous load and part-loaded conditions, including conditions with deck loading, and the ballast conditions. The calculations are to cover both departure and arrival conditions.
- (ii) Details of the specified loading where a class notation is desired permitting certain holds to be empty.
- (iii) Details of the proposed depths of liquid where water ballast or liquid cargo is proposed to be carried in the holds.
- (iv) Loading conditions for short, or sheltered water, voyages where higher still water bending moments are desired.
- (v) Details of mid-voyage ballasting or other proposed changes in the loading conditions.

311 Further information may be required when direct calculation procedures are adopted.

Approved Calculation Systems

312 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from the Society, calculations using the system for a particular ship may be submitted.

Design Bending Moment

313 The Rule hull midship section modulus is to be determined from the design bending moment in association with a maximum permissible stress which depends on the type of ship.

The design bending moment is to be taken as the sum of still water and wave bending moment components which are derived as follows.

314 The design still water bending moment, M_S, is the maximum moment, hogging or sagging, calculated for all the loading conditions given in 310.

315 The Rule wave bending moment, M_W, is calculated at amidships and is given by the expression:—

$$M_W = \sigma_W C_1 L^2 B (C_b + 0{,}7) \times 10^{-3} \text{ kN m (tonne-f m)}$$

where C_1 has the values given in Table D 3.2 and σ_W has the values given in Table D 3.4.

316 Where the wave bending moment is required at other positions along the length of the ship, the amidship value may be multiplied by the factors given in Table D 3.3. These factors are based on the Froude Number, F_n, which is defined as $\dfrac{0{,}164V}{\sqrt{L_{pp}}}$

For intermediate values of F_n the factor is to be determined by linear interpolation, and for values greater than 0,3, linear extrapolation is to be used.

Maximum Permissible Stresses

317 The permissible stress to be used in the calculation of hull section modulus is the combined stress, σ_C, given in Table D 3.4 for the appropriate ship type.

If higher tensile steel is used, *see* 325 and 326.

318 Ship types for Table D 3.4 are distinguished as follows:—

Type 1

Ships for the carriage of bulk liquid cargoes (e.g. oil tankers, ore or oil and OBO carriers, etc., but excluding liquefied gas carriers).

TABLE D 3.4

SHIP TYPE	σ_C	SEA-GOING SERVICE		SHELTERED WATER SERVICE		SHORT VOYAGES	
		σ_S	σ_W	σ_S	σ_W	σ_S	σ_W
TYPE 1	160,8 (16,40)	62,8 (6,4)	98,1 (10,0)	111,8 (11,4)	49,0 (5,0)	82,4 (8,4)	78,5 (8,0)
TYPE 2	178,0 (18,15)	79,9 (8,15)	98,1 (10,0)	129,0 (13,15)	49,0 (5,0)	99,5 (10,15)	78,5 (8,0)

NOTE. Units of stress are N/mm^2 (kgf/mm^2).

Stress at Deck and Bottom

321 The maximum stresses due to longitudinal bending at the deck and bottom are given by:—

$$\sigma \text{ deck} = \left(\frac{M_S + M_W}{\left(\frac{I}{y}\right) \text{deck}}\right) \times 10^3 \quad N/mm^2\ (kgf/mm^2)$$

$$\sigma \text{ bottom} = \left(\frac{M_S + M_W}{\left(\frac{I}{y}\right) \text{bottom}}\right) \times 10^3 \quad N/mm^2\ (kgf/mm^2)$$

where $\left(\frac{I}{y}\right)$ deck and $\left(\frac{I}{y}\right)$ bottom are the actual section moduli of the hull, in cm^3, and M_W and M_S are in appropriate units, *see* 301.

When the section modulus to deck or bottom is the minimum permitted by 319, the corresponding stress is equal to σ_C.

Short Voyages and Sheltered Water Service

322 For short voyages and sheltered water service, the still water bending moment may be increased by using σ_S as given in Table D 3.4. That is:—

$$M_S = \sigma_S \times \frac{I}{y} \times 10^{-3} \quad kN\ m\ \text{(tonne-f m)}$$

The loading conditions are to appear in the Loading Manual.

"Short voyages" are defined as voyages not exceeding 24 hours in duration, in reasonable weather.

"Reasonable weather" and "sheltered water" are defined in B 105.

Open Type Ships

323 For ships other than container ships, having large deck openings (*see* 305), or where warping stresses in excess of 14,7 N/mm^2 (1,5 kgf/mm^2) are likely to accur, local increases in section modulus within 0,4L amidships may be required and this will influence the maximum Rule still water bending stress.

Where such reinforcement is not required, the Rule stresses are to comply with ship Type 2 of Table D 3.4. For calculations for container ships, *see* 341 and subsequent paragraphs.

Fast Cargo Ships

324 In ships of length between 120 and 170 m and service speed greater than 17,5 knots, in association with a bow shape factor of more than 0,15 (*see* D 124), the Rule hull midship section modulus and the distribntion of longitudinal material in the forward half-length will be considered.

In general, the following requirements are to be complied with:—

(a) The vertical hull midship section modulus, about the horizontal neutral axis, is to be not less than 331 $L\ \Sigma\ A_b$ cm^3, or that required by 319, whichever is the greater. $\Sigma\ A_b$ is defined in D 124.

(b) The horizontal hull midship section modulus, about a vertical axis through the ship centreline, is to be not less than 32,5 L^2D cm^3.

(c) In the forward half-length, the section modulus is not to be a lesser percentage of the midship value than shown in Table D 3.5.

(d) Any load or ballast condition resulting in a sagging still water bending moment, or a hogging moment less than 80 per cent of the Rule value of still water bending moment will be specially considered with a view to minimizing the compressive stresses in the deck in waves.

TABLE D 3.5

POSITION	PERCENTAGE OF VERTICAL MODULUS	PERCENTAGE OF HORIZONTAL MODULUS
Station 10	100	100
12	98	87
14	95	62
16	81	38
18	44	17

NOTE. Intermediate values to be obtained by interpolation.

Modulus Correction for Higher Tensile Steel

325 Where higher tensile steel is used in the main hull structure, the hull midship section modulus as determined above is to be multiplied by the factor k, or by $0{,}059\,\frac{L}{D}$, whichever is the greater.

The higher tensile steel is to be used for the whole of the longitudinal continuous material at least to a distance $(1-k)\,y$ or $\left(1-0{,}059\,\frac{L}{D}\right)y$, whichever is the lesser, from the line of deck at side or keel.

326 Where higher tensile steel is proposed for the topsides only, the hull section modulus at deck is to be multiplied by the factor k, or by $\dfrac{0{,}059\,\frac{L}{D}}{2-0{,}059\,\frac{L}{D}}$, whichever is the greater.

The higher tensile steel is to be used for the whole of the longitudinal continuous material at least to a distance

$$(1-k)\,y \quad \text{or} \quad \left(1-\left(\frac{0{,}059\,\frac{L}{D}}{2-0{,}059\,\frac{L}{D}}\right)\right)y$$

below the line of deck at side, whichever is the lesser.

Calculation of Hull Section Modulus

327 All continuous longitudinal material is to be included in the calculation of the inertia of the hull midship section, and the lever, y, is to be measured vertically from the neutral axis to the top of keel and to the moulded deck line at side.

328 Lightening holes in girders need not be deducted, provided their depth does not exceed 20 per cent of the web depth.

Isolated weld scallops and drain and air holes in longitudinals need not be deducted, provided their depth does not exceed 10 per cent of the web depth, nor 75 mm, whichever is the greater. Such openings are considered isolated if they are spaced not less than 1 to 1,5 m apart.

329 In general, isolated deck openings need not be deducted, but compensation may be required, *see* D 408.

330 Where continuous hatch coamings are arranged, 80 per cent of the area of the coaming may be included in the calculation of hull section modulus, and the lever, y, is to be measured:—

(a) to the moulded deck line at side amidships,

(b) to a point a distance above the moulded deck line at side amidships equal to the height of the hatch coaming above the deck.

The hull section modulus with y measured as in (a) is to be 5 per cent greater, and as in (b) may be 10 per cent less, than that required by 319.

331 Where two or more hatchways are arranged abreast, the percentage of the material between hatchways to be included in the section modulus will be considered. Individual consideration will also be given to other special or unusual designs.

Shear Forces

332 The shear forces on the hull structure are to be investigated for all ships of the two longitudinal bulkhead design and for other types where any non-homogenous loading conditions are proposed.

The Rule wave shear force, F_W, at any position along the ship is given by:—

$$F_W = e^{-0{,}0035L} K_1 K_2 B L^2 (C_b + 0{,}70) \times 10^{-5} \text{ kN (tonne-f)}$$

where

K_1 = 0 at Station 0,
= 2216 (226) between Stations 5 and 7,
= 1383 (141) between Stations 9 and 11,
= 2314 (236) between Stations 15 and 17,
= 0 at Station 20.

Intermediate values to be determined by linear interpolation.

K_2 = 1,0 for sea-going service conditions,
= 0,5 for sheltered water service conditions,
= 0,8 for short voyage service conditions.

For reference purposes, values of $L^2 e^{-0{,}0035L} \times 10^{-5}$ are given by the factor in Table D 3.6.

TABLE D 3.6

L	FACTOR	L	FACTOR
90	0,059 11	260	0,272 11
100	0,070 47	280	0,294 24
120	0,094 61	300	0,314 94
140	0,120 07	320	0,334 11
160	0,146 23	340	0,351 68
180	0,172 56	360	0,367 62
200	0,198 63	380	0,381 91
220	0,224 10	400	0,394 56
240	0,248 67		

333 The actual still water shear force at each transverse section along the hull is the maximum value found from the longitudinal strength calculations for each of the loading conditions specified in 309.

The design still water shear force is to be calculated as given below, and the thickness of material increased if necessary such that the value is not less than the actual still water shear force.

334 Where no longitudinal bulkhead is fitted, the design still water shear force is given by:—

$$F_S = \frac{118\, I_1\, t_1}{100\, A\bar{y}} - F_W \text{ kN}$$

$$\left(F_S = \frac{12\, I_1\, t_1}{100\, A\bar{y}} - F_W \text{ tonne-f}\right)$$

In this expression:—

(a) t_1 = the combined thickness, in mm, of side shell, for both sides of the ship, at the neutral axis. Special consideration will be given to the inclusion of the effective thickness of any partial longitudinal bulkhead, depending on the arrangements of the structure.

(b) I_1 = the inertia, in cm^4, of the hull about the horizontal neutral axis at the section concerned.

(c) $A\bar{y}$ = the first moment of area, in cm^3, of the longitudinal material above the neutral axis at the section concerned.

(d) For ships of normal form and conventional structural design, the values of $A\bar{y}$ and I for the midship section may be used for the calculation of shear stress at any point along the length of the ship.

(e) The actual shear force obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkhead, if applicable. The calculation of these local forces is to be submitted for approval. Alternatively, the proportion of the load carried by the transverse bulkhead may be taken as

$$\frac{k_3}{k_2 \dfrac{l}{b} + k_3}$$

where these terms are defined in D 942.

335 Where double skin construction of the side shell is proposed, shear flow calculations may be required to be submitted.

336 Where two longitudinal bulkheads are fitted, the design still water shear force is generally given by the following expressions, but where the transverse distribution of load is non-uniform the shear forces in the longitudinal bulkhead and side shell may require to be examined by direct calculation procedures.

(a) In the shell plating

$$F_S = \frac{118\, t_2\, D}{0{,}16 + 0{,}075 \dfrac{A_S}{A_L}} - F_W \text{ kN}$$

$$\left(F_S = \frac{12\, t_2\, D}{0{,}16 + 0{,}075 \dfrac{A_S}{A_L}} - F_W \text{ tonne-f}\right)$$

(b) In the longitudinal bulkheads

$$F_S = \frac{118\, t_3\, D}{0{,}34 - 0{,}075 \dfrac{A_S}{A_L}} - F_W \text{ kN}$$

$$\left(F_S = \frac{12\, t_3\, D}{0{,}34 - 0{,}075 \dfrac{A_S}{A_L}} - F_W \text{ tonne-f}\right)$$

In these expressions

(a) t_2 = the thickness, in mm, of the side shell at the section concerned, at the neutral axis,

t_3 = the minimum thickness, in mm, of the longitudinal bulkhead plating at the section concerned within the 0,5D about mid-depth. Outside this range, no part of the bulkhead plating is to be less in thickness than $0{,}9t_3$ mm,

A_S = the area of side shell, in cm^2, at the section concerned, taken as the plating area over a depth equal to D,

A_L = the area of longitudinal bulkhead plating, in cm^2, at the section concerned, taken as the sum of plating areas from bottom to deck.

(b) Where it is necessary to increase the thickness of the side shell or longitudinal bulkhead to meet these requirements, the original thicknesses are to be used in the calculation of the cross-sectional areas A_S and A_L.

337 The calculation of shear forces immediately beyond the ends of the longitudinal bulkheads will be considered in relation to the arrangement of structure in these regions.

338 The above shear force calculations are based upon a maximum Rule combined shear stress of 117,7 N/mm^2 (12,0 kgf/mm^2).

339 Where more than two longitudinal bulkheads are fitted, direct calculation procedures are to be adopted, based on shear flow theory or an equivalent method.

Loading Manual and Loading Instruments

340 The Loading Manual is to be submitted for approval in respect of longitudinal strength for all ships.

The Manual is to contain details of the proposed load, ballast and part-loaded conditions, subdivided into departure and arrival conditions. Where applicable, the Manual is also to contain details of any other loading conditions for which the hull scantlings have been approved (*see also* 309).

Where non-homogenous loading conditions are proposed, or where it is likely that service conditions significantly different from those for which the scantlings were approved may arise, it is recommended that an approved means of determining the suitability of loading be placed on board the ship. Proposals to use such means will be specially considered, with particular reference to the suitability to the type of vessel and its intended service.

Combined Stress Calculations for Container Ships

General

341 The primary longitudinal strength of container ships having double skin construction or single skin construction in association with torsion box girders is to be examined using a combination of bending and torsional stress resultants when one or more of the following conditions apply:—

(a) $\dfrac{b}{B_1} \geqslant 0{,}7$

(b) $\dfrac{l_H}{l_{BH}} \geqslant 0{,}89$

(c) $\dfrac{b}{B_1} > 0{,}6$ and $\dfrac{l_H}{l_{BH}} > 0{,}7$

where these terms are defined in 305 and illustrated in Fig. D 3.1.

342 Direct calculation procedures using the methods outlined in 308 and applying long term prediction methods may also be used.

343 Where other arrangements of primary structure are proposed, or where new or unusual design features are to be incorporated, direct calculations will be required.

344 Special consideration will be given to ships having hatch openings of width greater than 0,85B, where the average rate of torsional deformation exceeds 0,006 degrees per metre, or where the elongation of the hatch opening diagonal under standard torque loading exceeds 35 mm.

Symbols and Definitions

345 In addition to the symbols defined in 301, the following terms are used:—

SWBM = the maximum still water bending moment, in kN m (tonne-f m), at the section under consideration, determined from the envelope embracing all the still water bending moments derived from the longitudinal strength calculations (*see* 310). All the proposed loading conditions are to be included.

VWBM = the design vertical wave bending moment, in kN m (tonne-f m), in a head sea, at the section under consideration. The value of VWBM at the middle of L_{pp} is given by:—

$0{,}981\ C_o\ L^2 B\ (C_{b_1} + 0{,}7)$ kN m

$(0{,}1\ C_o\ L^2 B\ (C_{b_1} + 0{,}7)$ tonne-f m).

where $C_o = 0{,}6 + 0{,}0942 \left(\dfrac{L}{100} - 1\right)$

C_{b_1} = moulded block coefficient at load draught, but is not to be taken less than 0,6. The block coefficient is to be determined using the length L.

The distribution of VWBM along the length of the ship is given in Table D 3.7.

HWBM = the design horizontal wave bending moment in kN m (tonne-f m), at the section under consideration. The value of HWBM at the middle of L_{pp} is given by:—

HWBM = 0,431 L^2B kN m

(HWBM = 0,044 L^2B tonne-f m)

The distribution of HWBM along the length of the ship is given in Table D 3.7.

T = the torque amidships, in kN m (tonne-f m), given by:—

$$9{,}81e^{-0{,}00295L}\frac{LB^3C_T}{10\,000}\left(1{,}75+1{,}5\frac{\varepsilon}{D}\right)\text{ kN m}$$

$$\left(e^{-0{,}00295L}\frac{LB^3C_T}{10\,000}\left(1{,}75+1{,}5\frac{\varepsilon}{D}\right)\text{ tonne-f m}\right)$$

where $C_T = 13{,}2 - 43{,}4C_W + 78{,}9C_W^2$

C_W = the water plane area coefficient, but need not exceed $0{,}165 + 0{,}95\ C_{b_1}$.

ε = the distance, in metres, of the shear centre below the base line of the ship.

The distribution of T along the length of the ship is to follow a curve of (1—cosα) form where α is a periodic function of L.

T_c = the cargo torque, in kN m (tonne-f m), created by uneven transverse distribution of weights, consumables or ballast. Except where higher value is specified, T_c may be taken as:—

$T_c = 15{,}7\ B\ n_s\ n_t$ kN m

($T_c = 1{,}6\ B\ n_s\ n_t$ (tonne-f m)

where n_s = the number of stacks of containers over the breadth B,

n_t = the number of tiers of containers in cargo holds amidships, excluding containers on deck or on the hatch covers,

but T_c need not be taken more than 24 520 kN m (2500 tonne-f m) at amidships, and is to be distributed along the length of the ship as given in Table D 3.7.

TABLE D 3.7

POSITION	DISTRIBUTION FACTORS		
	VWBM		HWBM and T_c
	$F_n \leqslant 0{,}20$	$F_n = 0{,}30$	
Station 0 (A.P.)	0,00	0,00	0,0
2	0,14	0,14	0,2
4	0,30	0,30	0,4
6	0,58	0,58	0,6
8	0,87	0,87	0,8
10(mid-L_{pp})	1,00	1,00	1,0
12	0,90	0,95	0,8
14	0,68	0,80	0,6
16	0,41	0,62	0,4
18	0,20	0,33	0,2
20 (F.P.)	0,00	0,00	0,0

NOTE. For definition of F_n, *see* 316.

The stress corresponding to HWBM is to be obtained from:—

$$\sigma = \frac{3\ b}{I_H}\text{ HWBM N/mm}^2\text{ (kgf/mm}^2\text{)}$$

where

b is defined in 305

and I_H is the inertia in cm^2m^2 of the hull, about a vertical axis through the centreline of the ship at the section concerned.

The warping stresses corresponding to T and T_c are to be calculated using a method which has received general approval from the Society.

Derivation of Stresses

346 The stresses are to be calculated for different positions along the length of the ship at the bottom and at the deck at the level of the top edge of the longitudinal bulkhead.

The stresses corresponding to SWBM and VWBM are to be evaluated from the values of these moments and of the hull section modulus at the section concerned.

Combined Stress Diagrams and Rule Stresses

347 A combined stress diagram, for the head sea condition, is to be prepared, showing the combination of the still water and vertical wave bending stresses.

The stresses at any point along the length of the ship are not to exceed the following values:—

(a) Still water bending stress at deck (from SWBM)

$$\sigma = \frac{88}{k}\times\frac{0{,}8}{C_{b_1}+0{,}2}\quad\text{N/mm}^2$$

$$\left(\sigma = \frac{9}{k}\times\frac{0{,}8}{C_{b_1}+0{,}2}\quad\text{kgf/mm}^2\right)$$

where C_{b_1} is as defined in 345.

(b) Combined stress (from SWBM and VWBM)

(i) At deck

$$\sigma = \frac{157}{k}\ \text{N/mm}^2 \qquad \left(\sigma = \frac{16{,}0}{k}\ \text{kgf/mm}^2\right)$$

(ii) At bottom

$$\sigma = \frac{137}{k}\ \text{N/mm}^2 \qquad \left(\sigma = \frac{14{,}0}{k}\ \text{kgf/mm}^2\right)$$

348 A second combined stress diagram, for the oblique sea condition, is to be prepared, showing the combination of the stresses derived from the following moments and torques:—

SWBM; 60 per cent of VWBM; HWBM; T; T_c

These stresses are to be combined as shown in Fig. D 3.2, and in no case is the stress at any point along the length of the ship to exceed

$$\sigma = \frac{157}{k}\ \text{N/mm}^2 \qquad \left(\frac{16{,}0}{k}\ \text{kgf/mm}^2\right)$$

Area of Topside Material

349 The total cross-sectional area of the topside box girders or equivalent structure, including all effective material within 0,19D of the upper deck but excluding hatch side coamings, over the range of cargo holds is not to be less than 0,15 Δ cm^2, where Δ is the full load displacement of the ship, in tonnes.

Section 4

DECK PLATING

Symbols

401 L = length of ship, in metres,

L_1 = length of ship, in metres, but need not be taken as greater than 190 m,

s = spacing of beams or longitudinals, in mm, but is not to be taken less than

$$470 + \frac{L_1}{0{,}6}\ \text{mm},$$

S = spacing of girders or transverses, in mm,

M_D = actual deck modulus, but is not to be taken greater than 1,5 M_{D_1},

M_{D_1} = Rule deck modulus from D 3,

$F_D = \frac{M_{D_1}}{M_D}$,

k = higher tensile steel factor, *see* D 116.

Construction

402 Provision is made for longitudinal or transverse framing at all decks, but for ships exceeding 120 m in length, longitudinal framing is to be adopted at the strength deck, except that special consideration will be given to proposals for transverse framing on ships where the deck width outside line of openings is less than 0,075B port and starboard. Where plating thicknesses exceed 50 mm, Grade E steel will generally be required.

STRENGTH DECK

403 The thickness of strength deck plating amidships outside the line of openings is to be that necessary to give the section modulus required by D 3, but it is not to be less than:—

(a) Longitudinal framing.

(i) $L \leqslant 190$ m,

the lesser of:—

$$\frac{s}{1000}\left(7 + \frac{L}{17}\right)\sqrt{\frac{F_D}{k}}\ \text{mm, or}\ \frac{s}{55\sqrt{k}}\ \text{mm,}$$

but not less than

$$\frac{s}{1200}\sqrt{Lk} + 2{,}5\ \text{mm}$$

(ii) $L > 190$ m,

the greater of:—

$$\frac{s}{55\sqrt{k}}\ \text{mm, or}\ \frac{s}{1200}\sqrt{Lk} + 2{,}5\ \text{mm.}$$

(b) Transverse framing.

The lesser of:—

$$\frac{s}{1000\left(1 + \left(\frac{s}{S}\right)^2\right)}\left(10 + \frac{L}{12}\right)\sqrt{\frac{F_D}{k}}\ \text{mm,}$$

or $\frac{s}{40\sqrt{k}}$ mm,

but is not to be less than

$$\frac{s}{910}\sqrt{Lk} + 2{,}5\ \text{mm}$$

Inside the line of openings, the thickness amidships is not to be less than:—

(c) Longitudinal or transverse framing

$$\frac{s}{1200}\sqrt{Lk} + 2{,}5\ \text{mm}$$

For grades of steel, *see* 413.

The midship thickness outside line of openings is to be maintained for 0,4L amidships and is to be tapered gradually to the end thickness. *See* Fig. D 4.1.

Extracts from the ‘Small Ships Rules for the Hull Construction of Steel Ships under 90m in Length 1976’ (1976 Small Ship Rules)

Small ships

Rules for the hull construction of steel ships under 90m in length

1976

LLOYD'S REGISTER OF SHIPPING

LLOYD'S REGISTER OF SHIPPING

Small Ships

Rules for the Hull Construction of Steel Ships Under 90 m in Length 1976

This edition includes all additions and amendments approved by the General Committee up to and including 14th August, 1975, and replaces the 1973 edition.

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b* 2

HULL CONSTRUCTION

Section 1

GENERAL

Application

101 This Chapter applies to sea-going ships of normal form and proportions of less than 90 m in length.

Ships of unusual form or proportions, intended for the carriage of special cargoes, or for special or restricted service, will receive individual consideration on the basis of the general standards of these Rules. For the carriage of liquefied gases, *see* the *Rules for the Carriage of Liquefied Gases in Bulk.*

102 The scantlings and arrangements in passenger ships will be specially considered in relation to the general design features.

Equivalents

103 Alternative arrangements or fittings which are considered to be equivalent to the Rules will also be accepted.

Definitions

104 Length L is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of rudder post, or to the centre of the rudder stock if there is no rudder post. L is not to be less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline.

Amidships is to be taken as the middle of the length L measuring from the fore side of the stem.

In ships with unusual stern arrangement the length L will be specially considered.

105 Breadth B is the greatest moulded breadth, in metres.

106 Depth D is measured, in metres, at the middle of the length L from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Sections.

When a rounded gunwale is arranged, the depth D is to be measured to the continuation of the moulded deck line.

107 Draught d is the summer draught, in metres, measured from top of keel.

108 Passenger ship is a ship, engaged on international voyages, which carries more than twelve passengers.

109 Other parameters are defined in the appropriate Sections.

Plans to be Submitted

110 Plans covering the following items are to be submitted:—

- Midship section.
- Longitudinal strength calculations.
- Longitudinal section.
- Shell plating (indicating extent of flat of bottom forward).
- Decks.
- Watertight bulkheads.
- Pillars and girders.
- Deep tanks.
- Oil fuel bunkers.
- Arrangement of fore body.
- Rudder.
- Sternframe.
- Propeller brackets.
- Main engine and thrust seating.
- Arrangement of after end.
- Superstructure and deckhouse.
- Hatchways.
- Strengthening for navigation in ice.
- Masts and derrick posts.
- Scheme of welding.
- Particulars for calculation of freeboard.
- Loading Manual.
- Fire protection, detection and extinction arrangements.

111 *See also* SD 4009 and SD 8008 for additional requirements.

Direct Calculations

112 The scantlings of structural items may be determined using direct calculations. In such cases, the assumptions made and the calculations are to be submitted for approval.

Ballasting

113 Attention should be given to the amount and distribution of water ballast. It has been found that satisfactory service has been obtained when the draught forward is not less than 0,027L and the longitudinal radius of gyration of the ballasted ship is less than 0,25L.

positions where cargo vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

Location and Attachment of Anodes

214 Where a cathodic protection system is to be fitted in tanks, a plan showing details of the location and attachment of anodes is to be submitted.

Particular attention is to be given to the location of anodes in relation to the structural arrangements and openings of the tank.

215 Anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted and these are to be so designed as to retain the anode even when the latter is wasted.

216 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service.

The following methods of attachment would be acceptable:—

(a) Steel core connected to the structure by continuous welding of adequate section.

(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support.

(c) Approved means of mechanical clamping.

217 Anodes are to be attached to stiffeners or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell.

The two ends are not to be attached to separate members which are capable of relative movement.

Where cores or supports are welded to the main structure, they are to be kept clear of toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web and the welding is to be kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be to the web or at the centreline of the face plate.

Aluminium and Magnesium Anodes

218 Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil but only in locations where the potential energy does not exceed 275J (28 kgf m). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1 m wide provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, then the height of the anode may be measured above that surface.

Aluminium anodes are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

219 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

External Hull Protection—Impressed Current Systems

220 When the external hull is protected by means of an impressed current system in association with a suitable high duty coating, the ship may be eligible for increased interval between drydockings. *See* B 802.

Plans showing the proposed layout of anodes and reference cells, the wiring diagram and the proposed means of bonding in the rudder and propeller are to be submitted. Where the deferment of drydocking is desired, details of the proposed hull coating are also required.

221 The arrangements for glands where cables pass through the shell are to include a small cofferdam.

Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of about 10 mm in thickness. *See also* M 1623.

Scantling Allowance for Corrosion Control

222 Scantlings in tanks may be reduced in accordance with Table SD 2.1 and associated Notes, provided that all surface areas are protected with an approved system of corrosion control. In such cases the notation "(cc)" will be entered in the *Register Book.*

Scantlings in dry compartments may be reduced similarly, but in such cases, only an approved coating system of corrosion control, or equivalent, would be acceptable.

223 Full particulars of the proposed corrosion control system are to be submitted, and the steelwork plans are to show both the Rule and the corrosion control scantlings.

Approved Systems of Corrosion Control

224 Systems of corrosion control installed in association with reduced scantlings and the notation "(cc)" are to comply with (a) or (b) below, as appropriate.

Combinations of these systems or other systems of corrosion control will be specially considered on the basis of providing equivalent protection.

(a) **Coating Systems**

The proposed coating must have been approved by the Society.

The coating is to be compatible with any previously applied primer.

All surface areas in tanks where scantling allowances have been permitted are to be coated.

The painting specification for these areas is to be submitted and is to include the following information:—

(i) Details of the surface preparation.

(ii) Name and type of primer coating (if any).

(iii) Name and type of proposed corrosion control coating.

(iv) Method of application, number of coats and total dry film thickness.

(b) **Cathodic Protection Systems**

All surface areas in the tanks above the normal liquid level, with a minimum of all surfaces in the top 1,5 m, are to be coated in accordance with (a) above. The coatings, and any previously applied primers, are to be suitable for use in association with a cathodic protection system. Anodes are to be fitted in the remainder of the tank. The location and attachment of anodes is to comply with the requirements of 214 to 217. In order that the number, type and distribution of anodes may be examined, a specification is to be submitted and is to include the following information:—

(i) Anode material and capacity of anode material. *See* 218 and 219.

(ii) Area of tank structure used in the calculations.

(iii) Size and shape of anodes, including the cross-sectional area, and gross weight.

(iv) Types of cargo to be carried.

As the protection afforded by anodes cannot be restricted to certain surfaces, the effect of uncoated surfaces adjacent to those which require protection (e.g. tank fittings) must be taken into account when assessing cathodic protection requirements.

Selective Corrosion Control Scheme for use in Crude Oil Carriers using Defined Ballasting

225 Where corrosion control is adopted for ships intended solely for the carriage of crude oil, reductions of scantlings in accordance with Table SD 2.1 will be permitted provided the requirements given below are fulfilled and the protection system complies with Table SD 2.2.

Provided the corrosion control scheme is appropriate to the proposed ballast conditions for the ship, the notation "(cc) crude oil—defined ballasting" will be entered in the *Register Book.*

The Owners or Builders will be required to affirm that the ship is intended solely for the carriage of crude oil, and that they are willing to accept the above notation and the associated restrictions on ballasting.

Inert Gas Systems

226 Where an inert gas system is installed and tested in accordance with E 1160 to E 1184 and the notation "IGS" entered in the *Register Book*, then the coating requirement at the top of cargo or cargo/ballast tanks may be omitted on the understanding that the system will be operated on a continuous basis.

Fitting of Ceiling in Holds

227 Ceiling is to be laid on the inner bottom of dry cargo ships under hatchways and over bilges, where it is to be fitted with readily removable portable sections. The spaces between frames at the top of the bilge ceiling are to be closed by wood chocks, cement or other suitable means.

228 Ceiling may be omitted provided that the inner bottom plating is increased by 5 mm in the case of ships designed for the carriage of heavy cargoes, or 2 mm in the case of other ships.

229 It is recommended that in any ship which is regularly to be discharged by grabs, the increase in thickness of the inner bottom plating should be not less than 5 mm and the plating be fitted with a flush surface. Alternatively, double ceiling should be fitted.

230 Ceiling is to be laid either directly on the inner bottom plating embedded in a suitable composition or on battens providing a clear space of at least 12,5 mm for drainage.

The thickness of wood ceiling is not to be less than 65 m. Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered for each case.

231 Where the covers or fittings of the manholes in the inner bottom project above the plating, they are to be protected by a steel coaming around each manhole, fitted with a hatch of wood or steel.

Cargo Battens in Holds

232 Where cargo battens or equivalent are fitted in the holds of dry cargo ships, the descriptive notation "SF" will be entered in the *Register Book.*

233 The battens, when fitted, are to extend from above the upper part of the bilge to the underside of beam knees in the holds, and in all cargo spaces in the 'tween decks and superstructures up to the underside of beam knees.

234 Wood cargo battens are to be not less than 50 mm in thickness and the clear space between adjacent rows is, in general, not to exceed 230 mm. The dimensions and spacing of battens made of other materials will be considered. Nets may be adopted in lieu of battens, and other alternative proposals will be specially considered.

235 For arrangements in way of refrigerated holds, *see* N 415 and N 416.

Deck Coverings

236 Where plated decks are sheathed with wood or approved composition, reductions in plate thickness may be allowed. *See* SD 425.

The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck.

237 Deck coverings are to be of a type which will not readily ignite where used on decks:—

(a) forming the crown of machinery or cargo spaces within accommodation spaces of cargo ships,

(b) within accommodation spaces, control stations, stairways and corridors of passenger ships.

Section 3

LONGITUDINAL STRENGTH

301 The section modulus at deck and keel is to be not less than the greatest of the following values:—

(a) M cm³

(b) $\frac{M}{3} + 9{,}38\ SWBM_L\ (C_b + 0{,}20)$ cm³ *See* Note 2

$\left(\frac{M}{3} + 92\ SWBM_L\ (C_b + 0{,}20)\ \text{cm}^3\right)$

(c) $\frac{M_1}{3} + 9{,}38\ SWBM_B\ (C_{b_1} + 0{,}20)$ cm³ *See* Note 2

$\left(\frac{M_1}{3} + 92\ SWBM_B\ (C_{b_1} + 0{,}20)\ \text{cm}^3\right)$

where $M = f\,K\,B\,(C_b + 0{,}70) \times 10^5$

$M_1 = f\,K\,B\,(C_{b_1} + 0{,}70) \times 10^5$

f = 0,85 generally, *but see* Note 3,

K is to be determined from Table SD 3.1,

C_b = the moulded block coefficient at load draught or 0,045L, whichever is the greater, but is to be taken as not less than 0,60. The block coefficient is to be determined using the length L as defined in SD 104,

C_{b_1} = the moulded block coefficient at the ballast draught, but to be taken as not less than 0,60. The block coefficient is to be determined using the length L as defined in SD 104, *see also* SD 113,

B = the moulded breadth, in metres,

TABLE SD 3.1 VALUES OF K

LENGTH L (Metres)	K	Difference in K per 1 m difference in L	LENGTH L (Metres)	K	Difference in K per 1 m difference in L	LENGTH L (Metres)	K	Difference in K per 1 m difference in L
					0,0056			0,0122
20	0,062		45	0,169		70	0,395	
		0,0032			0,0064			0,0142
25	0,078		50	0,201		75	0,466	
		0,0036			0,0074			0,0164
30	0,096		55	0,238		80	0,548	
		0,0042			0,0088			0,0186
35	0,117		60	0,282		85	0,641	
		0,0048			0,0104			0,0212
40	0,141		65	0,334		90	0,747	
		0,0056			0,0122			

$SWBM_L$ = the maximum still water bending moment, in kN m (tonne-f m), hogging or sagging in loaded conditions, *see* 303 to 306,

$SWBM_B$ = the maximum still water bending moment, in kN m (tonne-f m), hogging or sagging in ballast conditions, *see* 303 to 306.

NOTE 1. When the required modulus is M, the maximum associated still water bending moment in loaded conditions will be

$$\frac{71{,}1\ M}{C_b + 0{,}20} \times 10^{-3}\ \text{kN m}$$

$$\left(\frac{7{,}25\ M}{C_b + 0{,}20} \times 10^{-3}\ \text{tonne-f m}\right)$$

which corresponds to a stress of

$$\frac{71{,}1}{C_b + 0{,}20}\ \text{N/mm}^2 \quad \left(\frac{7{,}25}{C_b + 0{,}20}\ \text{kgf/mm}^2\right)$$

NOTE 2. Still water bending moments are to be calculated for all ships more than 65 m in length and with 100A1 in their class notation.

For ships 65 m and less in length having 100A1 in their class notation, the minimum modulus M will normally be adequate, provided the design and service requirements are normal.

NOTE 3. Special consideration will be given to ships designed for the carriage of dry cargoes, such that the loading (in at least one hold or compartment) is denser than that corresponding to a stowage rate of 1 m^3/tonne.

Short Voyage Stresses

302 Consideration will be given to proposals for still water bending stresses to be increased to:—

$$\frac{85{,}3}{C_b + 0{,}20}\ \text{N/mm}^2 \quad \left(\frac{8{,}7}{C_b + 0{,}20}\ \text{kgf/mm}^2\right)$$

during short voyages, not exceeding 24 hours duration, in reasonable weather, *see* B 105.

303 Where required by 301, the still water bending moment calculation for homogeneous and, if applicable, non-homogeneous load and part loaded conditions and for the ballast conditions (departure and arrival) is to be submitted.

304 Curves of still water bending moment and shear force may be required when unusual loading conditions are proposed.

305 The method of calculating the still water bending moment and shear force curves (where applicable) is to be submitted for approval. The assumed longitudinal distribution of lightship weight is also to be submitted.

306 When the still water bending moment is required to be calculated for conditions other than homogeneous load conditions, and when increased stresses as permitted by 302 are required, the approved loading is to be incorporated in the Loading Manual.

When water ballast is to be carried in holds, details of the proposed depths of water are to be included in the Loading Manual.

The Loading Manual is to be submitted for approval of the longitudinal distribution of cargo and ballast as shown therein.

307 All continuous longitudinal material is to be included in the calculation of the inertia of the section, and the lever y is to be measured from the neutral axis to the top of keel and to the moulded deck line at side. Lightening holes in girders need not be deducted, provided their depth does not exceed 20 per cent of the depth of the girder web. Scallops and isolated drain holes need not be deducted.

In general, isolated deck openings outside the line of hatches need not be deducted, but local compensation may be required, *see* SD 407.

308 Where continuous hatch coamings are arranged 80 per cent of the area of the continuous hatch coamings may be included in the calculation of the section modulus and the lever y is to be measured:—

(a) to the moulded deck line at side amidships,

(b) to a point a distance above the moulded deck line at side amidships equal to the height of the hatch coaming above the deck.

The modulus with y measured as in (a) is to be 5 per cent greater than required by 301, and with y measured as in (b) may be 10 per cent less than required by 301.

NOTE. Where continuous hatch coamings are supported by longitudinal bulkheads or equivalent, the total area of coaming may be included in the calculation of section modulus.

309 Where two or more hatchways are arranged abreast, the percentage of the material between hatchways to be included in the section modulus will be decided in each case. Similar consideration will be given to other special designs.

310 On ships having a length exceeding 65 m, where an erection is fitted extending within 0,5L amidships and having a length greater than 12 m and a breadth in excess of $\frac{B}{3}$, the requirements for longitudinal strength will be considered.

Higher Tensile Steel

311 Where higher tensile steel is used in the main hull structure, the hull midship section modulus as determined above is to be corrected in accordance with D 325 and D 326.

SD 22 and SD 23. However, the speed used in the calculations is in no case to be taken less than:—

IA Super	20 knots
IA	18 knots
IB	16 knots
IC	14 knots

If the actual maximum service speed of the ship is higher than the above values, the higher speed is to be used in the calculations, and no extra strengthening is required.

2490 For double plate rudders, the minimum thickness of plates and horizontal and vertical webs in the ice belt region is to be determined as for shell plating in the aft region in accordance with 2477.

2491 The rudder head and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means, for the Ice Classes IA Super and IA.

2492 Efficient rudder stops, a slip coupling or equivalent arrangements are to be fitted in order to protect the steering gear against excessive external loading.

Section 25

DECK LOADING

Permissible Cargo Loading on Decks and Hatch Covers having Minimum Rule Scantlings

Weather Decks

2501 Loading equivalent to a head of 1,2 m with a stowage rate of 1,39 m^3/tonne i.e., 8,53 kN/m^2 (0,87 tonne-f/m^2).

Cargo Decks

2502 Loading equivalent to a head equal to the 'tween deck height (h metres) with a stowage rate of 1,39 m^3/tonne i.e., 7,06 h kN/m^2 (0,72 h tonne-f/m^2). *See also* 2504.

Weather Deck Hatch Covers

2503 For hatch covers fitted on weather decks in positions 1 and 2 (*see* SD 2605), the maximum cargo load is that equivalent to a head of 1,5 m and 1,2 m respectively, with a stowage rate of 1,39 m^3/tonne, i.e. 10,59 kN/m^2 (1,08 tonne-f/m^2) in position 1 and 85,3 kN/m^2 (0,87 tonne-f/m^2) in position 2, unless the supporting deck girders and pillars are increased in size, in which case *see* 2509.

Lower Decks forming Crown of Deep or Tunnel Tanks

2504 Loading equivalent to the greater of the following:—

(a) A head equal to the 'tween deck height with a stowage rate of 1,39 m^3/tonne,

(b) A head equal to one-half the height of the air pipe above the tank crown with a stowage rate of 0,975 m^3/tonne.

Inner Bottom

2505 For ships having the class 100A1, the loading on the tank top may be that equivalent to a head of 1,4d with a stowage rate of 1,39 m^3/tonne. d is the load draught, in metres.

For ships having a heavy cargo notation, the inner bottom may be suitable for increased loads, *see* SD 606(b).

Specified Cargo Loading on Decks and Hatch Covers in excess of that given in 2501 to 2504

2506 If the actual loading is in excess of the nominal Rule loading, then the appropriate h values, with the exceptions given in 2507, 2508 and 2509, are to be increased in direct proportion.

2507 For weather deck hatch side coamings, hatch end beams, girders and pillars, the head h to be used is 0,14 p (1,39 p), plus an allowance for weather as follows:—

(a) where the basic h as obtained from SD 6 or SD 16 is 1,2 m or less, allowance for weather = 0.

(b) where h obtained from SD 6 or SD 16 is 1,5 m, allowance for weather = 0,3 m.

(Intermediate values are to be in proportion.)

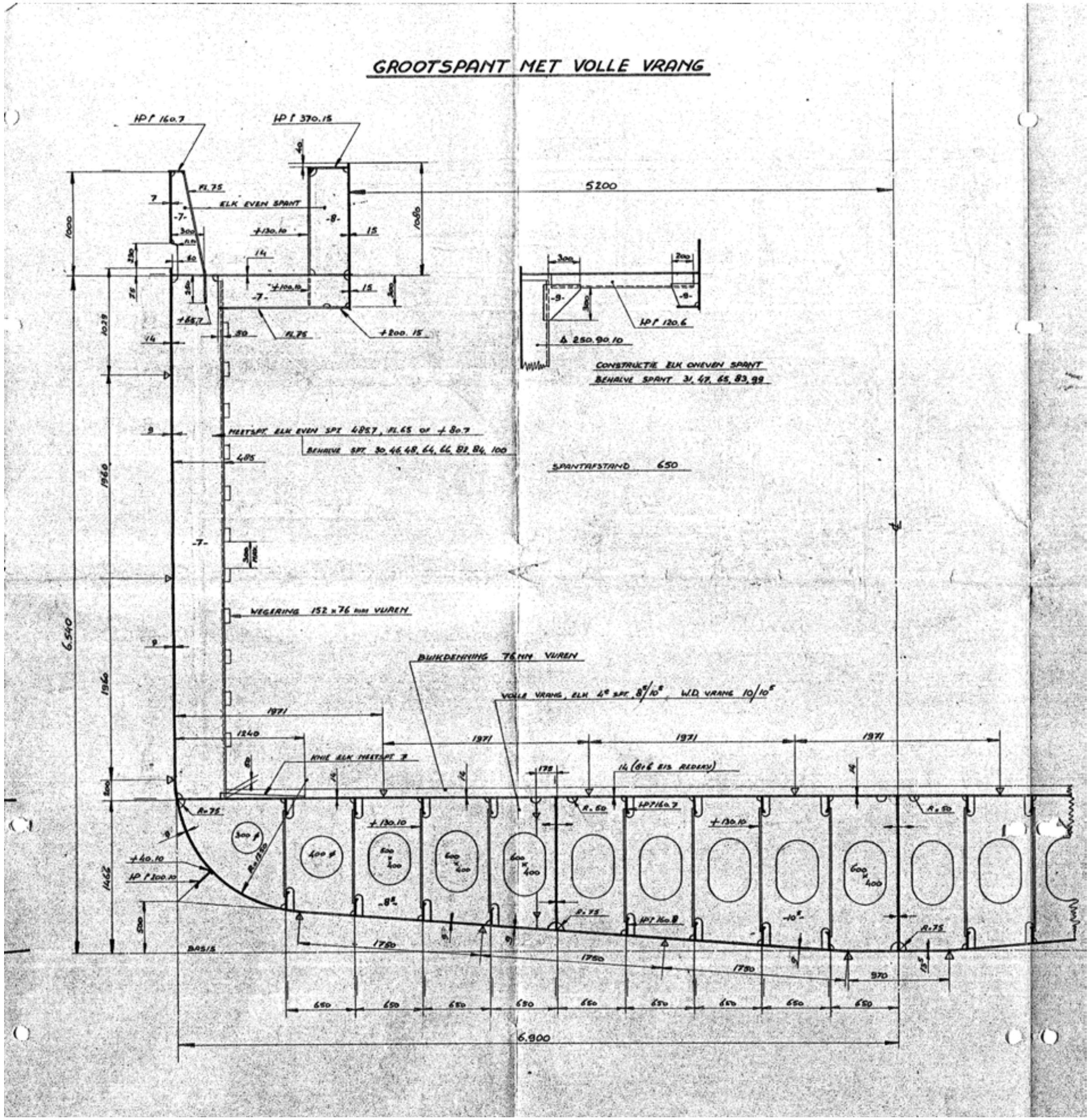
p = actual deck loading in kN/m^2 (tonne-f/m^2).

2508 For deck longitudinals and beams, the scantlings are to be obtained from SD 604 and SD 1609, using the head obtained from 2506 for cargo decks and 2507 for weather decks. The modulus of weather deck longitudinals or beams is not to be less than that obtained from SD 602 and SD 1606.

2509 Hatch covers in positions 1 and 2 need not be increased where the head obtained from 2506 (i.e. without any addition for weather) does not exceed that required by SD 2601; when it does exceed the head obtained from SD 2601, the scantlings are to be increased in direct proportion.

2510 Where heavy loads are to be carried, the side framing in way may require to be strengthened.

As-built Midships Section drawing for Hull 352 (*Carabeka VIII*)



BUREAU VERITAS
Coupe I 3/3 E (9888)
„VII" Cargo Deep Sea
Rotterdam, le 13 janvier 1987

HOOFDAFMETINGEN:

LENGTE OVER ALLES	81,00 M.
LENGTE TUSSEN LOODLIJNEN	74,80 M.
LENGTE OP 0,85 H	< 75,00 M.
LENGTE SCANTLINGS 0,97(74,80+1,50)	74,01 M.
BREEDTE SPANTEN	13,80 M.
HOLTE HOOFDDEK	6,54 M.
DIEPGANG	5,37 M.
VERMOGEN HOOFDMOTOR	2500 PK
SNELHEID PROEFTOCHT	CA. 12 KNOOP

KLASSE ——— LLOYD'S R.S. ✠ 100 A1 ✠ LMC.

STAAL, WAAR NIET ANDERS VERMELD, GRADE „A" OVEREENKOMSTIG P2 VAN DE RULES.

GOEDGEKEURD KLASSE 29-11-74
GOEDGEKEURD REDERIJ 22-10-74

ZEERSCHOOL				
MACHINEFABRIEK				
HOUTBEWERKING				
SPANTENVLOER / HELLING				
SPANTENVLOER / DOK				
BEDRIJFSLEIDING				
REDER			1/m	2x
SCHEEPVAART INSP.				
BUR. VAN TOEZICHT				
CLASS. BUREAU	5/0	4x	1/m	4x
MOTOR FABRIKANT				
T.K.M.B.				
T.K.S.B.				
DISTRIBUTIE		„A"		

AMELS B.V.
SCHEEPSWERF EN MACHINEFABRIEK
MAKKUM HOLLAND

GROOTSPANT MET DETAILS

LETTER	DATUM	WIJZIGINGEN
A	12-9	HOOFDD. SPT. 64-66, + DIV. WIJZIGINGEN
B	9-12	SPT. 64-66 + DIV. OPM. L.R.S. (zie BL.2)

BOUW No. 352

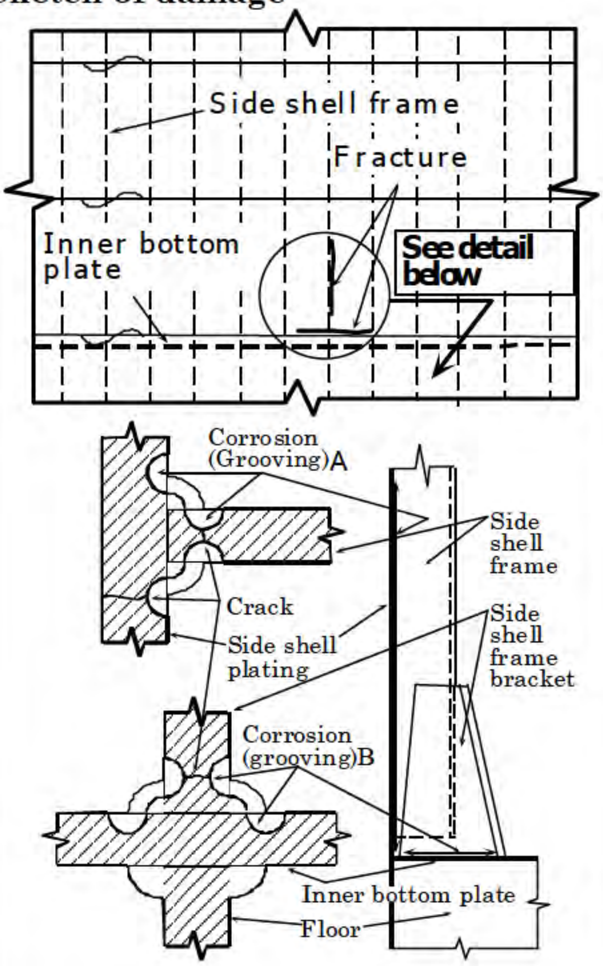
GET.	BLVT	TEK. NO.	BLD. NO.
DAT.	28-8-74	352-04	1
GEC.	MB	WIJZIGING	AANT. BL.
SCHAAL	1:25	A B	2

Annex I

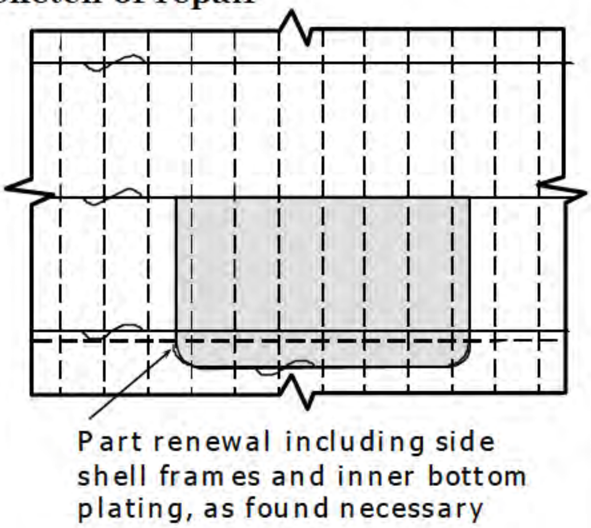
Extract from ‘IACS General Cargo Ships Guidelines for Survey, Assessment and Repair of Hull Structure’

GENERAL CARGO SHIPS	Guidelines for Surveys, Assessment and Repair of Hull Structure	
Part 1	Cargo hold region	Example No.
Area 2	Side structure	2
Detail of damage	Fractures in side shell frame/lower bracket and side shell plating near tank top	

Sketch of damage



Sketch of repair



Notes on possible cause of damage

1. Fracture in side shell plating along side shell frame: Heavy corrosion (grooving) along side shell frame (See A).
2. Fracture in side shell plating along tank top: Heavy corrosion (grooving) along tank top (See B) resulting detachment of side shell frame bracket from inner bottom plating.

Notes on repairs

1. Sketch of repair applies when damage extends over several frames.
2. Isolated fractures may be repaired by veeing-out and rewelding.
3. Isolated cases of grooving may be repaired by build up of welding.

Annex J

Comparison of survey requirements between IACS UR Z7.1, the 2008 INSB Rules and the 2011 ESP Code

Comparison of Survey Requirements between IACS UR Z7.1, the 2008 INSB Rules and the 2011 ESP Code

Survey details	IACS UR Z7.1 – Hull Surveys for General Dry Cargo Ships	2008 INSB Rules	2011 ESP Code
Survey planning	A survey planning meeting is to be held prior to the commencement of the special survey.	The surveyor is to study the vessel's structural arrangements and previous operational and survey records, whenever it is "deemed advisable" or required by the rules, to determine potential problem areas.	A specific survey programme is to be developed prior to a special survey or intermediate survey for vessels over 10 years of age. The survey programme, which includes the extent of the structure to be examined, should be developed based on a review of various documentation retained on board, including: • survey report file, consisting of structural survey reports, condition evaluation reports[1] and thickness measurement reports; • structural plans of the holds and ballast tanks; • previous repair history; • cargo & ballast history; • inspections by ship's staff; • other information to help identify critical structural areas and/or suspect areas.
General thickness measurement requirements	Thickness measurements, if not carried out by the classification society itself, are to be witnessed by a surveyor.	Thickness measurements are "*normally to be carried out under the surveillance of the attending Surveyor to I.N.S.B.*". However, the rules also state that "*The Surveyor may accept thickness measurements not carried out under his supervision. In this case the Surveyor should re-check the measurements for accuracy as deemed necessary.*"	Thickness measurements, if not carried out by the classification society itself, are to be witnessed by a surveyor. The surveyor should be on board to the extent necessary to control the process.

[1] A condition evaluation report of the survey and results, endorsed by the Administration or recognised organisation, should be issued to the owner and place on board for reference at future surveys.

Survey details	IACS UR Z7.1 – Hull Surveys for General Dry Cargo Ships	2008 INSB Rules	2011 ESP Code
Annual surveys	Suspect areas[2] identified at previous surveys are to be examined, and thickness measurements taken of areas of substantial corrosion[3]. For a vessel over 15 years of age, an overall survey of all cargo hold spaces is to be undertaken. This is to include a close-up[4] examination of a minimum of 25% of the hold frames, in order to establish the condition of their lower structure and the frame end attachments. Where this level of survey indentifies the need for repairs, a close-up survey is to be undertaken of all frames and the adjacent shell plating. Ballast tanks are also to be examined, as determined by the results of the special survey or intermediate survey. When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. Thickness measurements of the hold frames and ballast tank structure are to be carried out of if considered necessary by the surveyor, in particular where extensive corrosion exists. If the thickness measurements identify the presence of substantial corrosion, then the extent of thickness measurements is to be increased to determine the magnitude of the corrosion.	The 2008 INSB rules require that a general examination be undertaken of a vessel's hull and its closing appliances, as far as they can be seen. Cargo holds are to be surveyed as deemed necessary, depending on the vessel's "*overall condition*". For vessels over 5 years old, ballast tanks are to be internally examined where required as a consequence of the results of the special or intermediate surveys.	Suspect areas identified at previous surveys are to be examined, and thickness measurements should be taken of areas of substantial corrosion identified at previous surveys. For a vessel over 15 years of age, an overall survey of all cargo hold spaces is to be undertaken. This is to include a close-up examination of a minimum of 25% of the hold frames, in order to establish the condition of their lower structure and the frame end attachments. Where this level of survey indentifies the need for repairs, a close-up survey is to be undertaken of all frames and the adjacent shell plating. Ballast tanks are also to be examined, as determined by the results of the special survey or intermediate survey. When considered necessary by the Administration, or where extensive corrosion exists, thickness measurements are to be carried out.

[2] UR Z7.1 defines a suspect area as a location showing substantial corrosion and/or a location considered by the surveyor to be prone to rapid wastage.

[3] UR Z7.1 defines substantial corrosion as an extent of corrosion such indicating a wastage in excess of 75% of allowable margins, but within acceptable limits.

Survey details	IACS UR Z7.1 – Hull Surveys for General Dry Cargo Ships	2008 INSB Rules	2011 ESP Code
Intermediate survey	For a vessel over 15 years of age, the requirements for the intermediate survey are the same as applied during the previous special survey.	For vessels over 10 years of age, an internal examination of all salt water ballast spaces is to be carried out. Where such an examination reveals no visible structural defects, the examination may be limited to verification of the efficiency of the protective coating. However, if the protective coating in a salt water DB bottom tank is found to be in "poor" condition and is not renewed, annual internal examinations of the tanks may be required; thickness measurements are not required during these annual surveys, unlike for other ballast tanks. The rules note that "*When extensive corrosion is found, thickness measurements may be required*." for ballast tanks. The rules do not include a definition of "*extensive corrosion*". For vessels over 10 years of age, DB ballast tanks in way of a cargo hold are to be tested. An internal examination of all cargo holds is to be carried out for vessels over 15 years old.	For a vessel over 15 years of age, the requirements for the intermediate survey are the same as applied during the previous special survey.

[4] UR Z7.1 defines a close-up examination as being when the structural components are within the close visual inspection range of the surveyor, i.e. normally within reach of hand.

Survey details	IACS UR Z7.1 – Hull Surveys for General Dry Cargo Ships	2008 INSB Rules	2011 ESP Code
Special survey	The special survey is required to incorporate a survey of the hull in dry dock and an overall survey and examination of various areas, including the cargo holds and DB WB tanks. These examinations are to be supplemented by thickness measurements and close-up surveys in accordance with tabulated minimum requirements **(pages 5 to 8 of this Annex)**. This confirms that for a vessel over 15 years of age, a close-up examination is to be conducted of all hold shell frames, including the upper and lower end attachments and adjacent shell plating. A surveyor may extend the close-up survey and thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of the measurements is to be increased. Thickness measurements may also be dispensed with provided the surveyor is satisfied that there is no diminution based on the close-up examination. If the hard protective coating in a WB DB bottom tank is found to be in "poor" condition and is not renewed, the tanks in question may be examined at annual intervals. Thickness measurements are to be carried out in the tank as deemed necessary by the surveyor, or where extensive corrosion exists.	The special survey is to be conducted when the vessel is in dry dock or on a slipway. For a vessel over 15 years of age, the same key survey activities as required during an intermediate survey are to be undertaken. In addition, thickness measurements are to be conducted during the special survey of various structural elements. The rules refer to the thickness measurement requirements being defined in "*Table 11.1.4*". No such table exists in the rules, although Table A within the same section of the rules defines these requirements. A copy of this table is at **page 9 of this Annex**, which confirms that the surveyor may increase the number of thickness measurements, as deemed necessary, for vessels over 10 years of age. Where the coating of an area of structure is considered to be in "*good condition*", the surveyor may at his discretion, and subject to the approval of INSB Head Office, accept a reduced programme of thickness measurements.	The special survey is required to incorporate a survey of the hull in dry dock and an overall survey and examination of various areas, including the cargo holds and DB WB tanks. These examinations are to be supplemented by thickness measurements and close-up surveys in accordance with tabulated minimum requirements **(pages 10 to 12 of this Annex)**. This confirms that for a vessel over 15 years of age, a close-up examination is to be conducted of all hold shell frames, including the upper and lower end attachments and adjacent shell plating. A surveyor may extend the close-up survey and thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of the measurements is to be increased. Additional thickness measurement guidelines are included for the shell frames on single-side skin bulk carriers of over 150m in length carrying solid bulk cargoes with a density of 1780 kg/m³. The extent of the thickness measurements may also be specially considered provided the surveyor is satisfied that there is no diminution based on the close-up examination. If the hard protective coating in a WB DB bottom tank is found to be in "poor" condition and is not renewed, the tanks in question may be examined at annual intervals. Thickness measurements are to be carried out in the tank as deemed necessary by the surveyor, or where extensive corrosion exists.

Z7.1
(cont'd)

TABLE I

TABLE OF THE MINIMUM REQUIREMENTS FOR CLOSE-UP SURVEY AT HULL SPECIAL SURVEYS OF GENERAL DRY CARGO SHIPS

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No. 3 10 < Age ≤ 15	Special Survey No. 4 and Subsequent Age > 15
(A) Selected shell frames in one forward and one aft cargo hold and associated tween deck spaces. **(B)** One selected cargo hold transverse bulkhead. **(D)** All cargo hold hatch covers and coamings (plating and stiffeners).	**(A)** Selected shell frames in all cargo holds and tween deck spaces. **(B)** One transverse bulkhead in each cargo hold. **(B)** Forward and aft transverse bulkhead in one side ballast tank, including stiffening system. **(C)** One transverse web with associated plating and framing in two representative water ballast tanks of each type (i.e. topside, hopper side, side tank or double bottom tank). **(D)** All cargo hold hatch covers and coamings (plating and stiffeners). **(E)** Selected areas of all deck plating and underdeck structure inside line of hatch openings between cargo hold hatches. **(F)** Selected areas of inner bottom plating.	**(A)** All shell frames in the forward lower cargo hold and 25% frames in each of the remaining cargo holds and tween deck spaces including upper and lower end attachments and adjacent shell plating. **(B)** All cargo hold transverse bulkheads. **(B)** All transverse bulkheads in ballast tanks, including stiffening system. **(C)** All transverse webs with associated plating and framing in each water ballast tank. **(D)** All cargo hold hatch covers and coamings (plating and stiffeners). **(E)** All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches. **(F)** All areas of inner bottom plating.	**(A)** All shell frames in all cargo holds and tween deck spaces including upper and lower end attachments and adjacent shell plating. Areas **(B –F)** as for Special Survey No. 3.

(A) Cargo hold transverse frames.
(B) Cargo hold transverse bulkhead plating, stiffeners and girders.
(C) Transverse web frame or watertight transverse bulkhead in water ballast tanks.
(D) Cargo hold hatch covers and coamings.
(E) Deck plating and underdeck structure inside line of hatch openings between cargo hold hatches.
(F) Inner bottom plating.

See Figs 1 and 2 for the areas corresponding to (A), (B), (C), (D), (E) and (F) .

Note: Close-up survey of cargo hold transverse bulkheads to carried out at the following levels:

- Immediately above the inner bottom and immediately above the tween decks, as applicable.
- Mid-height of the bulkheads for holds without tween decks.
- Immediately below the main deck plating and tween deck plating.

Z7.1
(cont'd)

TABLE II

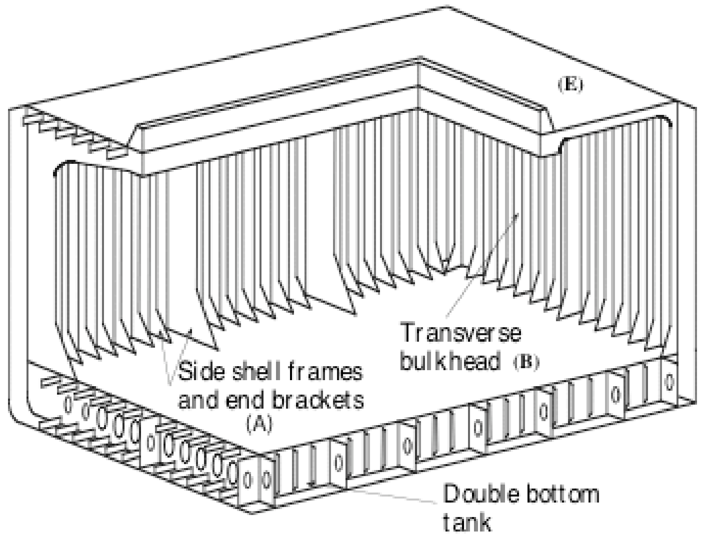
TABLE OF MINIMUM REQUIREMENTS FOR THE THICKNESS MEASUREMENT AT HULL SPECIAL SURVEYS OF GENERAL DRY CARGO SHIPS

Special Survey No. 1 Age ≤ 5	Special Survey No. 2 5 < Age ≤ 10	Special Survey No. 3 10 < Age ≤ 15	Special Survey No. 4 and Subsequent Age >15
1. Suspect areas.	1. Suspect areas. 2. One transverse section of deck plating in way of a cargo space within the amidships 0.5L. 3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to close-up survey according to Table I.	1. Suspect areas. 2. Two transverse sections within the amidships 0.5L in way of two different cargo spaces. 3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to close-up survey according to Table I. 4. Within the cargo length area, each deck plate outside line of cargo hatch openings. 5. All wind and water strakes within the cargo length area. 6. Selected wind and water strakes outside the cargo length area.	1. Suspect areas. 2. Within the cargo length area: a) A minimum of three transverse sections within the amidships 0.5L. b) each deck plate outside line of cargo hatch openings. c) Each bottom plate, including lower turn of bilge. d) Duct keel or pipe tunnel plating and internals. 3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to close-up survey according to Table I. 4. All wind and water strakes full length

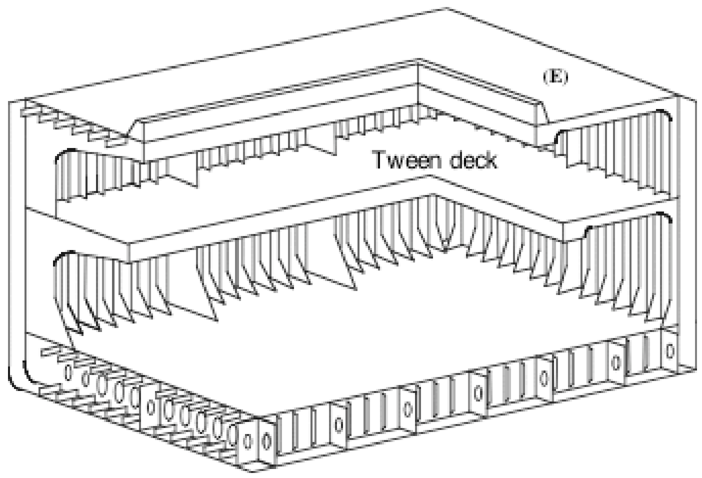
Notes:

1. Thickness measurement locations should be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.
2. For ships less than 100 metres in length, the number of transverse sections required at Special survey No. 3 may be reduced to one and the number of transverse sections at Special Survey No. 4 and subsequent surveys may be reduced to two.

Z7.1
(cont'd)



(a) Single Deck Ship



(b) Tween Deck Ship

Figure 1 Areas for Close-Up Survey of General Dry Cargo Ships

Z7.1
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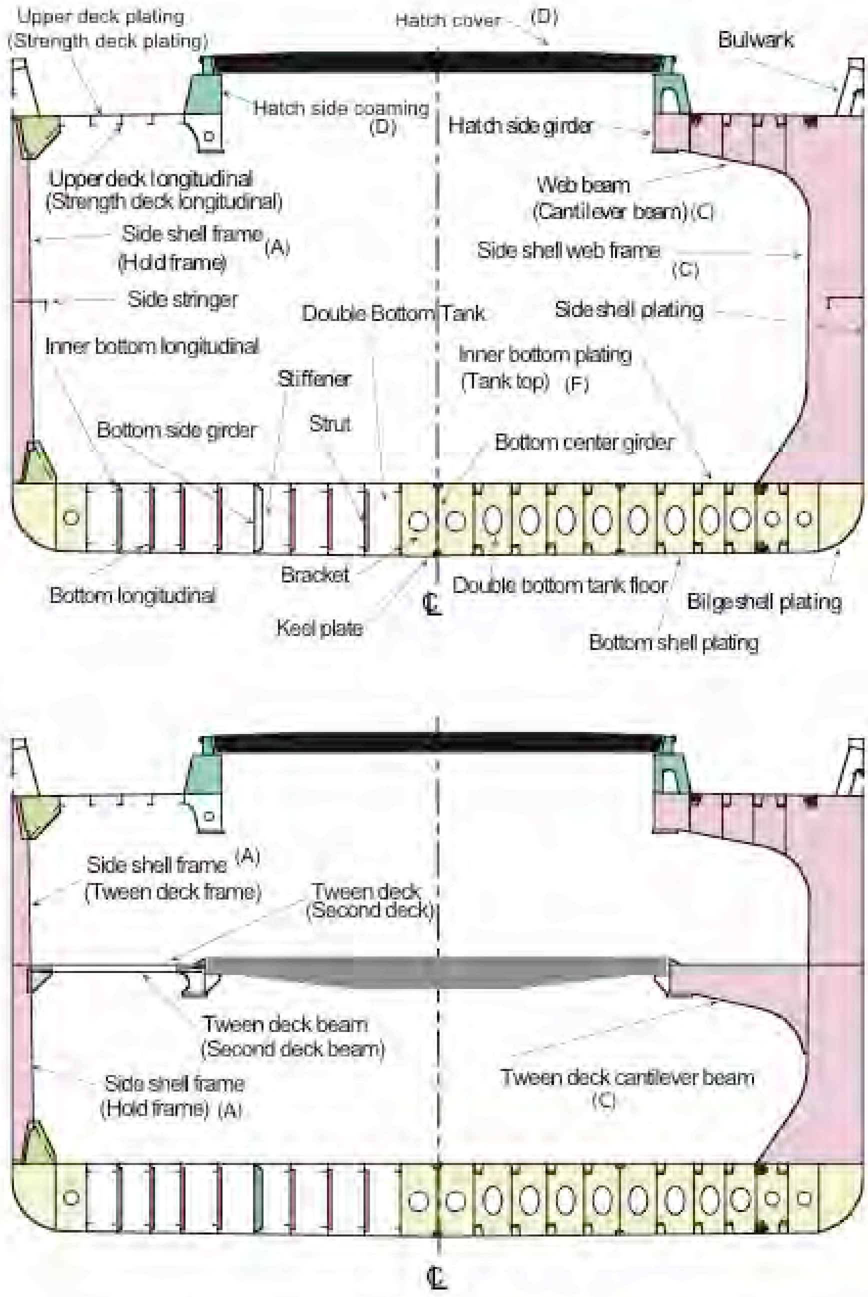

Figure 2 Areas for Close-Up Survey of General Dry Cargo Ships

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Table A Thickness measurements during Special Surveys

Special Survey I **Age of ship ≤ 5 years**	**Special Survey II** **Age of ship > 5, ≤ 10 years**	**Special Survey III** **Age of ship > 10, ≤ 15 years**	**Special Survey IV** **Age of ship > 15 years**
Main structural parts, plates and stiffeners showing signs of tear and wear	Main structural parts, plates and stiffeners showing signs of tear and wear	Main structural parts, plates and stiffeners showing signs of tear and wear	Main structural parts, plates and stiffeners showing signs of tear and wear
	Within the cargo length area or 0.5*L* amidships: – Selected deck plates – 1 transverse section – Selected tank top plates – Selected bottom plates – Selected wind and water strakes	Within the cargo length area or 0.5*L* amidships: – Each deck plate – 2 transverse sections – Selected tank top plates – Selected bottom plates – All wind and water strakes	Within the cargo length area or 0.5*L* amidships: – Each deck plate – 3 transverse sections – Each tank top plate – Each bottom plate – All wind and water strakes
	Outside the cargo length area or 0.5*L* amidships: – Selected deck plates – Selected wind and water strakes – Selected bottom plates	Outside the cargo length area or 0.5*L* amidships: – Selected deck plates – Selected wind and water strakes – Selected bottom plates	Outside the cargo length area or 0.5*L* amidships: – Each deck plate – All wind and water strakes – Each bottom plate
	The two first cargo hold hatch covers and coamings (plates and stiffeners)	All cargo hold hatch covers and coamings (plates and stiffeners)	All cargo hold hatch covers and coamings (plates and stiffeners)
	Collision bulkhead, forward machinery space bulkhead, aft peak bulkhead	Collision bulkhead, forward machinery space bulkhead, aft peak bulkhead, selected cargo hold transverse and longitudinal bulkheads (plates and stiffeners)	All transverse and longitudinal bulkheads (plates and stiffeners)
		Selected internal structural members such as floors and longitudinals, transverse frames, web frames, deck beams, tweendecks, girders, etc.	As for Special Survey III. Number of measurements may be increased as deemed necessary by the Surveyor

ANNEX 1

REQUIREMENTS FOR CLOSE-UP SURVEY AT RENEWAL SURVEYS

Age ≤ 5 years	**5 < Age ≤ 10 years**	**10 < Age ≤ 15 years**	**Age > 15 years**
Renewal Survey No. 1	**Renewal Survey No. 2**	**Renewal Survey No. 3**	**Renewal Survey No. 4 and subsequent**
(A) 25% of shell frames in the forward cargo hold at representative positions (A) Selected frames in remaining cargo holds (B) One transverse web with associated plating and longitudinals in two representative water ballast tanks of each type (i.e. topside, or hopper side tank) (C) Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (D) All cargo hold hatch covers and coamings (plating and stiffeners)	(A) All shell frames in the forward cargo hold and 25% of shell frames in each of the remaining cargo holds including upper and lower end attachments and adjacent shell plating (A) For bulk carriers of 100,000 dwt and above, all shell frames in the forward cargo hold and 50% of shell frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating. (B) One transverse web with associated plating and longitudinals in each water ballast tank (B) Forward and aft transverse bulkhead in one ballast tank, including stiffening system (C) All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (D) All cargo hold hatch covers and coamings (plating and stiffeners) (E) All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches	(A) All shell frames in the forward and one other selected cargo hold and 50% of frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating (B) All transverse bulkheads in ballast tanks, including stiffening system (B) All transverse webs with associated plating and longitudinals in each water ballast tank Areas (C), (D), and (E) as for renewal survey No.2	(A) All shell frames in all cargo holds including upper and lower end attachments and adjacent shell plating. Areas (B)–(E) as for column 3

(A) Cargo hold transverse frame.
(B) Transverse web or watertight transverse bulkhead in water ballast tanks.
(C) Cargo hold transverse bulkhead platings, stiffeners and girders.
(D) Cargo hold hatch covers and coamings.
(E) Deck plating inside line of hatch openings between cargo hold hatches.

See sketches of appendix 3 to annex 8 for areas corresponding to (A), (B), (C), (D) and (E).
See also sketch in annex 15 for zones of side shell frames for ships subject to compliance with resolution MSC.168(79).

Note: Close-up survey of transverse bulkheads to be carried out at four levels:

Level (a) Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.

Level (b) Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.

Level (c) About mid-height of the bulkhead.

Level (d) Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tank.

ANNEX 2

REQUIREMENTS FOR THICKNESS MEASUREMENTS AT RENEWAL SURVEYS

Age ≤ 5 years	5 < Age ≤ 10 years	10 < Age ≤ 15 years	Age > 15 years
1	**2**	**3**	**4**
1 Suspect areas	1 Suspect areas 2 Within the cargo length area: two transverse sections of deck plating outside line of cargo hatch openings 3 Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to annex 1 4 Wind and water strakes in way of transverse sections considered under point 2 above 5 Selected wind and water strakes outside the cargo length area 6 See 1.1.5 and annex 15 for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with resolution MSC.168(79)	1 Suspect areas 2 Within the cargo length area: .1 each deck plate outside line of cargo hatch openings .2 two transverse sections, one of which should be in the amidship area, outside line of cargo hatch openings 3 Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to annex 1 4 All wind and water strakes within the cargo length area 5 Selected wind and water strakes outside the cargo length area 6 See 1.1.5 and annex 15 for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with resolution MSC.168(79) 7 As required by annex 12 for ships subject to compliance with regulation XII/6.1of the Convention	1 Suspect areas 2 Within the cargo length area: .1 each deck plate outside line of cargo hatch openings .2 three transverse sections, one of which should be in the amidship area, outside line of cargo hatch openings .3 each bottom plate 3 Point 3 referred to in column 3 4 All wind and water strakes, full length 5 See 1.1.5 and annex 15 for additional thickness measurement guidelines applicable to the side shell frames and brackets on ship subject to compliance with resolution MSC.168(79) 6 As required by annex 12 for ships subject to compliance with regulation XII/6.1 of the Convention

Annex K

Diagram showing a typical top side and hopper tank arrangement on a bulk carrier

2. LOADS AND HULL STRUCTURE

2.1 TYPICAL BULK CARRIER STRUCTURAL CONFIGURATION

The most widely recognised structural arrangement identified with bulk carriers is a single deck ship with a double bottom, hopper tanks, single skin transverse framed side shell, topside tanks and deck hatchways. For guidance on the structural terminology adopted in this publication, a typical structural arrangement of a bulk carrier cargo hold space is illustrated in Figure 1. In addition, a typical transverse section in way of a cargo hold and a longitudinal section of a typical corrugated transverse watertight bulkhead are illustrated in Figures 2 and 3 respectively.

Bulk carrier design does not alter significantly with size; fundamentally, a bulk carrier of 30 000 tonnes deadweight usually has the same structural configuration as that of a ship of 80 000 tonnes deadweight.

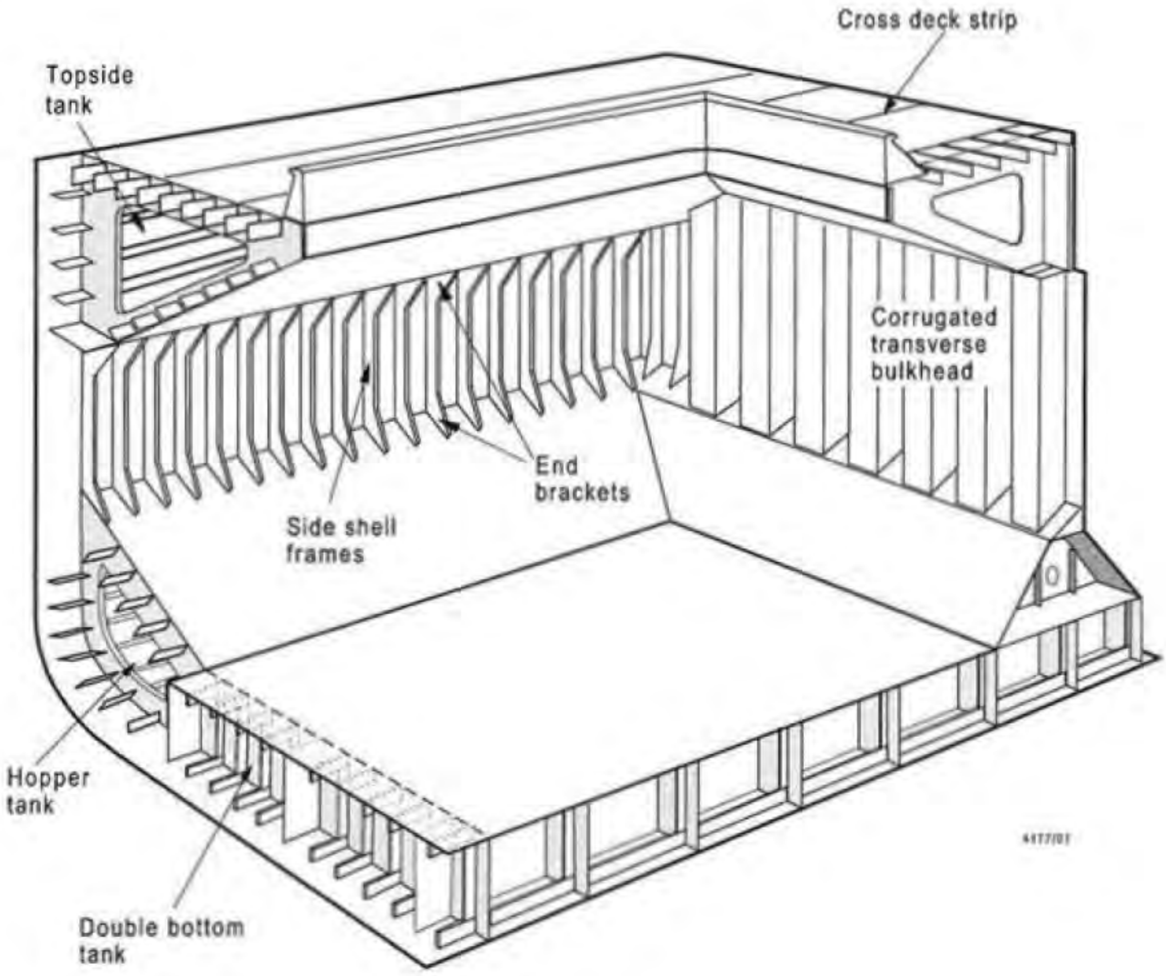

Figure 1
Typical Cargo Hold Structural Configuration for a Single Side Skin Bulk Carrier

Annex L

Technical data provided by CEMEX UK Materials Limited Legal Department for MOT Type 1 Limestone

CEMEX

Legal Department

28 March 2012

Inspector of Marine Accidents
MAIB
Mountbatten House
Grosvenor Square
Southampton
SO15 2JU

Legal Dept Fax: [redacted]

Our ref: [redacted]
Your ref:

Dear

Swanland

Thank you for your letter of 14th March 2012 and please accept my apology for the delay in responding.

Please find attached a laboratory test report from Celtest Company Limited dated 16th May 2008. This provides an independent evaluation to determine the Angle of Repose of Raynes Type 1 Sub-base. Although the document is dated in 2008 the material has not altered since then. The Density of Type 1 for stock calculations is 1.85 tonnes per cubic metre.

If I can be of any further assistance then please do not hesitate to contact me.

Yours sincerely,

[redacted]

UK Legal Director
Legal Department
Direct Line Tel:
Direct e-mail :

CEMEX UK Operations Limited
CEMEX House, Coldharbour Lane, Thorpe, Egham, Surrey TW20 8TD, United Kingdom.
Phone: +44 (0) 1932 568833 Fax: +44 (0) 1932 568933
www.cemex.co.uk
Registered in England and Wales. Company Number 658390 Registered Office as above

celtest
independent materials testing — diamond core drilling & sawing

Celtest Company Ltd
Trefelin
Llandegai
Bangor
Gwynedd
LL57 4LH

Tel: 01248 355269
Fax: 01248 351563
e-mail:
Web: www.celtest.com

Cemex UK Materials,
Cemex House,
Tanhouse Lane,
Widnes,
Chesire,
WA8 0SQ

Date: 16th May 2008
Our Ref. STR.: 143447

Contract.: **Raynes Quarry**

LABORATORY TEST REPORT

TEST REQUIREMENT: To determine the Angle of Repose of an aggregate sample in accordance with **Documented In-house Procedures**

SAMPLE DETAILS:

Certificate Enclosed:	**Yes**
Laboratory Ref. No:	**S23687**
Client Ref. No:	**84**
Date and Time of Sampling:	**09/05/2008**
Date of Receipt at Lab:	**09/05/2008**
Date of Start of Test:	**12/05/2008**
Sampling Location:	**Stockpile**
Delivery Ticket No:	**N/A**
Name of Source:	**Raynes Quarry**
Method of Sampling:	**Unknown**
Sampled By:	**Client**
Aggregate Type and Nominal Size.	**GSB Type 1**
Target Specification.	**N/A**

RESULTS:

Angle of Repose = **50^0**

COMMENTS/ DEPARTURE FROM SPECIFIED PROCEDURE:

Annex M

IMSBC Code datasheet for Limestone

LIMESTONE

DESCRIPTION

Limestone varies in colour from cream through white to medium dark grey (when freshly broken).
Moisture: up to 4%.

CHARACTERISTICS

ANGLE OF REPOSE	BULK DENSITY (kg/m^3)	STOWAGE FACTOR (m^3/t)
Not applicable	1190 to 1493	0.67 to 0.84
SIZE	**CLASS**	**GROUP**
Fines to 90 mm	Not applicable	C

HAZARD

No special hazards.
This cargo is non-combustible or has a low fire-risk.

STOWAGE & SEGREGATION

No special requirements.

HOLD CLEANLINESS

No special requirements.

WEATHER PRECAUTIONS

No special requirements.

LOADING

Trim in accordance with the relevant provisions required under sections 4 and 5 of the Code.

PRECAUTIONS

Bilge wells shall be clean, dry and covered as appropriate, to prevent ingress of the cargo.

VENTILATION

No special requirements.

CARRIAGE

No special requirements.

DISCHARGE

No special requirements.

CLEAN-UP

No special requirements.