Report on the investigation of

the structural failure of

MSC Napoli

English Channel

on 18 January 2007

Marine Accident Investigation Branch
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Report No 9/2008
April 2008

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Bodied seaman
BV	-	Bureau Veritas
CGM	-	Compagnie Générale Maritime
CROSS	-	Centre Regional Operationnel de Surveillance et de Sauvetage
DNV	-	Det Norske Veritas
DSC	-	Digital Selective Calling
ECR	-	Engine control room
EPIRB	-	Emergency Position Indicator Radio Beacon
FE	-	Finite element
GM	-	Metacentric height
GS	-	General Service
IACS	-	International Association of Classification Societies
ICS	-	International Chamber of Shipping
IMO	-	International Maritime Organization
ISM Code	-	International Management Code for the Safe Operation of Ships and for Pollution Prevention
kW	-	Kilowatt
LR	-	Lloyd’s Register
MCA	-	Maritime and Coastguard Agency
MF	-	Medium Frequency
MNm	-	Mega Newton metre
MOU	-	Memorandum of Understanding
MRCC	-	Marine Rescue Co-ordination Centre
MSC	-	Mediterranean Shipping Company
P&I	-	Protection and Indemnity
PMS	-	Planned Maintenance System

rpm	-	Revolutions per minute
SAR	-	Search and Rescue
SART	-	Search and Rescue Transponder
SHI	-	Samsung Heavy Industries
SMS	-	Safety Management System
SOLAS	-	International Convention for the Safety of Life at Sea
SOSREP	-	Secretary of State Representative
STCW	-	International Convention on Standards of Training, Certification and Watchkeeping incorporating the 1995 Amendments
TEU	-	Twenty foot equivalent unit (container size)
UTC	-	Universal co-ordinated time
VHF	-	Very High Frequency

All times in this report are UTC + 1 unless otherwise stated

SYNOPSIS

During the morning of 18 January 2007, when on passage in the English Channel, the 4419 TEU container ship *MSC Napoli* encountered heavy seas, causing the ship to pitch heavily. The ship was making good a speed of 11 knots and the height of the waves was up to 9m. At about 1105, the vessel suffered a catastrophic failure of her hull in way of her engine room. The master quickly assessed the seriousness of the situation and decided to abandon ship. Following the broadcast of a distress call at 1125, the 26 crew abandoned the vessel in an enclosed lifeboat. They were later recovered by two Royal Navy helicopters. There were no injuries.

MSC Napoli was subsequently taken under tow towards Portland, UK but, as the disabled vessel approached the English coast, it became evident there was a severe risk she might break up or sink, and she was intentionally beached in Branscombe Bay on 20 January 2007. A number of containers were lost overboard when the vessel listed heavily after beaching.

The investigation has identified a number of factors which contributed to the failure of the hull structure, including:

- The vessel's hull did not have sufficient buckling strength in way of the engine room.
- The classification rules applicable at the time of the vessel's construction did not require buckling strength calculations to be undertaken beyond the vessel's amidships area.
- There was no, or insufficient, safety margin between the hull's design loading and its ultimate strength.
- The load on the hull was likely to have been increased by whipping effect.
- The ship's speed was not reduced sufficiently in the heavy seas.

In view of the potential vulnerability of other container ships of a similar design, the MAIB requested the major classification societies to conduct urgent checks on the buckling strength of a number of ship designs. Over 1500 ships were screened, of which 12 vessels have been identified as requiring remedial action; a further 10 vessels were identified as being borderline and require more detailed investigation; and the screening of 8 container ships was still in progress at the time of publication. Remedial action has either been completed, planned, or is being arranged; where necessary, operational limitations have been agreed or strongly advised until the remedial work has been completed.

Recommendations have been made to the International Association of Classification Societies, which are intended to increase the requirements for container ship design, consolidate current research into whipping effect, and to initiate research into the development and use of technological aids for measuring hull stresses on container ships. Recommendations have also been made to the International Chamber of Shipping with the aim of promoting best practice within the container ship industry, and to Zodiac Maritime Agencies, with reference to its safety management system.

MSC Napoli

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *MSC NAPOLI* AND ACCIDENT

Vessel details

Registered Owner	:	Metvale Limited
Registered Operator	:	Zodiac Maritime Agencies Limited
Port of registry	:	London
Flag	:	United Kingdom
Type	:	Container (4,419 TEU)
Built	:	1991 – Samsung Heavy Industries Co Ltd Koje, South Korea
Classification society	:	Det Norske Veritas (DNV) from 2002 Bureau Veritas (BV) 1991 – 2002
Class notation (BV)	:	1A1 DG-P EO
Length overall	:	275.66m
Breadth	:	38.18m
Gross tonnage	:	53,409
Engine power and type	:	38792kW Sulzer 10RTA84C
Service speed	:	24.10kts (when built)

Accident details

Time and date	:	1102 LT 18 January 2007
Location of incident	:	Lat 49º 19.8' N Long 004º 34.8' W, 146º Lizard Point 45nm
Persons on board	:	26
Injuries/fatalities	:	None
Damage	:	Constructive total loss

1.2 BACKGROUND

MSC Napoli was built in 1991. She was originally named *CGM Normandie* and registered in France. The vessel's name was changed to *Nedlloyd Normandie* in 1995 and to *CMA CGM Normandie* in 2001. She was purchased by Metvale Limited in September 2002 when her registration was also changed to the UK flag. The vessel continued under charter to CMA/CGM until November 2004 when she was chartered by Mediterranean Shipping Company (MSC) and renamed *MSC Napoli*. Her initial trading route with MSC was between the eastern Mediterranean and north west Europe, but from November 2006 *MSC Napoli* plied between South Africa and northwest Europe; her charter speed was 21.5kts.

The vessel's port rotation was: Cape Town – Port Elizabeth – Durban – Port Elizabeth – Cape Town – Las Palmas – Felixstowe – Hamburg – Antwerp – Le Havre – Sines – Las Palmas.

On 29 December 2006, *MSC Napoli* sailed from Cape Town at the start of her north-bound voyage 4 days behind schedule. To save time, her charterer cancelled the planned port calls at Hamburg and Le Havre and arranged for the cargo that was planned to be loaded and discharged at those ports, to be transhipped at Antwerp instead.

When the vessel arrived at Felixstowe on the morning of 13 January 2007, she was 6 days behind her original schedule following the failure of one of her four main engine turbochargers. A second main engine turbocharger failed during the passage between Felixstowe and Antwerp; her main engine governor was also not operational[1]. All four turbochargers were working when the vessel sailed from Antwerp, but the main engine governor remained out of action. At the time of the accident, *MSC Napoli* was on passage from Antwerp, Belgium to Sines, Portugal, with a crew of 26[2]. Her ETA in Sines was 1800 on 19 January 2007.

1.3 NARRATIVE

1.3.1 Hull failure

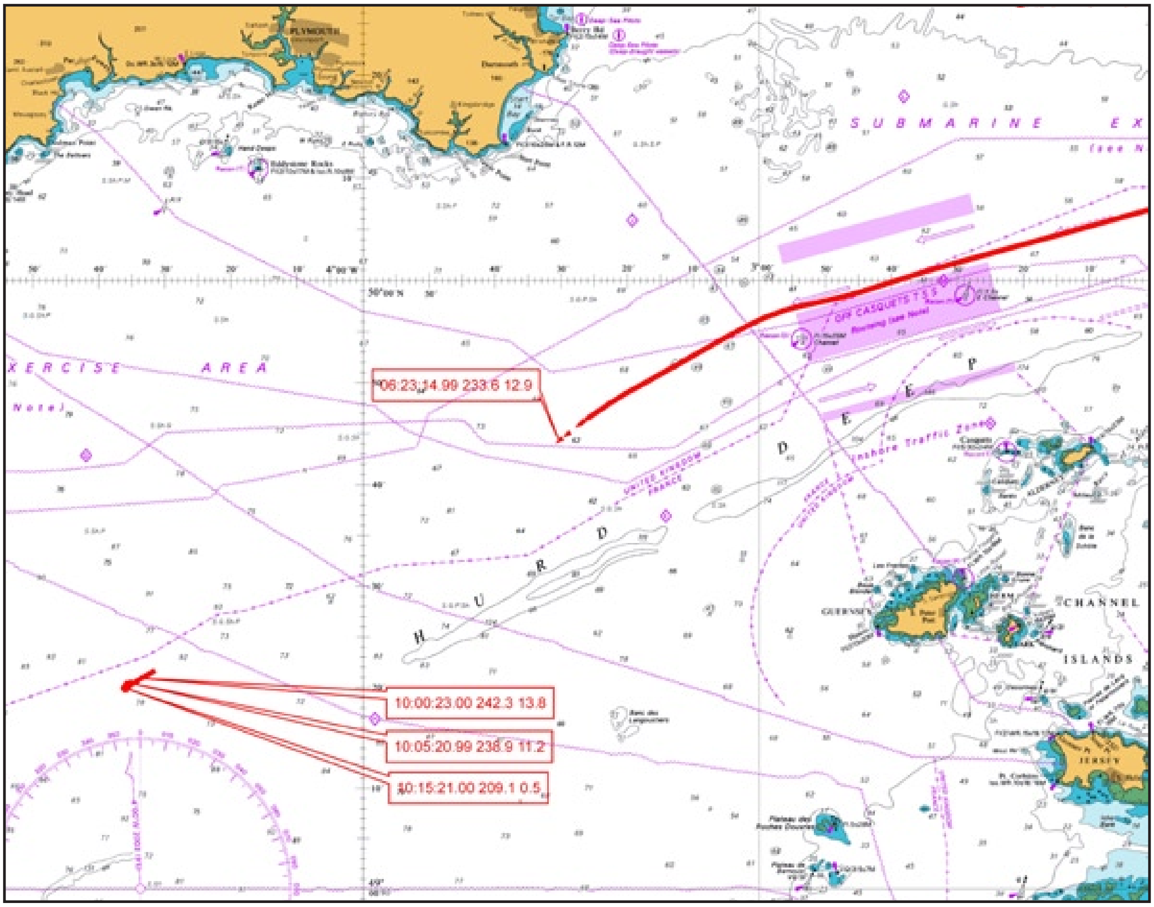
MSC Napoli departed her berth in Antwerp at 0812 on 17 January 2007. After disembarking her river pilot at 1521, the vessel passed through the Dover Strait before transiting the English Channel during the early hours of the following morning. The weather worsened overnight, and a deck log entry made during the 0400-0800 watch stated "*Vessel rolling and pitching moderately, vessel pounding heavily at times. Seaspray over focsle*". By the time *MSC Napoli* was about 45 miles south east of the Lizard Point in Cornwall, England **(Figure 1)**, she was heading into storm force winds. The vessel was occasionally pitching heavily into high seas but was no longer rolling to any significant extent. Her course was 240^{o} and her engine was at a speed which normally resulted in a vessel speed of 17kts[3]. She was making good a speed of 11 knots over the ground and her master was content with the vessel's motion and considered that there would be no damage caused to the forward containers.

[1] Details of the control of the main engine are at **Annex A.**

[2] Details of the crew are at **Annex B.**

[3] Company instructions to the master stated *"Under no circumstances should the vessel be forced to proceed in rough weather at speeds which could cause severe damage to the vessel's structure and engines and endanger the lives of the crew. Engine rpm shall be reduced to the extent that the vessel makes headway without causing shuddering and excessive vibration."*

Figure 1

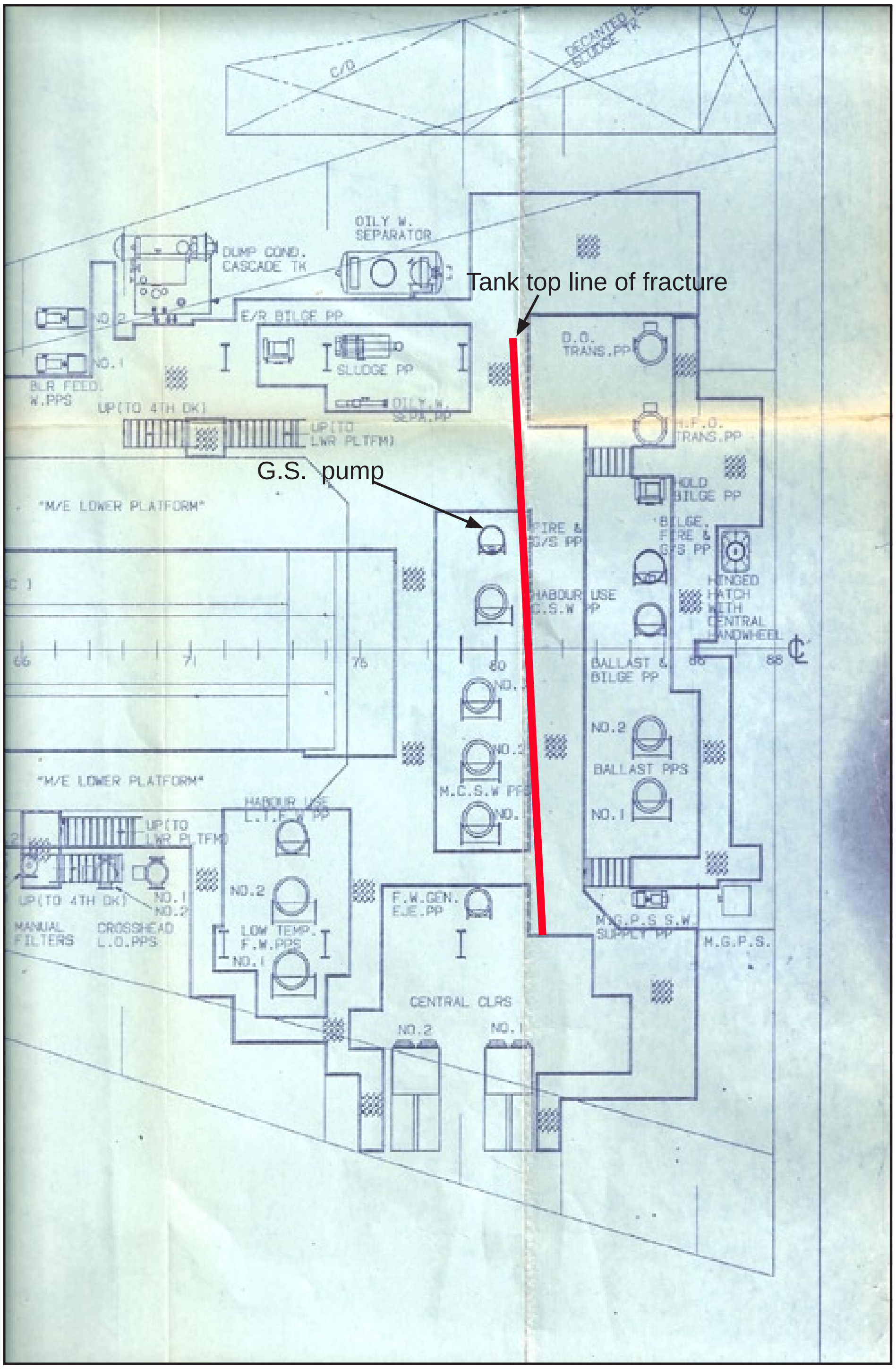


Ship's track as recorded by AIS (UTC)

Shortly after 1100, the ship encountered several large waves, which were described as "quite powerful strikes". One of the crew found it extremely difficult to stand in a shower cubicle during this period due to the vessel's movement. At about 1105 a loud crashing or cracking sound was heard. At the same time, the third assistant engineer, on watch in the engine control room (ECR), acknowledged an alarm indicating a high level of fluid in the engine room bilge. This was immediately followed by further bilge alarms and an engine room flood alarm.

The first assistant engineer quickly joined the third assistant engineer in the ECR. He telephoned the chief engineer on the bridge and informed him of the situation, while the third assistant engineer went to the bottom plates in the engine room to investigate the cause of the alarms. On arrival, the third assistant engineer saw water spraying from the general service (GS) pump delivery pipe just forward of the main engine. The pump was not running and he quickly shut both its delivery and suction valves. This stopped the water flow. The delivery pipe had sheared cleanly across, and the two sections had separated by about 150mm. The third assistant engineer also saw a large quantity of water sloshing from side to side under the engine room bottom plates. As he started to return to the ECR, the tank top forward of the main engine appeared to open up across the ship **(Figure 2)**, and a "wall of oily water" shot upwards before cascading down across the pump flat and bottom plates. The third engineer quickly evacuated the area and returned to the ECR.

Figure 2



Forward engine room arrangement showing fracture line

Following the call from the first assistant engineer, the chief engineer informed the master that the engine room might be flooding. He then quickly made his way to the ECR, where the third assistant engineer briefed him on what he had seen. The chief engineer went down to the bottom plates to assess the situation. He saw a lot of water swirling across the tank tops and under the bottom plates and, what appeared to be cracks, in the tank top. He also saw what he thought was a large fracture in the side shell plating on the starboard side close to the sea chest. Additionally, many of the cooling pumps in the pump flat had stopped operating. The chief engineer stopped the main engine before returning to the ECR, from where he informed the master of the situation. Having concluded that the ship had suffered serious structural failure, he then ordered all personnel to leave the engine room.

1.3.2 Abandonment

After talking to the chief engineer, the master went onto the starboard bridge wing from where he could see that the ship's side plating directly below the bridge was bulging outwards. He also saw what appeared to be a vertical fracture below the waterline as the ship rolled to port. When similar damage was seen on the port side, the master assessed that *MSC Napoli* had 'broken her back' **(Figure 3)**, and decided to abandon the vessel.

Reproduced courtesy of Marine Nationale

Figure 3

MSC Napoli following the structural failure

A distress message was sent via MF DSC at 1125 and the crew started to assemble on the bridge. A few minutes later, the vessel lost all electrical power. However, lighting was soon restored when the ship's emergency generator started automatically.

By now, the ship was stopped in the water, with her starboard side exposed to the wind and sea. Consequently, the master sent the bosun and three of the crew to prepare the port lifeboat for launch[4]. Others were sent to the provision locker to get cases of bottled water. After all crew had been accounted for, the master sounded the

[4] It was evident during the investigation that the master had placed a great deal of emphasis on the importance of safety drills and the maintenance of lifesaving equipment, and that the preparation and lowering of lifeboats had been well-practiced in accordance with company policy.

emergency alarm of seven long, and one short blasts on the ship's whistle to indicate to the crew to make their way to the lifeboat station. He then called Ushant Traffic on VHF radio to advise that he and his crew were abandoning into the lifeboat.

The master and third officer were the last to enter the lifeboat, having collected the SART, EPIRB and a number of the ship's documents. The lifeboat engine had been started and, following verbal confirmation from the chief officer that all 26 crew members were on board, the master ordered the chief engineer to lower the lifeboat by hauling down on the remote lowering wire.

The lifeboat smoothly descended the 16 metres to the sea. Once waterborne, the bosun released the fore and aft falls from inside the lifeboat. However, the crewman sitting nearest the forward painter release could not pull the release pin sufficiently far to allow the painter to disengage. He was squeezed between two other crew and his movement was restricted by his immersion suit. The painter was eventually cut by the chief engineer, who had a knife, and was able to reach the painter via the lifeboat's forward hatch.

After clearing *MSC Napoli*, the lifeboat was manoeuvred to a position between 1 and 1½ miles away from the stricken vessel. The master then activated the EPIRB and the SART. The motion of the lifeboat was violent and the atmosphere in the lifeboat was very uncomfortable; all of the crew suffered from sea sickness. Although the lifeboat was certified to accommodate up to 32 persons, the 26 crew wearing immersion suits and lifejackets were very cramped. They were very warm and several felt faint and de-hydrated. The situation became more tolerable after the crew cut off the gloves from their immersion suits with the chief engineer's knife. This allowed them to use their hands more effectively, and they were able to drink from plastic drinking water bottles they had brought with them.

On receipt of the "Mayday", CROSS Corsen initiated the assistance of a SAR helicopter and a tug. When the crew abandoned, Falmouth MRCC was also requested to assist. Falmouth MRCC activated two SAR helicopters, R193 and R194 **(Figure 4)**.

The first helicopter arrived at the scene at 1150. Initially, a highline[5] could not be passed to the lifeboat due to the severe weather conditions. However, at about 1230, a diver was lowered from R194 into the sea and swam to the lifeboat. A highline was rigged and the helicopter crew recovered 13 survivors from the lifeboat. R193 took over the winching operation at 1325, and by 1409 the remaining 13 survivors had been recovered.

1.3.3 Post-accident events

Following the successful abandonment of the vessel, *MSC Napoli was* taken in tow to Portland, Dorset. A towline was connected **(Figure 5)** but, as the disabled vessel approached the south coast of England, concern increased regarding her condition. In order to prevent the vessel from breaking up or sinking at sea, she was beached in Branscombe Bay on 20 January 2007 **(Figure 6)**. A number of containers were lost overboard when the vessel listed heavily after beaching.

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[5] A highline transfer is a method of lifting survivors from a confined area such as a lifeboat or liferaft into a helicopter. The technique involves the attachment of a messenger to the helicopter's winch hook to enable the hook to be accurately controlled and positioned by the persons in the confined space.

During the following 5 months, most of the vessel's fuel oil and the remaining containers were removed. *MSC Napoli* was refloated on 9 July 2007, but it was soon apparent that she was in a poor condition and she was re-beached 3 days later.

On 20 July 2007, the vessel was separated using explosive charges approximately in way of where the hull had failed on 18 January 2007 **(Figures 7 and 8)**. The forward section was then towed to the Harland and Wolff shipyard in Belfast for recycling. The after section remains off Branscombe at the time this report was published.

Reproduced courtesy of Marine Nationale

Figure 4

Recovery of the crew

Reproduced courtesy of Marine Nationale

Figure 5

MSC Napoli under tow

Figure 6

MSC Napoli beached at Branscombe Bay

Figure 7

MSC Napoli - forward section

Figure 8

MSC Napoli - aft section

1.4 ENVIRONMENTAL CONDITIONS

The wind was south west storm force 10 to 11[6]. There was a swell running from the south west and the wave height was estimated to have been between 5m and 9m. The distance between successive wave peaks was 150m, with an interval of between 9 and 10 seconds. The charted depth of water was about 80m.

High water at Dover on 18 January was at 1120. The predicted tidal stream at 1120 is shown at **Figure 9**. The tidal range was 60% of the spring range.

Figure 9

Tidal Stream Atlas for 1020 UTC

The following weather forecasts were issued by the U.K. Meteorological Office and received on board *MSC Napoli* on 17 and 18 January:

At 1130 on 17 January

German Bight Humber Thames Dover Wight Portland

southwesterly 6 to gale 8 increasing severe gale 9, perhaps storm 10 later. rough or very rough, occasionally high in Portland later. Rain. moderate or good

At 0015 on 18 January

Wight Portland Plymouth

southwesterly 6 or 7, increasing gale 8 to storm 10, perhaps violent storm 11 later. Very rough becoming high. rain or showers. moderate, occasionally poor

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[6] On the Beaufort scale, a wind strength of force 11 (violent storm) indicates the wind has a mean velocity of between 56 knots and 63 knots (28.5-32.6m/s). In conjunction with the high wind speed, exceptionally high waves with a probable height of up to 11.5m are possible.

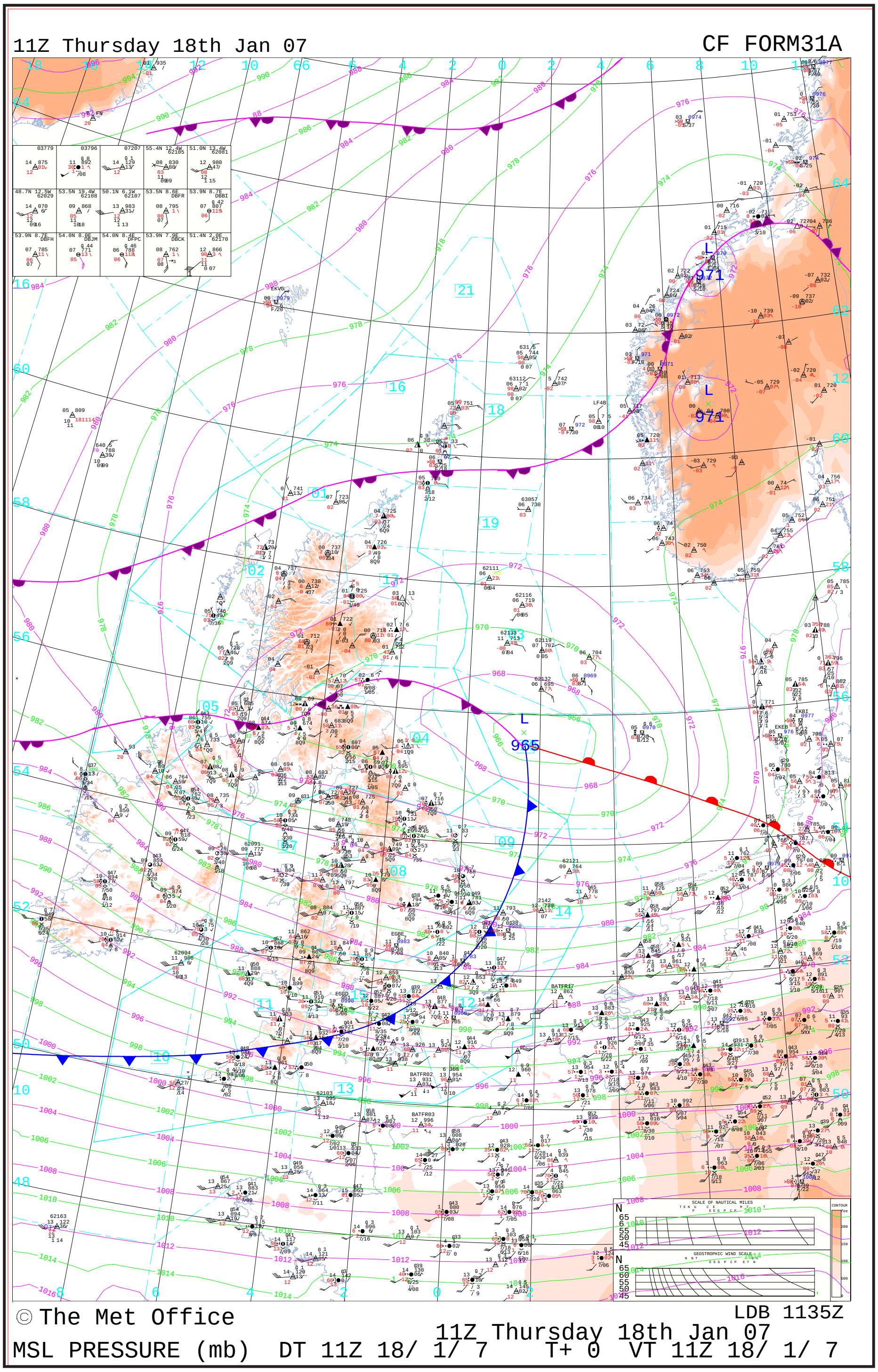
At 0505 on 18 January

Wight Portland Plymouth

southwesterly 7 to severe gale 9, occasionally storm 10, perhaps violent storm 11 later. Very rough or high rain or showers. moderate, occasionally poor

The surface analysis chart for 1100 UTC on 18 January 2007 is shown at **Figure 10**.

Figure 10



Surface analysis for 1100 UTC

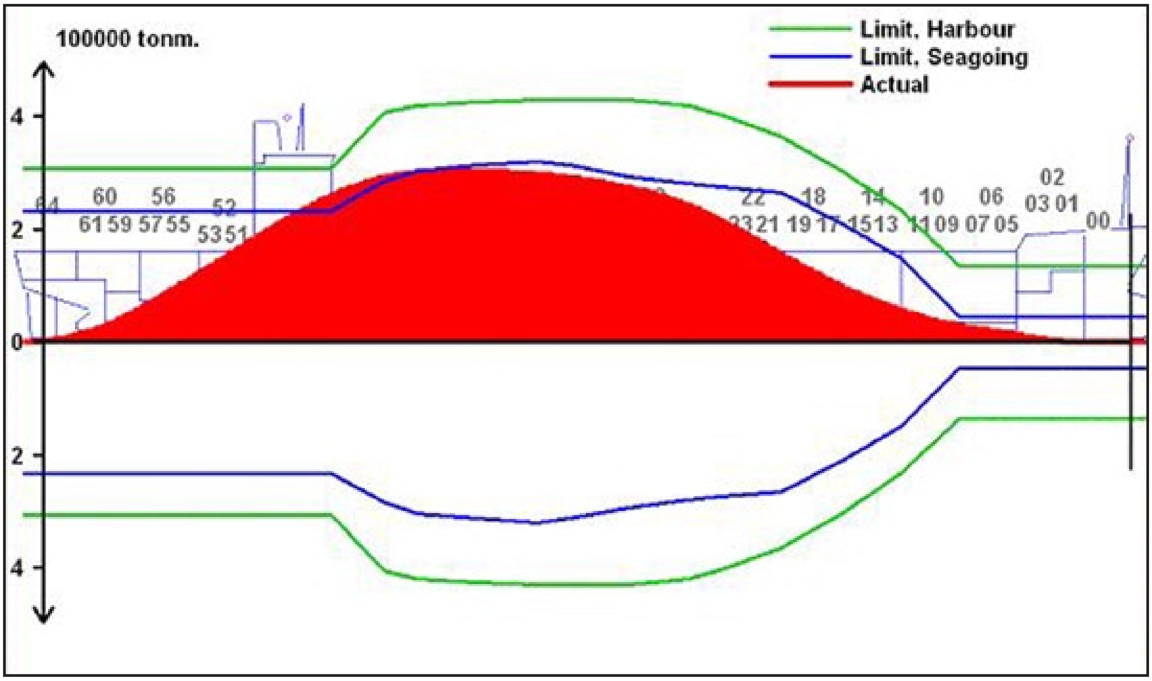
1.5 LOADED CONDITION

1.5.1 On sailing Antwerp

It was intended that *MSC Napoli* would have a maximum draught of 13m on completion of container operations at Antwerp to allow her to sail at any state of the tide. The maximum permitted draught to leave the port was about 15m.

In an attempt to achieve the desired draught, various ballast configurations were input to the vessel's loading computer[7] together with the planned distribution and weights of the containers to be loaded. The only condition that enabled a maximum aft draught of 13m resulted in harbour and sea bending moments[8] of about 88% and 116% **(Figure 11)** of their respective maxima. This condition, which required the ship to be ballasted forward during the cargo operations, was approved by the master, on the basis that the bending moments would be reduced to within the seagoing limit, by adjusting the ballast configuration during the river transit towards the open sea. When loaded, it was normal for the vessel to be in a 'hogged' condition[9].

Figure 11



Departure condition on leaving the berth in Antwerp

MSC Napoli departed Antwerp on 17 January with 2318 containers on board, of which about 700 were stowed on deck. The ship's draught on departure was 13m aft and 12.6m forward. After passing through the harbour locks at about 1000, the chief officer adjusted the ballast during the passage down the river as planned. This action was

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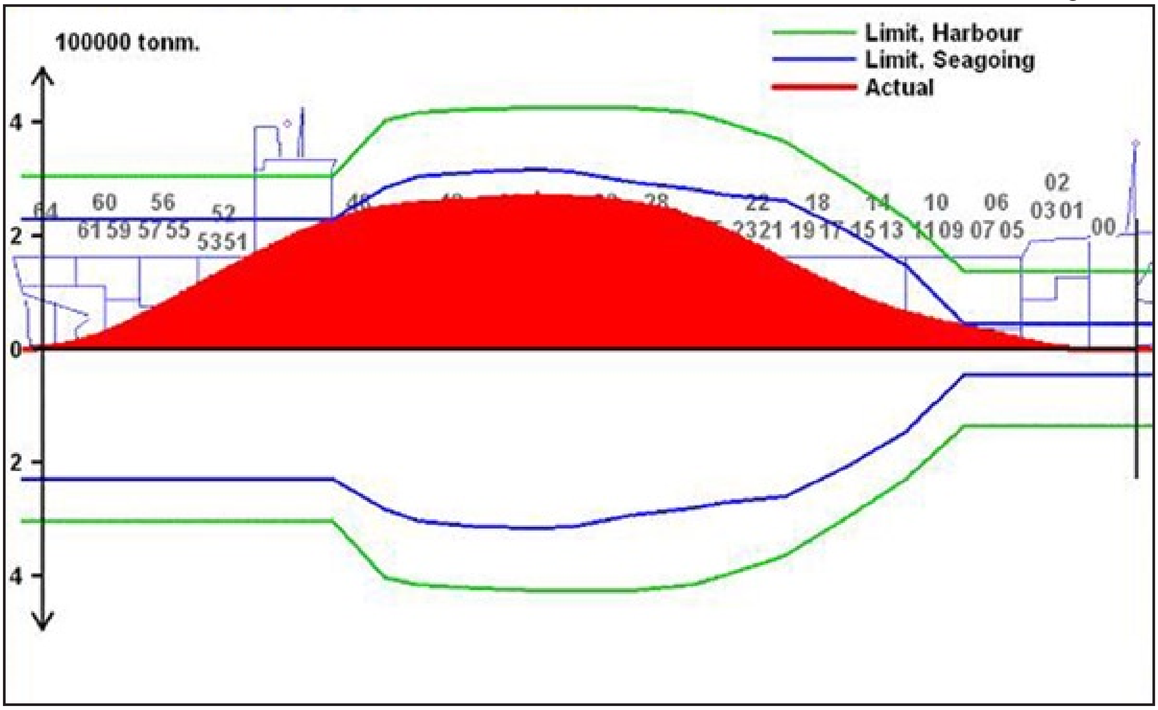
[7] *MSC Napoli* was equipped with an Easecon version 4.01 loading computer. The computer was approved by BV on 28 January 2000. When the ship's classification was changed in 2002, DNV re-checked the computer for accuracy against the vessel's loading manual and issued a letter of approval on 21 June 2002. Following the accident on 18 January, the loading computer was again checked for accuracy and found to be correct.

[8] Seagoing bending moments are 76% of harbour bending moments or still water bending moments. The 24% difference is the margin of safety required to allow for wave loading at sea.

[9] Hogging is the stress a ship experiences that causes the center of the hull to bend upward.

completed by 1510 and had the effect of reducing the seagoing bending moments to 99% of the allowed maximum **(Figure 12)** and of increasing the draught aft to about 13.5 metres. The pilot was not informed of the changes in draught and trim.

Figure 12



Condition on leaving the River Schelde

To facilitate berthing at any state of the tide at Antwerp, the vessel had arrived at the port on 120% of her maximum permissible seagoing bending moments. Data recovered from the ship's loading computer indicated that the vessel had arrived or departed from berths or other ports on several occasions on up to 122% of her maximum permissible seagoing bending moments.

1.5.2 Deadload[10]

Before sailing from Antwerp, the chief officer read the vessel's draught marks forward, amidships and aft from the dockside, after first ensuring the vessel was upright. The draughts were then entered into the loading computer and the deadweight corresponding to the recorded draughts was calculated and compared against the calculated loaded deadweight. The deadload on departure from Antwerp (having used a constant of 483MT to allow for known weights such as fuel, water ballast, spares etc) was about 1250MT.

MSC Napoli often had large deadloads on completion of loading. In May and June 2005 MSC arranged for two draught surveys to determine the cause of the discrepancies, but no significant deadload was found on these occasions.

[10] The deadload is the difference between a vessel's deadweight calculated from her observed draught and a vessel's deadweight calculated from known weights such as cargo, fuels and water ballast. In theory, the deadload should be the difference between the calculated or estimated weight of cargo and the actual cargo on board, although other 'unknown weights' such as accumulated mud in ballast tanks can also contribute. There is no evidence to suggest that a significant amount of mud had accumulated in *MSC Napoli*'s ballast tanks prior to her departure from Antwerp.

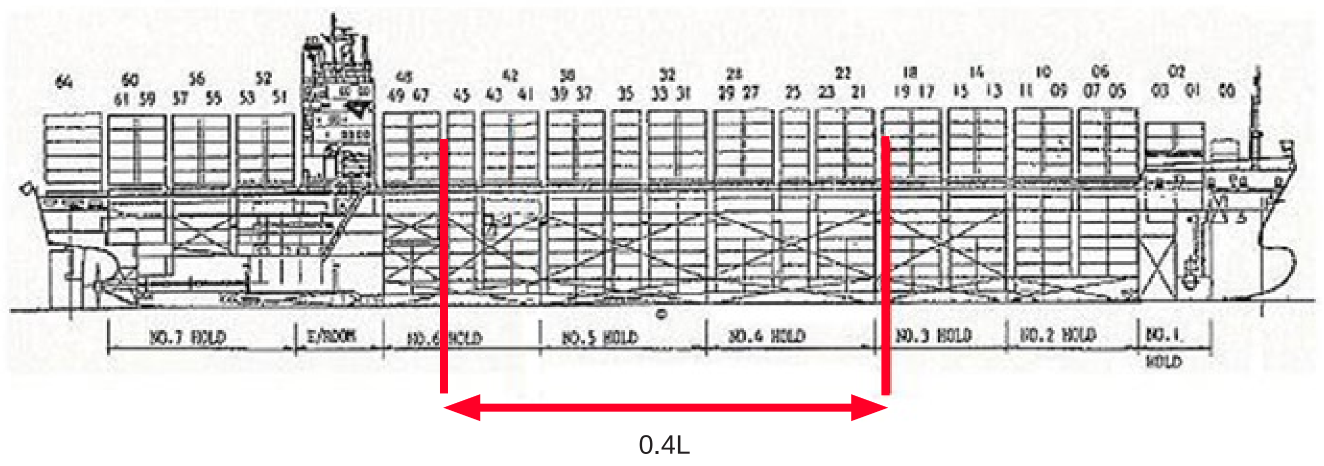
1.6 VESSEL DESIGN AND CONSTRUCTION

1.6.1 Overview

MSC Napoli was designed and built by Samsung Heavy Industries (SHI), South Korea and was a post-panamax container ship, i.e. her beam was too great to enable her to transit the Panama Canal. At the time of her construction, she was one of the largest container ships to have been built. SHI based her design on the design of an existing smaller vessel, but increased the breadth in order to increase the carrying capacity. *MSC Napoli* had no sister vessels.

The vessel had seven cargo holds, with the engine room and accommodation block situated at approximately 3/4L from forward between No 6 and No 7 holds **(Figure 13)**. Containers were carried within the cargo holds and also above deck on the hatch covers. The location of the engine room and accommodation block was not uncommon for a container ship.

Figure 13



MSC Napoli profile showing 0.4L amidships region and engine room

While the underwater hull form was relatively fine with a low block coefficient[11], the deck at the ends of the ship above water were wider in order to increase the stowage space for deck containers, and resulted in moderately large bow and stern flare angles.

1.6.2 Hull framing

Forward of the engine room the hull was longitudinally framed, i.e. the shell plate was reinforced by closely spaced stiffeners (longitudinals) which ran in the fore and aft direction. Generally, the longitudinals were spaced at 870mm intervals in the bottom structure and supported by transverse floors spaced a maximum of 3200mm apart.

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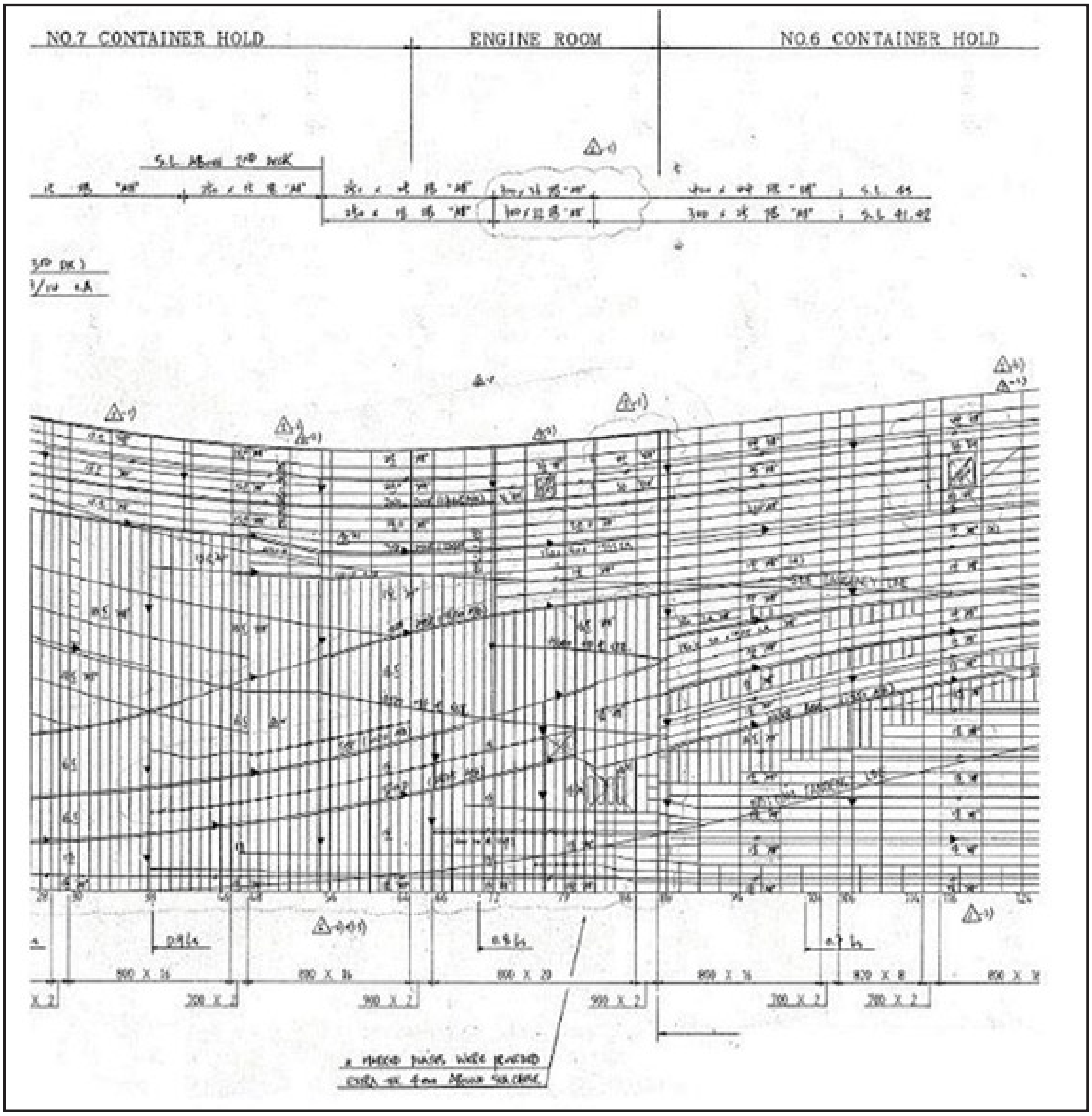
[11] The shape of a hull is often expressed in terms of measured ratios, known as hull coefficients, which compare the immersed section of a hull shape to that of rectangular shapes of the same overall dimensions. The block coefficient (Cb) is the principal measure of a vessel's underwater hull form. The block coefficient of *MSC Napoli* was 0.609 whereas the block coefficient of an oil tanker would typically be about 0.9.

Aft of the engine room forward bulkhead (frame 88) the bottom structure and lower portion of the side shell up to the 4th deck (9620mm above base) changed to being transversely framed with plate floors spaced at 800mm **(Figure 14)**. There was an area of framing transition in the bottom structure aft of frame 88 where longitudinals from the cargo hold region continued aft for a short distance before termination or replacement by intercostal stiffeners.

Figure 14



Extract of shell expansion drawing

Additional structural changes occurring in way of the engine room and accommodation block included the reduction in thickness from 44mm to 36mm of the upper deck plate, the reduction in depth and thickness of the hatch coaming, and the discontinuation of wing tanks.

1.6.3 Material

Three grades of steel were used in the construction of the vessel's hull:

- Mild steel (Grade A) with a minimum yield stress[12] of 235 N/mm^2.
- High tensile steel (Grades AH/DH) with a minimum yield stress of 315 N/mm^2.
- High tensile steel (Grades AH36/EH36) with a minimum yield stress of 355 Nmm^2.

Grades AH/DH were generally used in areas of higher stress although AH36/EH36 was used to a very limited extent in some areas such as the hatch coaming. Mild steel was used in all other areas.

1.6.4 Bureau Veritas rules and calculations

The contract for the construction of *CGM Normandie* was signed on 12 December 1989, and her keel (hull No. 1082) was laid on 1 April 1991. The classification society used during the vessel's construction was Bureau Veritas (BV). The role of a classification society during a vessel's design and construction is to establish and apply the technical requirements detailed in the society's published rules. This is achieved by scrutiny of the design specification and by regular site survey and inspection throughout the building of a vessel. Certificates of classification are issued on delivery following successful plan approval and survey. Part II of the society's rules regarding hull structure applied during the vessel's design and construction, included:

> *"3-14.11. Scantlings*[13] *are given for the midship region and the end regions... In the intermediate regions, scantlings are to vary gradually from the midship region to the end regions."*

BV's rules also specified the buckling criteria which was to be used to assess hull scantlings, but these criteria were only applicable to 0.2L[14] either side of a vessel's midships (frames 102 to 232 on *MSC Napoli*) **(Figure 13)**. No buckling calculations were required to be undertaken in way of the engine room.

A report on the "3-D Stress Analysis of the Hold Structure" for *CGM Normandie* was produced by BV in 1990. The analysis covered the central cargo hold region (frames 156 to 202 in Nos. 4 and 5 holds); it did not consider the structure in way of the engine room. The scope of this analysis complied with the applicable BV rules at the time of build, which required direct calculation (i.e. Finite Element Analysis) of the primary members in the hold space. When the vessel's classification was changed from BV to DNV in 2002, a reassessment of the hull scantlings was not undertaken. Both societies

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[12] The yield strength or yield point of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible.

[13] Scantling refers to the collective dimensions of a vessel's framing and structural supports. The word is most often used in the plural to describe how much structural strength in the form of girders, I-beams, etc. is in a given section.

[14] 0.2L is the fraction of a vessel's length overall.

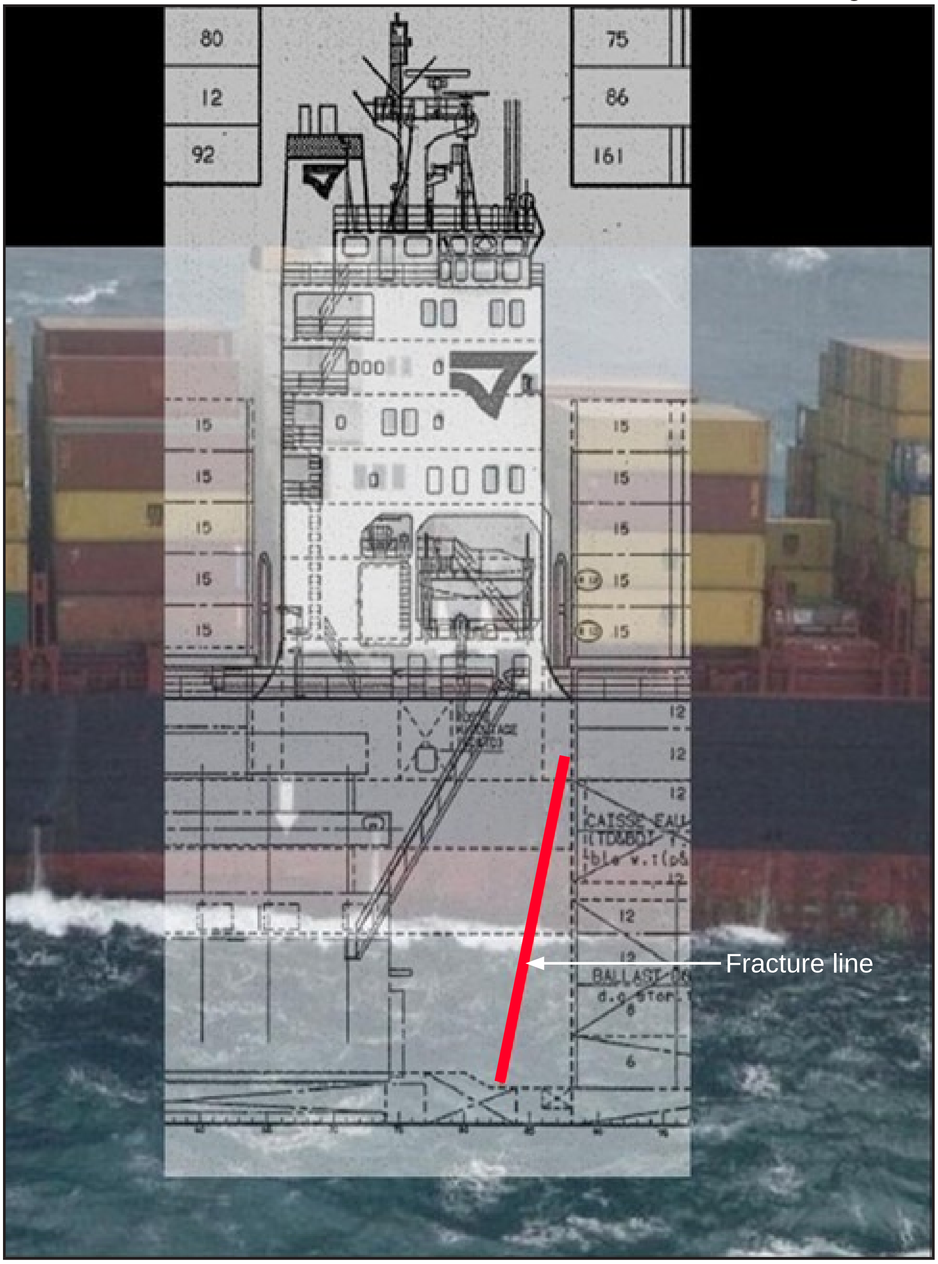
are members of the International Association of Classification Societies (IACS)[15] in which the rules of the member societies are mutually accepted. Therefore, DNV was not obliged to reassess *MSC Napoli's* hull scantlings against its own rules.

1.7 HULL CONDITION

1.7.1 Survey

The MAIB completed a number of internal and external surveys of *MSC Napoli* while she was beached at Branscombe Bay. Dive and on board surveys indicated that the hull fracture on the starboard side of the ship extended from the bottom hull plating at frame 82, upwards and forwards to frame 88 via the sea chest area **(Figure 15)**.

Figure 15



Path of fracture line established during dive surveys

15 Other classification societies which are members of IACS are: American Bureau of Shipping, China Class Society, Germanischer Lloyd, Lloyd's Register, Nippon Kaiji, Registrano Italiano, Russian Register and the South Korean Register.

There was no indication of any damage to the bow area, or the forward-most containers. Once the forward section of the hull had been detached and taken to the Harland and Wolff dry dock **(Figures 16-18)**, it was possible to perform a more detailed inspection of the fracture, which confirmed the earlier indications with respect to the path of the failure.

The inspections in Belfast were able to confirm that the vessel had been built in accordance with the ship's drawings. It was established that not all longitudinal girders in the double bottom were continuous in the area of the failure. While the port side girders were continuous, the centreline and starboard side girders were intercostal between floors. In addition, it was noted that there were fractures through the throats of fillet welds at the sites of discontinuous longitudinal girders, while the continuous girders had generally failed mid frame.

1.7.2 Material tests

Eighteen samples of steel were removed from the fracture path by the MAIB. A further three samples were removed from immediately forward of the fracture path on behalf of the vessel's charterers. All of the samples were sent to the Test House, Cambridge, for analysis. A summary report of this analysis is at **Annex C**. The Test House concluded:

> *"…the vessel's failure was not attributable to any identifiable material or metallurgical deficiencies or issues and that steel work was thought to have been in good order, in terms of freedom from both corrosion wastage and significant cracking, at the time of the casualty."* [sic]

Figure 16

Forward section of hull in Belfast dock

Figure 17

Localised plate buckling - port sea chest

Figure 18

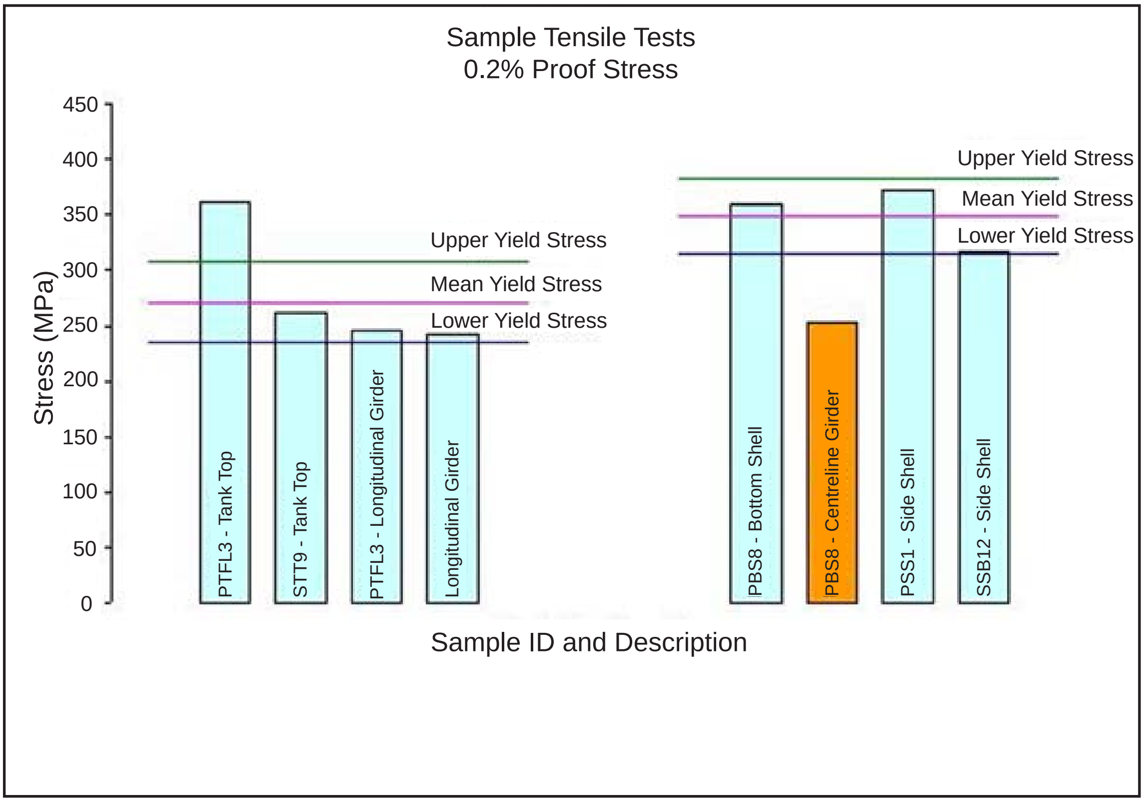
Starboard side hull collapse near lower sea chests

The main findings of the material tests on the 18 samples removed from the fracture path were:

- **Steel Grades**

  The grades of steel used in the construction were generally as specified in the vessel's drawings, or of higher grade **(Figure 19)**. The only sample that did not meet the required properties was the centreline girder, where mild steel (Grade A) was used instead of high tensile steel (AH32).

Figure 19



Comparison of tensile steel results with expected yield stress ranges

- **Weld sizes**

  A number of fillet welds were found to be marginally under the specified minimum size. However, the cross cruciform joint strength was found to be significantly stronger than expected from shipyard construction fillet welding and would have potentially negated any shortfalls in weld size.

- **Corrosion**

  Thickness measurements taken on the steel samples using a calibrated digital vernier indicated minimal corrosion of structure in way of the failure **(Table 1)**. The results support surveys conducted by BV and DNV during the service life of the vessel and visual observations during the hull inspection.

Table 1

Sample ID	Item	Measured Thickness (mm)	Specified Thickness (mm)	Diminution (mm)	Diminution (%)
PSS1	Lower Side Shell	17.6	18	0.4	2.2%
	Upper Side Shell	18.6	18	-0.6	-3.3%
PTF2	Transverse Floor	19.3	19	-0.3	-1.6%
PTFL3	Tank Top	19.7	19	-0.7	-3.7%
	Longitudinal Girder	20.0	19	-1	-5.3%
	Transverse Floor	19.4	19	-0.4	-2.1%
PTFL4	Transverse Floor	15.8	15	-0.8	-5.3%
	Longitudinal Girder	24.3	25	0.7	2.8%
	Tank Top	15.1	15	-0.1	-0.7%
CL5	Transverse Floor	14.1	15	0.9	6.0%
	Longitudinal Girder	15.0	15	0	0.0%
CLTT6	Tank Top	14.9	15	0.1	0.7%
STL7	Transverse Floor	14.7	15	0.3	2.0%
	Longitudinal Girder	24.7	25	0.3	1.2%
PBS8	Bottom Shell	18.1	18	-0.1	-0.6%
STT9	Tank Top Stbd Side	19.3	19	-0.3	-1.6%
	Tank Top Port Side	15.0	15	0	0.0%
SSB10	Bottom Shell	18.4	18	-0.4	-2.2%
STL11	Transverse Floor	15.1	15	-0.1	-0.7%
	Longitudinal Girder	19.2	19	-0.2	-1.1%
SSB12	Side Shell	18.0	18	0	0.0%
P13	Tank Top	19.0	19	0	0.0%
S14	Tank Top	19.1	19	-0.1	-0.5%
	Average			-0.1	-0.6%

Steel sample thickness measurements

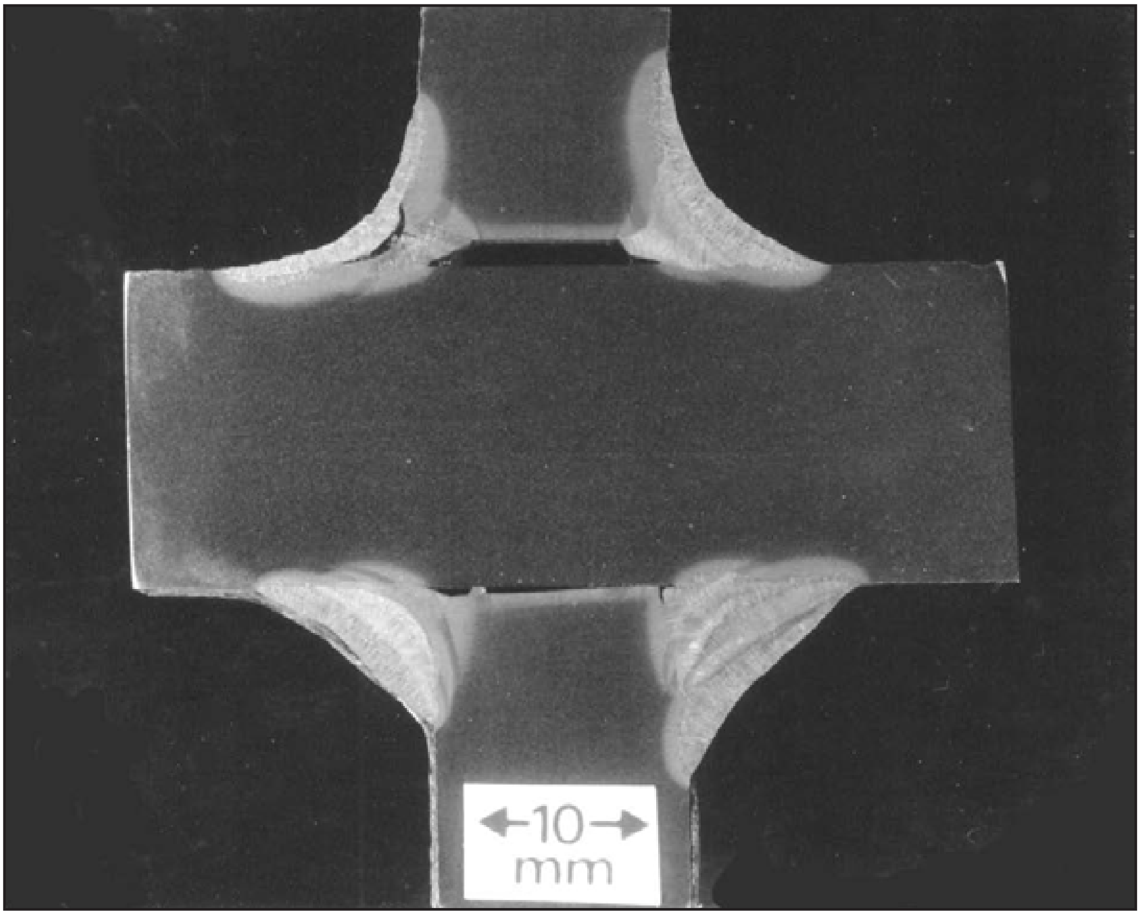
1.7.3 Post-build repairs to welds

Three of the steel samples showed evidence consistent with repairs or joint repositioning being completed when the ship was in service. One of these samples (STL11), which was taken from the connection between a transverse floor and longitudinal girder number 3 at 6050mm off the ship's centre line inside the starboard sea chest at frame 84 **(Figure 20)**, exhibited evidence that at least one of the four fillet welds forming the cruciform joint **(Figures 21 and 22)** had been repaired. With regard to this sample, the Test House report **(Annex C)** concluded "*Piece STL11 exhibited a fatigue crack that had initiated from a region of weld metal exhibiting pre-existing centre bead segregation, or liquation type hot cracking. The lower fatigue portion of the crack, by contrast, contained an in situ corrosion product consistent with its formation in a marine environment. Collectively, the evidence suggests that a solidification defect had been present in the throat of the original construction weld. The crack had grown by a mechanism of fatigue and had been open to the elements, during which time the lower crack regions had suffered corrosion. The crack had then been partly excavated and a capping weld run applied over the previously open and corroded crack*."

Figure 20

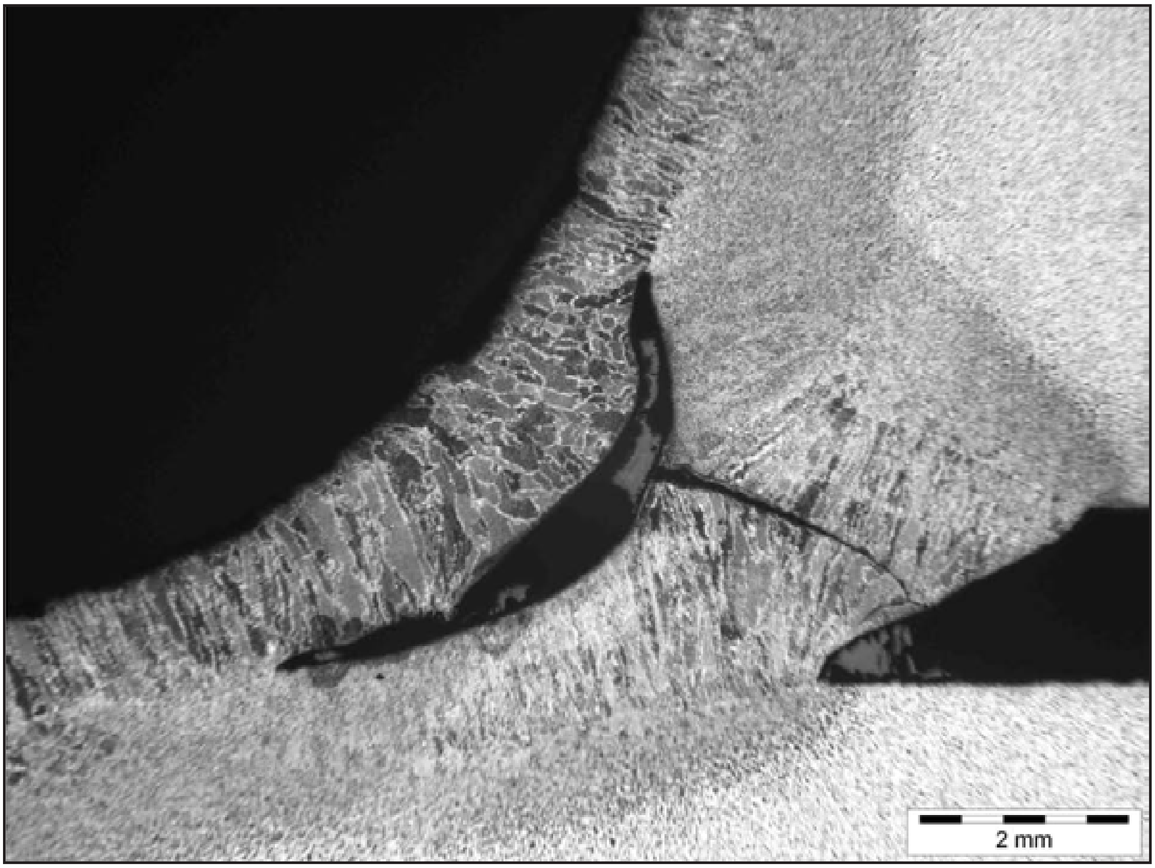
Transverse floor and longitudinal girder number 3 at 6050mm off centre line (including fillet weld connection) inside sea chest, frame number 84 starboard side prior to removal from the vessel

Figure 21



Macrophoto of specimen taken from sample removed from the sea chest showing weld repair

Figure 22



Macrograph of specimen taken from sample removed from the starboard sea chest showing detail of fatigue crack and repair

It was not possible from the metallurgical evidence available to determine when the repairs were conducted, and no record could be found of any welding repairs to the ship's main structural girders in way of her engine room.

1.7.4 Previous damage

During a routine dry docking in January 2001, the vessel's starboard side hull plating was indented following misalignment of the blocks. Permanent repairs were completed in March 2001. In April 2001 the vessel ran aground at full sea speed in the Malacca Straits **(Figure 23)**. Material damage was caused to the bottom plating and internal structures from the bow to frame 210 **(Figure 24)**. Cargo holds No. 1 to No. 4, the bulbous bow, the fore peak tank, No. 1 deep tank and the bow thrusters room were all flooded. The vessel was aground for 60 days while cargo was removed. She was then towed to Vietnam, where approximately 90m of the forward section of the vessel (bow to frame 212) from the keel to the summer load line (15m) was replaced. This required 3000 tonnes of steel.

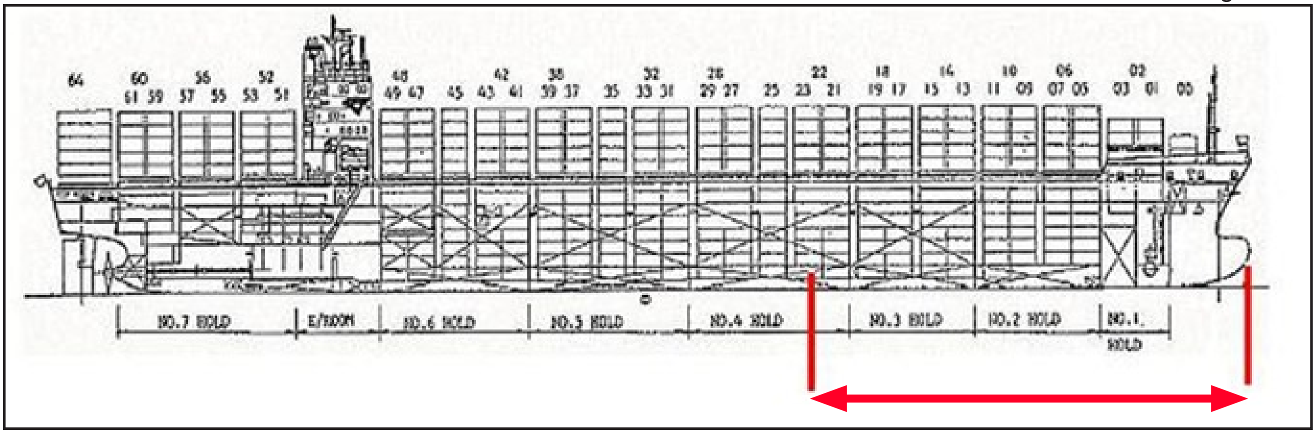
The ship returned to service in October 2001 but landed heavily onto a berth in Jeddah in December 2001, which resulted in fractures and indents to the port side of her hull in way of No. 4 and No. 5 fuel oil tanks. Following hull survey and provisional repairs, the ship was able to continue in service.

The vessel grounded again in August 2002 in Jeddah, but damage was limited to scoring of the underside hull coating.

Figure 23

MSC Napoli (formerly *CMA CGM Normandie*) aground in 2001

Figure 24



Extent of bottom damage

1.8 CLASSIFICATION RULE DEVELOPMENTS

Since *MSC Napoli* was built, IACS has updated its rules regarding structural requirements and the loads applied to a ship's hull. For steel ships greater than 90m in unrestricted service, the hull girder strength requirements have been common to all IACS members since 1992 (Unified Requirement S11[16] – Longitudinal Strength Standard). However, S11 only requires bending strength to be calculated for the 0.4L midships region; S11 specifies that bending strength outside this region may be determined at the discretion of the relevant classification society. S11 also specifies the requirements for the calculation of buckling strength of plate panels and longitudinals which are subject to hull girder bending and shear forces in the amidships region.

16 Subject to the ratification by the governing body of each member society, Unified Requirements are incorporated into the rules and practices of those societies. Unified Requirements are minimum requirements; each member society remains free to set more stringent requirements.

As computing power has developed, the degree to which structural designs for new buildings is analysed has also increased, albeit each classification society has, to date, set its own requirement in this area. For example, it is now quite usual for global strength to be assessed using a mathematical model of the entire hull, rather than the central cargo holds within the 0.4L range defined by S11. Similarly, most classification societies now routinely check the ability of the bottom shell and inner bottom plating to resist buckling forces at areas outside of the 0.4L range.

1.9 LOAD AND STRENGTH ASSESSMENTS

1.9.1 DNV

Following the loss of *MSC Napoli*, DNV conducted a load and strength assessment of the vessel's hull structure **(Annex D)**. The analysis comprised three main elements: hydrodynamic wave load analysis; global finite element (FE) analysis of the entire hull with a standard mesh model in the engine room region (frames 64 to 106), and; advanced non-linear stress and ultimate capacity analysis using a finer mesh between frames 79 and 92. The objective of the assessment was to provide a probable load range for the vertical bending moment and shear force in way of the forward engine room bulkhead (frame 88) and the corresponding structural hull capacity range.

To estimate the wave load range, two sets of environmental parameters (wave height, wave interval, vessel heading, vessel speed, water depth, wave spectra and wave spread) were used to give a 'high' and a 'low' case. Both cases were considered relevant to the conditions experienced. The resultant calculated load range was 3400MNm to 4300MNm.

The basis and main assumptions for the linear and non-linear FE models were: 'as built' dimensions of scantlings were used; no margins for corrosion were deducted; the model was constructed in accordance with the vessel's drawings, and; normal fabrication tolerances were represented by geometrical imperfections. A capacity range was achieved by using the lower and upper yield strengths of the three steel grades used in the vessel's construction. The resultant capacity range was 4200MNm to 4950MNm.

1.9.2 BV

In parallel, BV conducted a load and capacity assessment in way of *MSC Napoli*'s forward engine room bulkhead (frame 88) **(Annex E)**. Two sets of environmental parameters were used which were considered to be relevant to the conditions experienced. The resultant calculated load range was 3650MNm to 4170MNm. The society also calculated the total bending moment at frame 88 in accordance with the requirements of the current UR S11 to be 4220MNm.

The FE model developed by BV to determine the vessel's ultimate capacity at frame 88 incorporated frames 79 to 92 from the ship's bottom to the first deck of the accommodation on the port side only. Geometrical symmetry was assumed for the starboard side of the vessel. A capacity range was achieved by using the upper and lower yield strengths of two of the steel grades used in the vessel's construction. The highest grade of steel was not used due to its limited use in the area of failure. In this model, global collapse occurred between 4600MNm to 4700MNm.

1.10 SLAMMING AND HULL WHIPPING

Slamming occurs when a ship's hull impacts heavily with the water surface. There are two types of bow slamming: bottom slamming, where the ship's bottom emerges from the water and undergoes a severe impact on re-entry; and bow flare slamming, when the upper flared part of the bow is forced deeper into the wave. Stern slamming can also occur where there is large flare in the aft hull. Both bow and stern slamming give rise to a sudden vertical deceleration at the bow or stern, and lead to a flexural vibration of the hull girder, known as whipping.

A whipping event starts when a ship is in a sagged condition[17] and slams into a wave. The hull girder whipping response does not decay quickly and therefore contributes to a subsequent hogging bending moment. Whipping response on container ships has been monitored on actual ships and model tests. The results indicate that the additional wave load is typically between 10% and 50%. A 2D analysis of whipping effect included in the BV load assessment **(Annex E)** concluded that the effect increased wave bending moments for *MSC Napoli* by 30%.

The University of Southampton also assessed the possible contribution of whipping to the wave loading experienced by *MSC Napoli*. The university performed 2D hydroelasticity calculations to determine the bending moments and shear forces arising due to the vessel's movement into head seas. However, the university was only able to effectively model bottom slamming. The university's summary of its study is at **Annex F** and included:

> *Within the limitations of the 2D investigation carried out, the bending moment, shear force and stresses due to whipping are not considered significant enough to influence the structural failure in way of frames 82 and 88. However, during the investigations it was observed, with or without the inclusion of slamming, that the keel stresses in the vicinity of the aft quarter, namely frames 82 and 88, can be as large as the keel stresses amidships. This is an issue of concern to us, irrespective of the effects of whipping.*

Whipping was not included in the DNV analysis **(Annex D)** because it considered that the required software to analyse the effect has not yet been developed due to the complexity and unpredictable nature of the phenomenon.

In view of the highly technical and specialised requirements of this investigation, MAIB engaged the expertise of BMT SeaTech Ltd to provide an independent assessment of the various reports and analyses, and to assist with the analysis of the technical factors considered in **Section 2** of this report.

1.11 CONTAINER AUDIT

There is no requirement for containers to be weighed at a port in Europe prior to being loaded onto a vessel. The weight of each individual container is declared by the packer or shipper, and this declared weight is used until it reaches its final destination. All of *MSC Napoli*'s containers were weighed when they were removed from the vessel in Branscombe. Almost all the containers loaded below decks had been submerged below water due to internal flooding within the holds **(Figure 25)**, and their weights therefore differed significantly from the declared weights listed on the cargo manifests

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17 Sagging is the stress a ship's hull or keel is placed under when a wave is the same length as the ship and the ship is in the trough of two waves. This causes the middle of the ship to bend down slightly.

due to water absorption. About 660 containers stowed on deck, which had remained dry, were also weighed. The weights of 137 (20%) of these containers were more than 3 tonnes different from their declared weights. The largest single difference was 20 tonnes, and the total weight of the 137 containers was 312 tonnes heavier than on the cargo manifest.

During the removal of the containers, the positions of 700 containers on deck were compared with the positions recorded by the terminal operator (i.e. the positions entered into the loading computer to determine the stability condition). Of these units, 53 (7%) were in either the wrong position or declared as the wrong container. It is generally agreed within the container industry that up to 10% of containers loaded onto a vessel might not be in their planned positions.

Figure 25

Waterlogged containers in hold

1.12 CONTAINER SHIP INDUSTRY

1.12.1 Growth

The first ship to carry containers plied between Port Newark and Houston in the USA in 1956. The first international voyage of a container ship was in 1966 between Port Elizabeth, USA and Rotterdam, Netherlands. By the late 1960's, the container shipping industry had become established and grew exponentially throughout the 1970s and 1980s. By 1983 the world container industry transported the equivalent of 12 million

TEUs and continued to expand. Over the last 5 years, the volume of loaded containers shipped has grown on average 10% each year. Today, most of the world's manufactured goods are carried in containers, and the equivalent of about 141 million TEU was transported by sea in 2007.

1.12.2 Advantages

The growth of the container ship industry, and its pivotal role in the worldwide intermodal system of transportation, has been due to a number of advantages that containers and container ships have over more traditional methods of sea transportation. In particular, a modern container ship has a monthly capacity of between 3 and 6 times more than a conventional cargo ship. This is primarily due to transhipment times. On average it takes between 10 and 20 hours to unload 1000 TEUs compared to 70 and 100 hours for a similar quantity of bulk freight. As a consequence, typical port turnaround times have reduced significantly following the introduction of containerisation. In addition, container ships are on average 35% faster than conventional freight ships (19 knots versus 14 knots).

1.12.3 Container ship design

Historically, most vessel types such as general cargo ships and early tankers had engine rooms positioned amidships. However, as the length of vessels increased, the position of the engine room was moved to the aft end. This also required a corresponding increase in their longitudinal strength.

The design of container ships evolved in parallel with the growth of the container industry and liner services. The size of these ships also increased but, unlike many other ship types, they retained a slender hull form and were equipped with large engines to enable them to cover long distances at a fast speed. Due to the fine lines aft, the engine room on container ships was increasingly positioned further forward.

Towards the end of the 1980's, orders for ships of post-Panamax size of around 4000 TEU were placed with a number of shipyards. Today, the largest container ships have a capacity of about 12000 TEU, are over 400m in length and are typically powered by engines with power in excess of 100,000hp. The increase in size has been due to the economies of scale the larger vessels provide. A 5000 TEU container ship generally has operating costs per container 50% lower than a 2500 TEU vessel and the increase from 4000 TEU to 12000 TEU reduces the operating costs per container by about 20%.

1.12.4 World fleet

As of October 2007, the global fully cellular container vessel fleet stood at 4,178 vessels with more than 1400 on order. The average age of the world fleet was 11 years, but more than 1000 vessels were greater than 20 years old. No container ships were scrapped in 2005, and only 17 ships were scrapped between 2006 and 2007. The typical lifespan of a container ship is approximately 26 years.

Details of the world container ship fleet by TEU, and classification society are shown in **Table 2**.

Table 2

	<1000	1000 - 2000	2000 - 3000	3000 - 4000	4000 - 5000	5000 - 6000	6000 - 7000	7000 - 8000	8000 - 9000	9000 - 10000	10000 - 11000	11000 - 12000	12000 - 13000	13000 - 14000	14200	(blank)	Grand Total
American Bureau of Shipping	58	160	76	50	76	59	7	40	29				8			4	567
Biro Klass Indonesia	50	2														2	54
Bulgarski Koraben Registar	3																3
Bureau Veritas	62	87	37	18	18	27	8		13	4		15					289
China Class Society	104	42	10	9	16	13			5							5	204
China Corp Register	11	17	1	7	10	3											49
Det Norske Veritas	20	33	50	20	61	18			1							2	205
Germanischer Lloyd	555	749	443	179	164	108	63	16	78	40	1	3	16	8		1	2424
Hellenic Register	2																2
Indian Register	2																2
Korea Class Society	2	1															3
Lloyds Register	93	85	91	74	137	22	55	7	24	14	15					7	624
Nippon Kaiji	116	187	80	38	56	37	47		7	18							586
Registro taliano	6	6	17	5													34
Rinave Portugesa	1																1
Russian Register	23	5															28
South Korean Register	71	36	12		23	11	11		10								174
Turk Loydu	2																2
Vietnamese Register	3																3
(blank)	118	46	26	12	61	11	23		24		4		41	32	1	21	420
Grand Total	1302	1456	843	412	622	309	214	63	191	76	20	18	65	40	1	42	5674

Distribution of the world container fleet by capacity and classification society

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 SIMILAR ACCIDENTS

The only other recorded catastrophic failure of a container ship hull structure occurred in 1997. *MSC Carla* broke in half in the North Atlantic with 1600 containers on board. Although her forward section sank, her aft section was recovered. Inspection of the aft section indicated that the hull fracture had followed a welded seam joining a new section of hull which had been inserted after build to increase the vessel's length.

2.3 STRUCTURAL ANALYSES

The load and strength assessment conducted by DNV **(Annex D)** investigated the ultimate structural hull capacity using non-linear finite element modelling. The level of modelling undertaken was considerably more advanced than that typically performed during the structural design process, and was necessary to accurately represent the collapse of the hull.

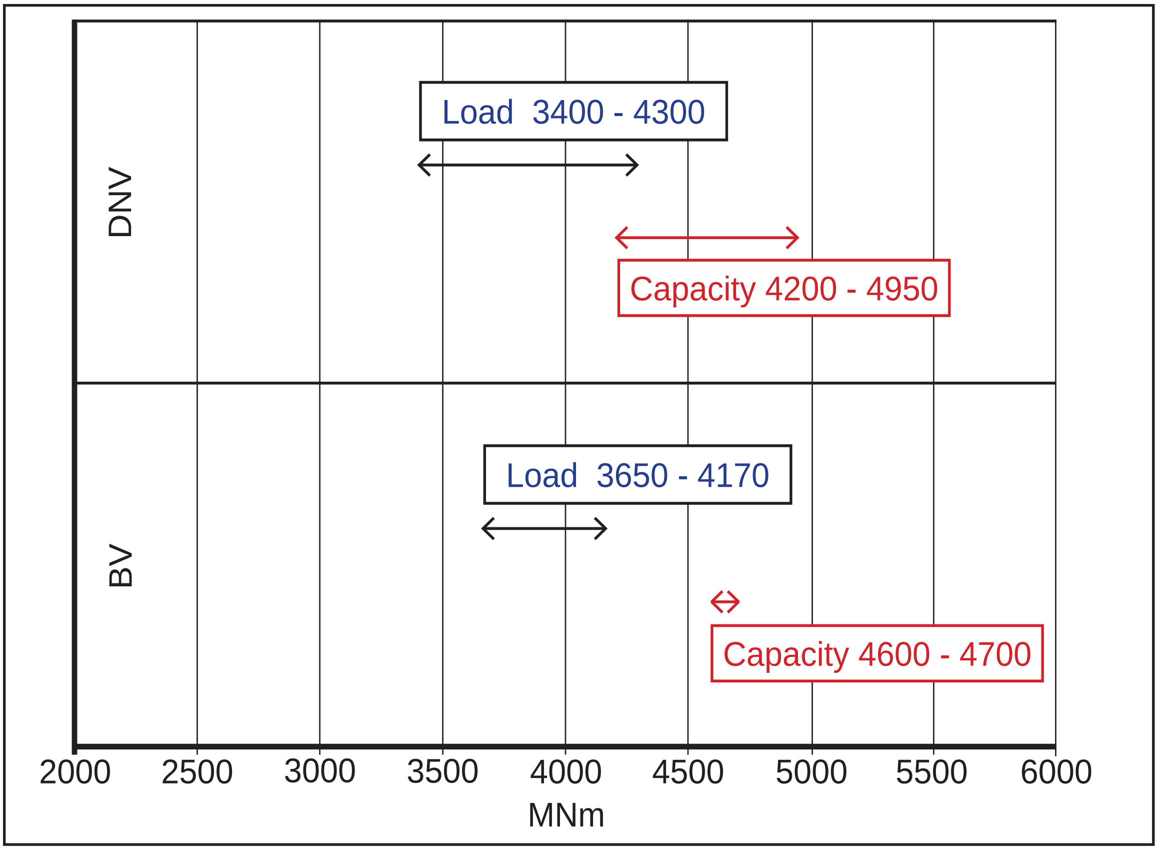
In view of the findings of the material tests **(paragraph 1.7.2 and Annex C)**, the assessment's use of as-built scantlings is considered to be valid. Its inclusion of small geometrical imperfections in the hull shell and tank top areas corresponding to normal fabrication and tolerance levels is also considered appropriate in order to accurately model the onset of collapse. Without these imperfections, the model would reflect an ideal structure with a capacity in excess of what would practically have been achievable.

The ultimate strength analysis undertaken by BV also used FE modelling, albeit on a smaller scale, but included some local detail not taken into account in the DNV model, which conversely included scattered geometrical imperfections not used in the BV model. Consequently, although the DNV and BV models simulated the path of the failure of the hull structure in way of frames 82 and 88 using similar, but not identical, wave loading parameters, the total load and capacity ranges of the two analyses differed to some extent **(Figure 26)**.

The DNV model indicates there was no margin between the maximum vertical bending moments experienced at the time of the failure and the design capacity of the hull structure. The BV analysis indicates the margin between the two values was about 430MNm. However, this margin was removed when whipping effect was taken into account.

To determine the factors which contributed to the failure of the hull structure, it is necessary to examine and compare the loads experienced at the time, to the maximum loads allowed for in the vessel's design and the ultimate capacity of the vessel.

Figure 26



Comparison of DNV and BV load and capacity assessments

2.4 LOADING

2.4.1 General

The loads acting on the hull of *MSC Napoli* at the time of the failure can be classified according to how they vary with time: static, slowly varying and rapidly varying. The static (or essentially static) loads were the 'still water' loads due to the weight of the hull, cargo and consumables, and the buoyancy. Slow varying loads included wave pressure loads on the hull due to the combination of wave encounter and resulting ship motion. Rapid varying loads can occur as a result of slamming, where the hull impacts severely with the water's surface.

2.4.2 Static loading condition

The still water loading condition applicable at the time of the hull failure produced a hogging bending moment at the engine room bulkhead (frame 88) of 2243MNm. This was 98.9% of the vessel's seagoing limit **(Figure 12)**. Shear forces and torsional moments were also within acceptable limits.

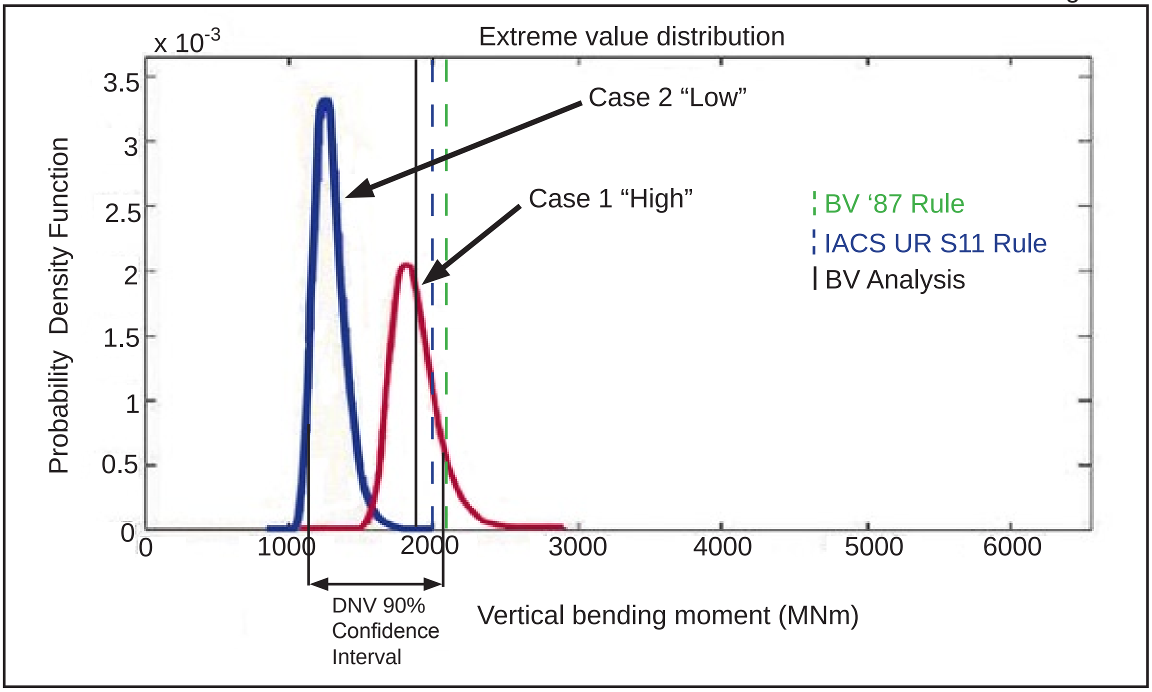
Although the discrepancies in the weight and distribution of the containers **(paragraph 1.11)** would have adversely affected the vessel's still water bending moment, particularly if the additional weight was concentrated towards the vessel's bow and stern, there were insufficient dry containers to establish the likely deviation in still water bending moment with any confidence. However, the additional weight carried probably equated to the vessel's deadload, and the resulting deviation to the still water bending moment would have been extremely small in comparison to the potential variability of the wave loading. Therefore, the effect of the discrepancies alone would have been insufficient to cause hull failure. Nevertheless, they would have contributed to the reduction of the safety margin available.

2.4.3 Wave loading

Assessing the sea conditions at the time of the accident is subject to considerable uncertainty. As part of its load and strength assessment, DNV consulted a variety of sources to identify the range of possible sea conditions experienced by the vessel on 18 January 2007. The parameters used to model the wave loading such as the significant wave heights, wave spectra, wave lengths and water depth were selected to replicate the actual conditions experienced. These parameters have been reviewed separately by BMT SeaTech, which has concluded they are the most accurate possible in the absence of definitive information on the actual conditions.

A comparison of the "high" and "low" wave loading cases used by DNV, the load range calculated by BV, the wave bending moments at frame 88 calculated in accordance with the BV rules applicable at the time of build (10^{-8} probability level), and the current IACS UR S11 requirement is shown at **Figure 27**. Although this comparison is simplistic and the results cannot be considered in isolation, it does indicate that the ''high" DNV case and the upper end of the BV range were very close to the design bending moment required by the society's rule and the current IACS requirement. However, although the vertical wave bending moment acting on the hull at the time of the accident was potentially very high, it was unlikely to have appreciably exceeded either of the design values. Therefore, the waves encountered were within the bounds of normal wave theory; they were not freak waves.

Figure 27



Comparison of wave bending moments

2.4.4 Slamming and hull whipping

It is likely that the hull of *MSC Napoli* was subjected to additional load due to whipping. First, the vessel impacted with several large waves immediately before the failure of her hull. Second, she was built with moderately large bow and stern flare angles. Finally, empirical data indicates that whipping effect can typically increase wave bending moments on container ships from between 10% and 50%. Any increase in the wave bending moment above the normal design level would inevitably erode the margin between loading and hull strength.

However, from the different results obtained from the 2D analyses conducted by BV, which calculated a 30% increase in wave loading, and by Southampton University, which concluded that the increase in wave loading was not significant, it is apparent that whipping effect is currently very difficult to reliably calculate or model. Classification societies are therefore unable to predict its magnitude or effect on a ship's structure, with any confidence, and as a consequence they are not generally calculated during the structural design process.

In view of the potential increase in wave loading due to whipping effect, further research is required by classification societies to ensure that the effect is adequately accounted for in ship design and structural analyses, and that sufficient allowance is made for the effect when determining design margins.

2.5 VESSEL CAPACITY (STRENGTH)

2.5.1 Keel section modulus[18] distribution

As detailed in **paragraph 1.6.2** the structural framing of *MSC Napoli* changed significantly between the cargo hold section and the engine room. This, and other factors such as the reduction in depth of the hatch coaming and the discontinuation of the wing tanks, combined to reduce the strength of the hull in this region. This reduction in strength is demonstrated by the longitudinal distribution of the keel section modulus in **Figure 28**. It is recognised that this figure is simplistic in that it does not accurately represent the continuity of the longitudinal structural members along the vessel's entire length. However, it is considered to be accurate within the region between the area of failure and amidships.

2.5.2 Buckling strength requirement

At the time *MSC Napoli* was built, her fine lines and resulting low block coefficient required her engine room to be further forward than most of the other ships being built at that time. However, because it was outside of the 0.4L amidships area, the applicable classification society rules did not require the buckling strength of the hull in this area to be checked. As a result, no calculations were made by either the ship builder or BV.

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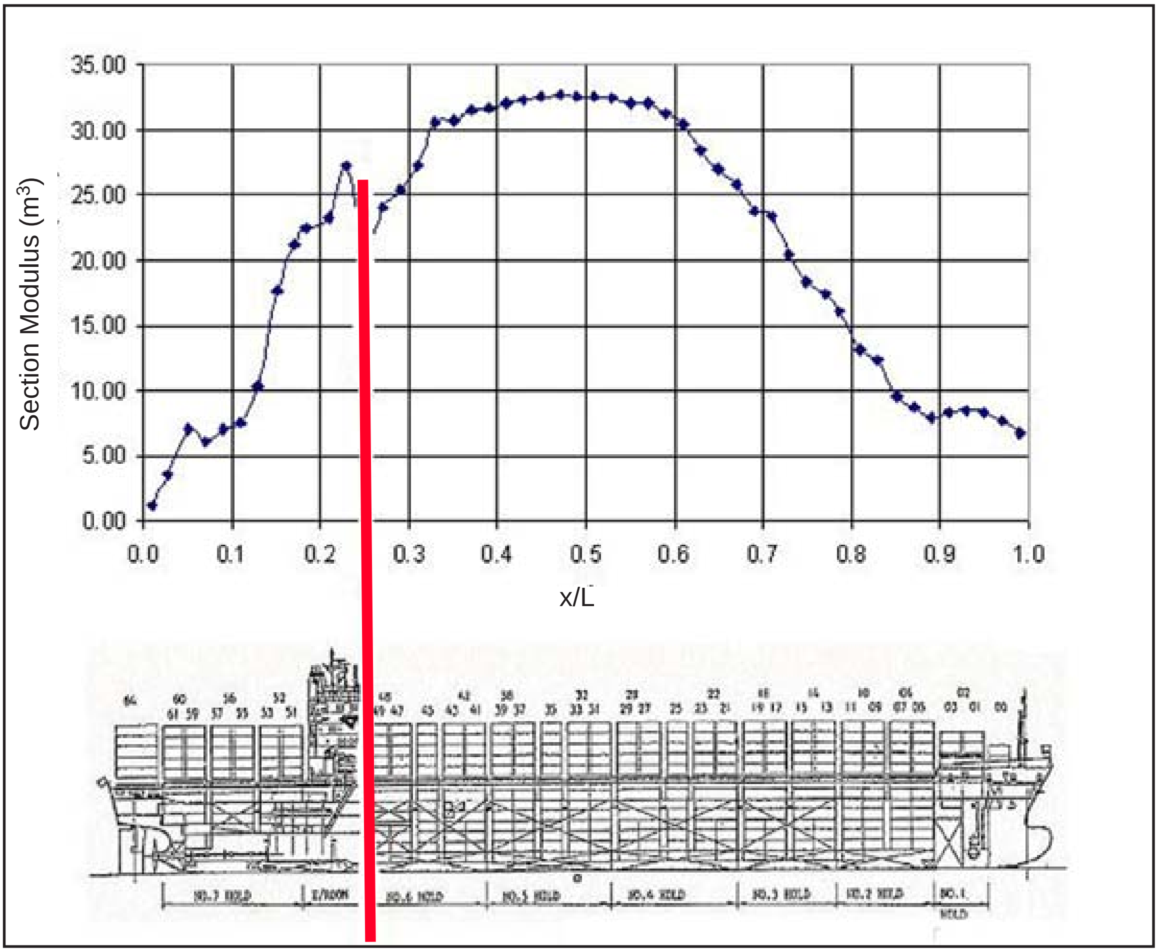
[18] Section modulus is a measure of the relative strength (and resistance to bending) of a structural element, dependent on its cross sectional shape, thickness and orientation). In simple terms, it indicates the bending strength of a ship's hull.

Figure 28



Keel section modulus

For a ship structure that maintains the same structural configuration over the majority of its length, the requirement to vary scantlings gradually from the amidships region to the end regions will give a gradual reduction in buckling strength outside the amidships region. This reduction in strength complements the usual reduction in global bending loads outside the amidships region. However, this assumption was not valid on *MSC Napoli* where there was a change in structural configuration from longitudinal framing amidships to transverse framing in the engine room where the hull stresses were almost as great as at her amidships region. The transverse framing in the engine room of *MSC Napoli* was an inherently weak structure under compressive loading.

2.5.3 Buckling strength assessment

The DNV assessment identified the mode of failure on the hull structure of *MSC Napoli* as a localised plate buckling. The failure mechanism started as elastic buckling of the hull shell plating in the bilge area in way of frames 82 to 88, which progressed into the bottom, double bottom and up into the ship's side. This path is consistent with the damage observed during inspection of the vessel's forward section in Belfast **(Figure 16)**.

To assess the buckling strength of the hull in the engine room, BMT SeaTech used the formulas specified in the 1987 BV rules (Part II, Chapter 3, Section 3-7), and also the current IACS Unified Requirement S11 (rev.5). It is acknowledged that the BV buckling criteria applied only to the amidships region and were intended for regular flat panels and not for complex box and curved structure, which are inherently more resistant to buckling, such as between frames 80 and 85. The UR S11 requirements for the assessment of buckling strength apply only to plate panels and longitudinals subject to hull girder stresses in the 0.4L amidships region. UR S11 was not applicable at the time of the *MSC Napoli*'s design and construction.

The buckling strength calculations undertaken by BMT SeaTech **(Annex G)** are summarised in **Table 3**. The results are presented in terms of 'utilisation', which indicates how much of the panels' buckling capacity has been used To meet the buckling criteria, the utilisation should be less than 1.

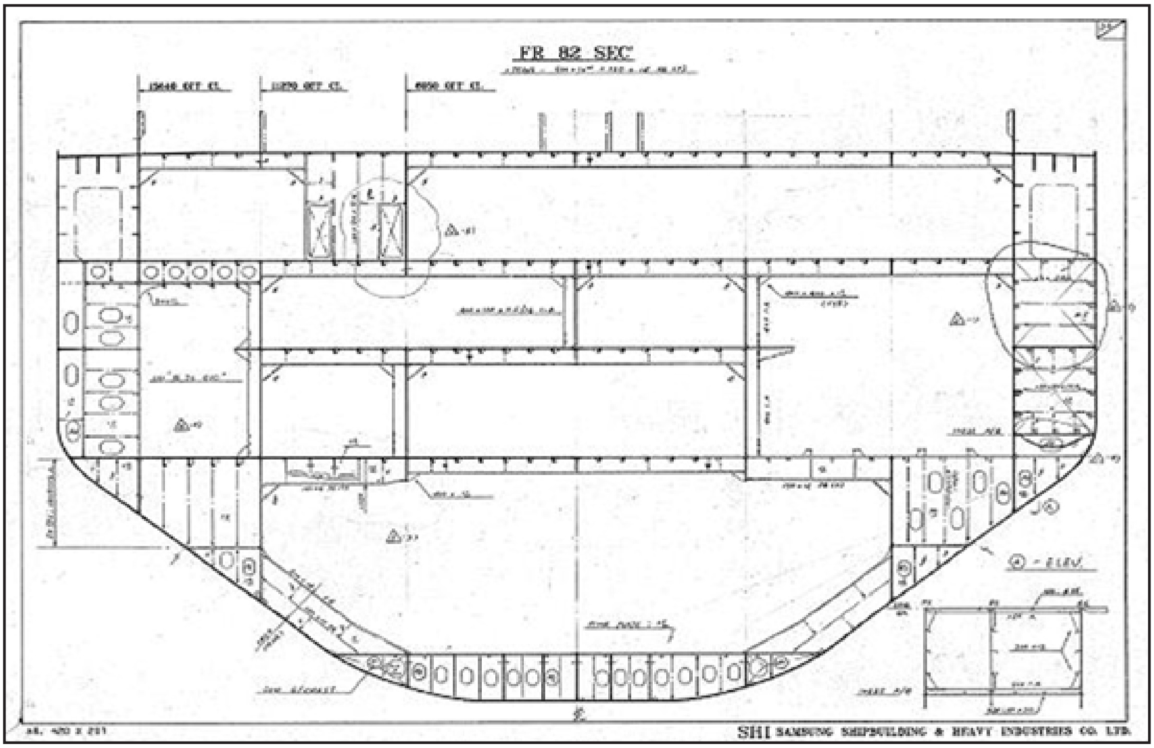
Table 3

Item	Utilisation	
	BV Rules (1987)	**IACS URS11**
Bottom Shell – between CL girder and girder 1210 off CL	*1.1*	*1.0*
Bottom Shell – between girders 1210 and 2605 off CL	*0.8*	*0.8*
Bottom Shell – between girders 2605 and 6050 off CL	*1.4*	*1.2*
Bottom Shell – between girder 6050 off CL and tank top	*1.5*	*1.3*
Side Shell – between tank top and bhd 11270 off CL	*1.2*	*1.0*
Tank Top – between CL girder and girder 1210 off CL	*1.3*	*1.1*
Tank Top – between girders 1210 and 2605 off CL	*0.9*	*0.9*
Tank Top – between girders 2605 and 6050 off CL	*1.7*	*1.5*
Tank Top – between girders 6050 off CL and side shell	*1.1*	*1.0*

Summary of buckling strength checks conducted by BMT SeaTech

Similar results were obtained for the two sets of rules. A number of panels in the tank top, bottom and lower side structure in the region of frame 82 were found to be deficient **(Figure 29)**. Other panels, although passing the buckling checks, were close to the buckling criteria. Consequently, it is likely that when the vessel's hull girder strength was reduced due to the buckling of the weaker panels, the remaining structure had insufficient margin to withstand the increased load. This failure mechanism is consistent with the failure mechanism identified in the FE analyses.

Figure 29



Frame 82

2.5.4 Hull construction and condition

2.5.4.1 Materials

The strength of the hull of *MSC Napoli* at the time of its failure would have been dependent on whether the hull was constructed in accordance with the design drawings and any deterioration over the lifetime of the ship. The material tests conducted on the 18 samples removed from the fracture path identified a number of minor deficiencies, which are not considered to have adversely affected the strength of the hull.

In particular, the centreline girder was made of mild steel (A) rather than high tensile steel (AH32) and its yield strength was therefore inadequate. However, as its ultimate tensile strength met the requirements of AH32, it is considered that its use would not lead to a significant reduction in the ultimate collapse moment of the hull girder.

A number of weld sizes were also marginally under size and a number of fractures through fillet welds were evident. However, structural analysis of the hull indicates that the longitudinal girders had a higher buckling strength relative to the tank top and shell plates. Therefore, it is highly probable that the girders failed as a result of being placed under additional load following the initial buckling of bottom and tank top plating, irrespective of their continuity and weld sizes. Consequently, the presence of fractures through the fillet welds at sites of discontinuous longitudinal girders is not surprising.

2.5.4.2 Weld repairs

In its conclusions, the Test House stated "*The apparent widespread evidence of local repair welding, some of which was clearly and demonstrably post build, would suggest that there had been earlier local structural integrity problems and issues in respect of fillet weld integrity in particular*." [sic]

Fatigue cracking and welding repairs are not unusual in a vessel of *MSC Napoli*'s age, and the repair of fatigue cracks and welds by on board fitters or riding gangs is a common practice. However, given the location of the sample removed from the starboard sea chest, this repair could only have been undertaken with the provision of an external cofferdam or when the vessel was in a dry dock. No record exists to indicate when these repairs were undertaken, and they were not reported to either of the vessel's classification societies.

Although it is a requirement to report structural damage including fatigue cracks to classification societies, it is possible that this requirement is not fully understood. It is also possible that, due to the incidence of fatigue cracking, and hence the need for weld repairs on board container ships, it is occasionally overlooked. Such reporting affords the opportunity for underlying problems to be investigated, and for permanent remedial action to be taken. In this instance, the fatigue cracking and weld re-positioning identified after the vessel entered service was possibly indicative of a local design issue but did not contribute to the vessel's structural failure. However, a failure to report structural damage could result in an opportunity missed for a design problem to be investigated and permanently rectified.

2.5.4.3 Previous accidents

There is no evidence to indicate that the strength of the hull structure in way of the engine room had been reduced as a result of the damage sustained by *MSC Napoli* in previous accidents, particularly the vessel's grounding in 2001 **(paragraph 1.7.4)**.

2.6 IACS – UNIFIED REQUIREMENTS

It has been identified that the hull structure of *MSC Napoli* failed due to a lack of buckling strength in the engine room region. At the time of build, no buckling checks were required by the applicable rules, and none were made. However, as the current requirements specified in UR S11 leaves buckling checks outside the 0.4L amidships region to the discretion of individual classification societies, there is a possibility that even if *MSC Napoli* had been built after 1992, the lack of buckling strength in way of her engine room would still not have been identified. Importantly, it is highly probable that there are a number of other container ships of a similar design to *MSC Napoli* which are also vulnerable to localised buckling in severe conditions. It is essential that such designs are quickly identified and remedial action is taken where necessary.

It is apparent that UR S11 has lagged behind the development of container ship design and operation and requires immediate revision. The failure to the hull of *MSC Napoli* highlights that buckling strength checks must be based on global hull stresses along the entire length of the hull, and not limited to the 0.4L amidships, or left to the discretion of individual societies. The use of common methodologies in this respect would also provide greater assurance that the strength of all new build container ships is being adequately addressed.

The load and capacity assessments conducted by DNV and BV **(Figure 26)** show that, in the case of *MSC Napoli,* the design margin of safety was either insufficient when whipping is taken into account (BV), or non-existent (DNV). The analyses are supported by the fact that the vessel broke her back when within her seagoing limitations and, although the conditions were severe and had a low probability of occurrence, they were nevertheless equivalent to the current UR S11 design value.

Although it is implicit in UR S11 that the design of a ship ensures that her ultimate strength is in excess of the maximum loads expected, the scope of the excess or safety margin is not defined. In practice, it is generally based upon a classification society's experience, and does not explicitly take into account factors which increase bending moments such as whipping, or other variables such as inaccuracies in container weights and distribution. Given the importance of the design safety margin in ensuring an acceptable level of safety, a more methodical and objective approach is warranted.

2.7 IMMEDIATE ACTION TAKEN TO IDENTIFY SHIPS VULNERABLE TO LOCALISED BUCKLING

Following its structural analysis of the hull failure of *MSC Napoli*, DNV, at the request of the MAIB and in co-operation with LR developed a two-stage methodology to identify other container ships which were potentially vulnerable to localised buckling in severe conditions.

As soon as a methodology had been determined, the Chief Inspector of Marine Accidents wrote to the Chief Executives of the IACS member societies and the China Corporation Register to inform them of the circumstances of the hull failure of *MSC Napoli*, and his concern that other container ships might also be vulnerable to localised buckling in severe conditions. Societies were advised of the methodology developed by DNV and LR to identify such vessels, and were requested that each society use the methodology (or similar) to screen its vessels, focussing on vessels of 2500 TEU and greater, with two or more cargo bays aft of their accommodation/engine room.

As a result of the screening process, which involved over 1500 container ships, at the time of the publication of this report: 12 vessels were identified as potentially having insufficient buckling strength in severe conditions and requiring remedial action; a further 10 vessels were identified as being borderline and require more detailed investigation; and the screening of 8 container ships was still in progress.

2.8 VESSEL OPERATION

2.8.1 Speed and heading in heavy weather

Despite the progressively worsening weather conditions during the morning of 18 January, with the ship 'pounding heavily' into the sea, the vessel's course and speed were considered at the time to be appropriate and in keeping with the ship manager's instructions. Engine speed had been reduced overnight from 82rpm to 71rpm, but this had been prompted by difficulty in controlling the main engine, rather than the risk of damage to the forward part of the vessel or her containers. The DNV load and strength assessment of *MSC Napoli* found that variations in the speed of the vessel in the modelled sea conditions significantly changed the vertical wave bending moment experienced. Its analysis determined that a variation of 5kts on the vessel's average speed changed the wave load by approximately 10% (lower speeds giving lower bending moments). Similarly, variations in the ship's speed would have had a significant effect on the occurrence and magnitude of slamming and whipping, with higher loads at higher speeds. Therefore, it is almost certain that a reduction of speed would have significantly reduced the risk of hull failure.

As *MSC Napoli* was making good 11kts over the ground when the structural failure of her hull occurred, there was ample scope to reduce speed further and still maintain steerage.

The DNV study indicated that changes to the ship's heading relative to the waves between 0º and 15º had negligible effect on the vertical bending moment. While in larger alterations away from the sea, torsional effects might become more pronounced, adjustment of course is nevertheless an important tool in reducing stresses in heavy weather.

A number of accidents to large tankers and bulk carriers some years ago, resulted from structural failure. These prompted the use of hull stress monitoring equipment on such vessels to determine the hull stresses experienced and to assist the masters of these vessel types to identify when such stresses reached a given threshold. Such monitoring also ultimately led to significant changes to the design of bulk carriers and tankers.

The container industry has utilised guidance systems to reduce the prevalence of bow damage and container loss due to heavy weather. However, given the importance of speed with regard to wave loading and whipping effect and the failure of the hull of *MSC Napoli*, it is evident that the absence of damage to a vessel's bow or containers is not always an accurate indicator of the appropriateness of a vessel's speed. Consequently, research into the potential benefits of hull stress monitoring and/or vessel motion sensing should be considered.

2.8.2 Operation of the main engine without a governor

An electronic main engine governor facilitates the direct control of an engine from the bridge or the engine control room. It also prevents a main engine from over-speeding and tripping when the propeller emerges from the sea in heavy weather. Both of these functions are important factors in a vessel's safe operation and, given the weather and sea conditions forecast in the English Channel, the decision to sail from Antwerp without an operational governor was questionable.

The chief engineer and technical superintendent were aware that control of the engine was only possible from the engine's side. The control of the engine from this position is an emergency mode; the expectation that watch officers would maintain this mode of operation continuously, standing next to the main engine for the entire passage to Sines, in the expected sea conditions was unrealistic.

The ship manager was obliged to inform the vessel's classification society, DNV, of failures to critical machinery on board its vessel. In this case, it is debatable whether or not the main engine governor was critical to the safe operation of the vessel. However, had the ship manager erred on the side of caution, and at least discussed the status of the defect with the classification society, this might have allowed a more informed consideration of its consequences when deciding if the vessel was in a fit material state to sail from Antwerp.

Given the potentially adverse effect on the vessel's manoeuvrability in restricted waters, the pilot should have been informed of the governor situation.

2.8.3 Departure and arrival hull loading conditions

In Antwerp, *MSC Napoli*'s trim was adjusted to allow the vessel to sail from her berth at any state of the tide. To achieve this, the vessel was ballasted to produce a maximum draught aft of 13 metres. However, this meant that, in her departure condition, the vessel's seagoing maximum bending moments were exceeded. The draught of the vessel had been similarly adjusted at Felixstowe, again resulting in her exceeding her seagoing maxima for bending moments. On both occasions, *MSC Napoli* was within the maxima for harbour bending moments and, after clearing the locks at Antwerp, the vessel was reballasted during the transit of the River Schelde to bring her bending moments to within the maximum seagoing limit.

It is recognised that the harbour bending moment maxima is often applied in sheltered or enclosed waters. However, the practice of routinely sailing from berths on stresses in excess of the seagoing maxima was potentially detrimental to the safety of the vessel. First, altering the draught of *MSC Napoli* when navigating in restricted waters, was inherently dangerous, particularly as the pilot was not kept informed. Second, conducting ballasting operations during periods of standby could have been distracting, and slack ballast tanks could have adversely affected vessel stability. Finally, the overstressed condition of the vessel could have made the consequences of an accident, particularly grounding, considerably worse.

Data from the ship's onboard loading computer, experience from other investigations to container ships, and anecdotal evidence from other ships' crews indicate that the practice of arriving and departing from berths with ship stresses in excess of permissible seagoing maxima is commonplace within the container ship industry. It is known that some vessels remain above the maximum seagoing limit when in open water, particularly when the distance between terminals is short.

2.9 WEIGHT OF CONTAINERS

The audit of the containers removed from *MSC Napoli* and the deadload calculated on departure, indicate that the declared weights of many of the containers carried by the vessel were inaccurate. This discrepancy is widespread within the container ship industry and is due to many packers and shippers not having the facilities to weigh containers on their premises. It is also due to shippers deliberately under-declaring containers' weights in order to: minimise import taxes calculated on cargo weight; allow the over-loading of containers; and to keep the declared weight within limits imposed by road or rail transportation.

In view of the fact that container ships invariably sail very close to the permissible seagoing maximum bending moments, the additional undeclared weight has the potential to cause vessels to exceed these maxima. Container shipping is the only sector of the industry in which the weight of a cargo is not known. If the stresses acting on container ships are to be accurately controlled, it is essential that containers are weighed before embarkation.

2.10 CONTAINER SHIP INDUSTRY

2.10.1 Environment and culture

Container ships are a key link within the worldwide transportation system, and their numbers and size have increased rapidly over the last 40 years. Without the ability to quickly ship large quantities of containers across the oceans, containerisation would generally be constrained within the continents. However, the commercial advantages of containerisation and intermodalism such as speed and quick turnarounds appear to have become the focus of the industry at the expense of the safe operation of its vessels. The industry is very schedule driven, and operators inevitably have an eye on the timetable when making key decisions.

In this case, the decisions to: sail without an operational governor; sail in excess of the maximum permissible seagoing bending moments in order to allow greater flexibility for the time of departure; to operate at near maximum bending moments when underway; and to keep the ship's speed as fast as possible when pounding into heavy seas, were symptomatic of the industry's ethos to carry as much as possible as quickly as possible. However, although these decisions were undoubtedly made in the belief that the ship was operating within acceptable limits, this investigation has shown that unknown variables such as whipping effect and container weights are able to erode or eliminate the safety margins in place.

No ship is unbreakable. Classification societies apply structural strength limitations which are contingent on the application of good seamanship and prudent operational practice. It has been apparent during the course of this investigation that these caveats are not widely recognised by many in the container ship industry. Unlike other large vessels such as bulk carriers, which can frequently disregard the effect of the sea, due to their lines and limited engine power, container ships cannot. It is essential that companies recognise this difference and put in place controls and procedures to ensure that container ships operate within safe limits at all times.

2.10.2 Industry code of best practice

In its report on the investigation of the collapse of cargo containers on *Annabella*, which was published in September 2007, the MAIB noted:

> *Unlike in other sectors of the international shipping industry, there is currently no dedicated trade organisation which routinely provides guidance on best practice for the container industry. Working practices relating to the planning, loading, transportation and discharge of containers are largely unregulated and have been understandably focussed on the need to maximise efficiency and speed of operation. While key industry players will attest that safety is of paramount concern, evidence obtained during this and other MAIB investigations into container shipping accidents suggests that in reality, the safety of ships, crews and the environment is being compromised by the overriding desire to maintain established schedules or optimise port turn round times.*

The report identified that there was a clear need for an Industry Code of best practice. As a result, the following recommendation was made to the International Chamber of Shipping (ICS):

Work with industry to develop, then promote adherence to, a best practice safety code to ensure that (inter alia):

- Effective communications and procedures exist between all parties involved in the planning and delivery of containers to ensure ship's staff have the resources and the opportunity to safely oversee the loading and securing of cargo.
- Cargo securing manuals are comprehensive and in a format which provides ready and easy access to all relevant cargo loading and securing information.

- Loading computer programmes incorporate the full requirements of a vessel's cargo securing manual. Such computers should be properly approved to ensure that officers can place full reliance on the information provided.
- The availability or otherwise of a reliable, approved, loading computer programme is a factor to be included in determining an appropriate level of manning for vessels on intensive schedules.
- The resultant increase in acceleration forces and consequent reduction in allowable stack weights when a vessel's GM is increased above the value quoted in the cargo securing manual is clearly understood by vessels' officers. The consequential effect on container stack weight, height and lashing arrangement for changes in the vessel's GM should be readily available and clearly displayed to ships' staff.
- Those involved in container operations are aware that containers with allowable stack weights below the ISO standard are in regular use and must be clearly identified at both the planning and loading stages to avoid the possibility of such containers being crushed.
- With respect to cargo planning operations:
    - cargo planners have appropriate marine experience or undergo training to ensure ship safety considerations are fully recognised,
    - cargo planning software provided is able to recognise and alert planners to the consequences of variable data e.g. GM, non standard container specifications,
    - lessons learned from problems identified during container planning operations are formally reviewed and appropriate corrective measures put in place,
    - ships' staff are provided with sufficient time to verify/approve proposed cargo plans.

2.11 ABANDONMENT

The abandonment of a vessel in any conditions is problematic. Therefore, the abandonment and successful recovery of the 26 crew from *MSC Napoli,* in the severe conditions experienced, is praiseworthy. By the time the master arrived at the lifeboat embarkation position, the crew were on board and wearing immersion suits and lifejackets, the engine was running, extra water had been stowed on board, and VHF radios, SARTs and the EPIRB were ready for use. Despite the vessel rolling heavily, the enclosed lifeboat was lowered without incident and then manoeuvred clear of the stricken vessel. Although there were a number of practical issues that should be noted, this successful abandonment clearly demonstrates the importance and value of regular maintenance and drills.

SECTION 3 – CONCLUSIONS

3.1 SAFETY ISSUES CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. The effect of the discrepancies in the declared weights of the containers would not have been sufficient to cause hull failure, but it would have contributed to the reduction of the safety margin between the total bending moment experienced and the strength of the hull. [2.4.2]

2. Although it is likely that the wave loading experienced by *MSC Napoli* was increased by whipping effect, classification societies are unable to predict its magnitude or effect on a ship's structure with any confidence. [2.4.4]

3. In view of the potential increase in wave loading due to whipping effect, further research is required within the industry to ensure that the effect is adequately covered by ship design and structural analyses, and that sufficient allowance is made for the effect when determining a design margin. [2.4.4]

4. As the area of the hull which failed was outside of the 0.4L amidships area, the applicable classification society rules did not require the buckling strength of the hull in this area to be checked. Therefore the buckling strength of the hull in way of the engine room was not calculated by either the ship builder or BV. [2.5.2]

5. The transverse framing in the engine room of *MSC Napoli* was an inherently weak structure when under compressive loading. [2.5.3]

6. It is apparent that UR S11 has lagged behind the development of container ship design and operation, and requires immediate revision. Buckling checks must be based on global hull stresses along the entire length of the hull and not left to the discretion of individual societies. The use of common methodologies in this respect would provide greater assurance that the strength of all new build container ships is being adequately addressed. [2.6]

7. In view of the importance of the design safety margin in ensuring an acceptable level of safety, a more objective approach is warranted. [2.6]

8. Given the importance of speed with regard to wave loading and whipping effect, research into the provision of hull stress monitoring and/or vessel motion sensing on container ships should be considered. [2.8.1]

9. Although the vessel's speed was considered to be appropriate in the conditions experienced, it is almost certain that a reduction of speed would have significantly reduced the risk of hull failure. [2.8.1]

10. The stresses acting upon a container ships hull cannot be accurately controlled unless containers are weighed before embarkation. [2.9]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

11. It is possible that the requirement to report structural damage, including fatigue cracking and weld repairs on main structural members, to classification societies is either not fully understood or is occasionally overlooked. [2.5.4.2]

12. Although it is debatable whether or not the defect to the main engine governor was critical to the safe operation of the vessel, had the ship manager discussed the status of the defect with the classification society, this might have allowed a more informed consideration of its consequences when deciding if the vessel was in a fit material state to sail from Antwerp. [2.8.2]

13. Despite the potentially adverse effect on the manoeuvrability of the vessel in restricted waters, the pilot was not informed of the defect to the main engine governor. [2.8.2]

14. The practice of arriving and departing from berths, in a loaded condition that was in excess of permissible seagoing maxima, was potentially detrimental to safety but is commonplace within the container ship industry. [2.8.3]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

15. As a result of the screening of over 1500 container ships by their respective classification societies, 12 vessels were identified as being potentially vulnerable to localised buckling in severe conditions and requiring remedial action. [2.7]

16. The commercial advantages of containerisation and intermodalism such as speed and quick turnarounds appear to have become the focus of the industry at the expense of the safe operation of its vessel. [2.10]

SECTION 4 - ACTION TAKEN

4.1 CLASSIFICATION SOCIETIES

The classification societies of the 12 container ships identified as being potentially vulnerable to localised buckling and requiring remedial action are, in consultation with the vessels' owners, in the process of determining permanent technical solutions. Further investigation of the 10 ships requiring more detailed examination and the screening of the remaining 8 ships is ongoing. Where necessary the immediate safety of the ships identified as being at risk or requiring more detailed investigation will be ensured by the imposition of operational limitations until technical solutions can be undertaken. The Chief Inspector has written to the Chief Executive of one classification society which has not yet completed its screening process strongly advising that similar action be considered should any of its vessels be found to require permanent remedial action.

4.2 INTERNATIONAL CHAMBER OF SHIPPING

Following the MAIB recommendation 2007/176 made in its report on the investigation of the collapse of the cargo containers on *Annabella* (Report No 21/2007), the Chamber has convened a group of container ship industry experts and, with the assistance of the World Shipping Council, has started work to develop and publish a code of best practice for the industry. The code is expected to be completed by the end of 2008, after which it will be presented to IMO for adoption.

4.3 MARITIME AND COASTGUARD AGENCY

In May 2007, the MCA tabled a paper at the Paris MOU Port State Control Committee on the subject of operational checks and the human factor in loading of ships and whether adequate checks were being carried out prior to sailing. The paper highlighted the loading of tankers and compliance with damage stability criteria. Also, as a late addition because of the structural failure to *MSC Napoli*, and anticipating concerns regarding container ships, the paper also mentioned carrying out container weight and ship longitudinal strength checks on such vessels. The UK will lead a task force to consider these checks for a concentrated inspection campaign planned for 2010, taking into account the findings of this report.

SECTION 5 – RECOMMENDATIONS

The International Association of Classification Societies is recommended to:

2008/128 Review the contents of UR S11 (Longitudinal Strength Standard) to ensure:

- Hull girder strength and buckling checks are carried out on all critical sections along the entire length of the hull.
- An evaluation of the suitability of current UR S11 design wave bending moment criteria for vessels with low block coefficient is undertaken.
- Member societies use common methodologies when complying with the requirements of this rule.

2008/129 Consolidate the results of current research undertaken by its member societies into the effect of whipping on hull structures and to incorporate these results into future revisions of its unified requirements.

2008/130 Research and review the technological aids available which would assist masters to measure hull stresses in port and at sea.

The International Chamber of Shipping is recommended to:

2008/131 When developing a Code of Best Practice for the container industry (MAIB recommendation 2007/176 refers):

- Engage with IACS on the incorporation of issues within the Code which are of mutual interest, e.g. the need to adhere to operational limits on hull stress as set by the relevant classification society and the need for the objective assessment and reporting of fatigue cracking.
- Ensure the Code addresses the following:
  - the need to establish the actual weight of containers before being loaded onto a vessel.
  - the importance of safe speed and prudent seamanship when navigating in conditions of heavy weather.

Zodiac Maritime Agencies Ltd is recommended to:

2008/132 Review its safety management system and auditing procedures to ensure:

- Guidance and instructions to masters regarding speed in heavy weather take into account the lessons learned from this accident.
- Its shore management consults with the relevant classification societies when there is any doubt regarding the criticality of machinery items on board its vessels, which are defective or unserviceable.
- Its masters are fully aware of the requirement to inform embarked pilots of all factors affecting manoeuvrability and stability.

Marine Accident Investigation Branch
April 2008

Safety recommendations shall in no case create a presumption of blame or liability