Report on the investigation of

the loss of cargo containers overboard from

P&O Nedlloyd Genoa

North Atlantic Ocean

on 27 January 2006

Marine Accident Investigation Branch
Carlton House
Carlton Place
Southampton
United Kingdom
SO15 2DZ

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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 li ability or blame.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

DPA	-	Designated Person Ashore
ETA	-	Estimated Time of Arrival
GM	-	Metacentric Height
GMDSS	-	Global Maritime Distress and Safety System
HSE	-	Health and Safety Executive
ISM	-	International Safety Management
LT	-	Local Time
m	-	metres
MARIN	-	Maritime Research Industry Netherlands
mb	-	millibars
MRCC	-	Maritime Rescue Co-ordination Centre
OOW	-	Officer of the Watch
point	-	11¼ degrees
SEC	-	Ship's Equipment Centre
rpm	-	revolutions per minute
SOG	-	Speed over the Ground
Wt	-	Weight in tonnes
great circle	-	A circle on a sphere whose plane passes through the centre of the sphere. The great circle route is the shortest distance between two points.
metacentric height	-	Measure of a vessel's initial stability and major factor in determining vessel's roll period.
primary wave	-	Term used to describe the height or direction of the predominant swell, as opposed to the local effect of the wind on the sea direction.
rhumb line	-	A line which cuts all meridians at the same angle. A rhumb line route will be longer than the great circle route between the same two points.
'Securité'	-	Spoken three times, the word prefixes an important navigational or meteorological warning.

Container vessel terminology:

bay	-	Transverse deck areas, numbered sequentially from forward, available for container stowage.
Grand Alliance	-	A container line trading alliance comprising of; Hapag-Lloyd Container Line, MISC Berhad, Nippon Ysen Kaisha, and Orient Overseas Container Line. *P&O Nedlloyd Genoa* was operating as part of the alliance at the time of the accident.
Hi-cube	-	A container with a height of 9’ 6”.
row	-	A horizontal co-ordinate used to define the position of a container across a bay. A row is given numerical designation from the centre line (00) even to port (02,04,06 etc) and odd to starboard (03,05,07 etc).
stack	-	A number of containers stowed vertically within a given row.
tier	-	A vertical co-ordinate used to define the height of a container in a given row. A tier is given numerical designation commencing from the deck or hatch cover level (82). Each tier level increasing incrementally by 02.

SYNOPSIS

Narrative

On 27 January 2006, while on passage from Le Havre, France to Newark, USA, the British registered container vessel *P&O Nedlloyd Genoa* encountered heavy weather in position 50° 15' N 034° 02' W.

The passage was part of the vessel's regular trading pattern between northern Europe and the east coast of North America. The master, who had extensive container ship experience, had been employed on the route since 1999.

After departing Le Havre, the master decided on the vessel's route across the Atlantic based upon weather routing information supplied to the ship. The vessel's design made it susceptible to the effects of swell approaching within an envelope three points either side of the bow. The master consequently chose a northern combined great circle and rhumb line route which he subsequently modified further, because of the forecast swell direction, taking the vessel north of his planned track.

On 27 January, weather conditions deteriorated and the vessel encountered wind speeds up to 68 knots and an estimated swell height of 5 to 6m. During the day, the master adjusted course and speed to reduce rolling and slamming. Late afternoon, aware that the prevailing conditions could induce parametric rolling, he altered course directly into the swell at slow speed.

At 1718, after a succession of larger swell waves approached from the port and starboard bows, the vessel took a series of five large rolls. While returning to the upright from the fourth roll the master and chief officer saw a steep sided swell wave estimated between 10 to 12m in height. The wave struck in the vicinity of bay 14 on the port bow, and created a significant increase in acceleration forces back to the upright.

As the vessel returned to the upright, she suffered a container collapse in bay 34, directly in front of the bridge, which resulted in 27 containers lost overboard, 28 containers collapsed on deck, and 9 containers remained secured in position.

Analysis

The nature of the accident, lack of precise dynamic information on the vessel's actual pitch and roll accelerations, and the wide spectrum of damage sustained by the affected containers and lashings has meant that an exact cause of accident could not be determined with certainty.

However, the investigation has found that the requirements of the cargo loading manual were not followed, such that the weight distribution in bay 34 was out of tolerance. The lashings on the affected containers in bay 34 were destroyed, but it is considered probable that the stow was sufficiently out of tolerance for the excessive heavy rolling to cause the refrigerated container lowest in Row 07 to buckle and collapse, resulting in a progressive collapse of the rows to port.

The investigation also found that:

- The current container inspection requirements do not assess structural strength and rigidity.
- The process of lashing containers is physically highly demanding and potentially dangerous, and if the process is not closely supervised then shortfalls are likely to occur.
- The cargo planning programme used by Blue Star Ship Management met statutory requirements, but it did not provide the chief officer with the information necessary to identify weaknesses in the loading plan.
- No mechanism existed for verifying declared container weights.
- In countering the effects of heavy weather, the master was generating the pre-conditions for parametric rolling.

Recommendations

Blue Star Ship Management has been recommended to:

- Undertake a risk assessment on the vulnerability of its vessels to parametric rolling. Should significant risk exist, implement control measures to include vessel specific guidance to masters on when parametric rolling might be encountered, and instructions on how to avoid it.
- Emphasise to its crews the importance of lashing checks to ensure compliance with the cargo securing manual and, when correct lashing can not be achieved, identify alternative arrangements or impose limitations as necessary to ensure the safety of the cargo.
- Introduce an independent check of lashing arrangements on all vessels, as part of its internal ISM audit regime.

The Maritime and Coastguard Agency has been recommended to:

- Consult with the United Kingdom Chamber of Shipping and representatives from the marine insurance industry, with the objective of including in the ship's stability information for the use by the ship's crew, vessel specific parametric rolling data.
- In consultation with MARIN , review the contents of container vessel cargo securing manuals and, if appropriate, issue further guidance on their minimum required content.
- Use the data from the current MCA/HSE study into container damage, to review container structural strength and rigidity standards, and the need to improve container inspection regimes.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *P&O NEDLLOYD GENOA* AND ACCIDENT

Vessel details

Registered owner	:	P&O Nedlloyd Genoa Limited
Manager	:	Blue Star Ship Management BV
Port of registry	:	London
Flag	:	British
Type	:	2902 TEU - Container Ship
Built	:	1998, Kvaerner Warnow Werft, Germany
Classification society	:	Lloyd's Register
Construction	:	Steel
Length overall	:	210.11 metres
Gross tonnage	:	31333.00
Engine power and type	:	28880.0kW - DMR MAN 8K80 MC C
Service speed	:	23.5 knots
Other relevant info	:	1300kW Bow thruster

Accident details

Time and date	:	1918 UTC 27 January 2006
Location of incident	:	50° 15'N 34° 02'W
Persons on board	:	22
Injuries/fatalities	:	None
Damage	:	27 forty foot containers lost overboard, and 32 forty foot containers suffered varying degrees of damage. Structural damage to lashing points, pedestal stands, and lashing equipment.

Photograph courtesy of FotoFlite

P&O Nedlloyd Genoa

1.2 NARRATIVE

1.2.1 Time zones

All times contained in the report are ship's time. Clocks onboard were retarded 1 hour at 0200 on the mornings of 26, 27, and 28 January 2006.

1.2.2 Schedule

Operated by Netherlands based Blue Star Ship Management, *P&O Nedlloyd Genoa* was trading as part of the 'Grand Alliance' on the Europe/North Atlantic route. The operating route consisted of visits to the European ports of Hamburg, Rotterdam, Antwerp, Le Havre, and Southampton. North America was served by visits to Newark and Norfolk.

Although the order of European port visits varied, the schedule was based around a 22 day return cycle, and covered 7265 miles. Because of the relative scarcity of container terminal berths, the policy of the 'Grand Alliance' was to pre-book 'berth slots' at scheduled ports many months in advance, requiring guaranteed arrival times to avoid delays and associated financial penalties.

To achieve the pre-booked arrival times, planning staff allowed time in the schedule for anticipated North Atlantic weather conditions, port delays, and unplanned maintenance.

P&O Nedlloyd Genoa's maximum speed was 23.5 knots. Typical data extracted from passages in October and November 2005 showed that the round trip required an average speed of 17.8 knots. The westbound North Atlantic crossing was planned requiring a speed of 17.8 knots, the same as the average speed, and the eastbound crossing planned for a speed of 18.2 knots.

The master did not feel pressured by the required passage speed, nor did he feel unable to make substantial deviations of course and speed to counter the effects of the heavy weather. The company's ISM manual directed masters to consider both options as a method of minimising heavy weather damage.

1.2.3 Passage plan

The proposed passage plan from Le Havre to Newark consisted of a combined great circle and rhumb line track, which kept distance to a minimum and passed safely south of Newfoundland on the rhumb line track to Newark.

The vessel was provided with the 'Orion' package of software supplied by Weathernews, which was capable of providing the master with an optimum route plan for the North Atlantic crossing.

The master analysed the weather prognosis provided by Orion on the evening of the 24 January which showed several low pressure systems passing to the south between latitudes 40 degrees and 50 degrees north. Being more concerned about the likely size and direction of the associated swell, he assessed the 'north about' route to be the safer option. The proposed great circle route was modified, taking the vessel further north and reaching a maximum latitude of 57° 13'N. Although this would increase the overall passage distance, the master felt content that the ETA could be met safely.

It was common practice to routinely amend the passage plan after due consideration had been given to the latest weather forecast.

1.2.4 The passage

As part of her European circuit, *P&O Nedlloyd Genoa* had previously made calls to the ports of Hamburg, Rotterdam, Antwerp and Southampton. At both Rotterdam and Antwerp cargo work had been carried out at bays 14 and 34, the securing arrangements being undertaken by contracted stevedores. The vessel's logbook showed that deck container lashings had been inspected by the second officer and found to be in order.

At 1100 on 23 January 2006, *P&O Nedlloyd Genoa* departed from Southampton bound for her final European destination of Le Havre, where she arrived at 2000 that evening. There was no cargo work undertaken on bays 14 and 34, and the vessel sailed from Le Havre at 1300 on 24 January. The ship's logbook contained a stamp stating that deck container lashings had been inspected and found in order, however there was no signature confirming that the action had been completed.

At 1500 on 24 January, the vessel was clear of Le Havre and commenced passage to the west. The vessel was moving easily, making good a speed of 23 knots with assistance from a Beaufort force 4 easterly wind. The pressure was 1028mb, falling slowly. The planned ETA at Newark was 0100 LT on 31 January, which required *P&O Nedlloyd Genoa* to make good an average passage speed of 20 knots. The waypoints for the amended passage plan were recorded in the master's night orders, accompanied by instructions for the second officer to adjust the plan accordingly overnight.

On 25 January, the vessel continued the voyage on the modified route, making good a speed of 22.6 knots assisted by an easterly Beaufort force 5 wind. The barometric pressure continued to fall slowly, reaching 1025mb by 2000. Logbook extracts showed that at 1105, after a fire and abandon ship exercise, the second officer carried out checks of the cargo lashings. There were no adverse comments entered in the logbook regarding the state of lashings.

That evening, the master downloaded the latest Orion weather routing data and checked that the amended route was still suitable given the latest forecast.

On 26 January, a 976mb depression lying over Newfoundland started to influence the weather pattern facing *P&O Nedlloyd Genoa.* Overnight, the wind had veered to the south west and increased to Beaufort force 6. Having almost reached the most northerly point of the amended track, at 0348 the course was altered from 315° to 278°. A speed made good of 22 knots had been maintained.

Throughout the day the wind backed but stayed steady at Beaufort force 6, and by 1600 was reported to be blowing from the North, and the barometric pressure had fallen to 1018mb.

At 1700, the master downloaded the latest Orion prognosis. He became immediately aware that the weather would deteriorate over the next 24 hours, but did not adjust the passage plan because he felt that there was no viable alternative. The course being steered was now 217°, and the speed made good was still in excess of 22 knots.

At 2027, the master wrote his night orders instructing all OOWs to:

> *' follow the charted courses as per the current passage plan. If the ship begins to pitch any more than moderately call the master immediately'*

At midnight the wind was variable, Beaufort force 2. The vessel was recorded as rolling and pitching easily to slight seas and moderate swell, the visibility was good.

Concerned that the weather might have deteriorated overnight, the master requested an early morning call on 27 January. He arrived on the bridge at 0600, and found that the wind had increased to Beaufort force 6 and veered south easterly. The latest forecast showed a marked deterioration in weather with a depression passing to the north. By 0800, the wind had increased to Beaufort force 8, the sea was recorded as very rough and the vessel was rolling and pitching moderately. From 0900 onwards, the master ordered the following changes to the speed of the vessel:

Time	**Course**	**rpm / Speed**
0908	218	97rpm 21.8 knots
0909	218	88rpm 18.8 knots
0920	218	71rpm 11.5 knots
1030	218	57rpm 7.0 knots
1220	218	42rpm 4.9 knots

The logbook showed that by 1200 the wind had increased to Beaufort storm force 10, but remained south easterly. The logbook recorded that *P&O Nedlloyd Genoa* was rolling and pitching heavily in very rough seas and a heavy swell, was taking seas over the forecastle, and visibility was poor due to rainstorms. The barometric pressure had fallen dramatically over the preceding 8 hours, recorded in the logbook as 1020mb at 0400, 1011mb at 0800, 1003mb at 1200, and by 1600 the pressure had fallen to 999.1mb.

To counter an increase in pitching, the master ordered speed to be reduced at 1220 to 42rpm, producing a speed over the ground a little under 5 knots. The swell was now approaching from 35 to 40 degrees on the port bow and gradually lengthening. The master recalled that, at about this time, he considered the possible effects of parametric rolling, with the distance between swell crests comparable to a little under the length of the vessel. The vessel's roll was increasing with no increase in the height of swell, but the master was content that this was not attributable to synchronous rolling.

At 1532, the logbook recorded that the vessel rolled heavily, which prompted hand steering to be engaged. Thereafter, courses and speeds were adjusted as per the master's orders. The master made the decision to steer 180° directly into the predominant direction of the swell in an attempt to reduce the possibility of the vessel being affected by parametric rolling and to ease her through the head seas.

At 1600, the chief officer was about to take over the watch when the master ordered him to carry out rounds of the accommodation and the under deck side passageways, to check cargo security. The master then took the 1600 to 2000 watch. The chief officer soon returned to the bridge, having deemed it unsafe to proceed out on deck in the prevailing weather conditions. When he returned to the bridge, the vessel was on a course of 180°, speed over the ground of 5 knots, and the wind was in excess of 40 knots. Although the vessel was still pitching heavily in a swell estimated to be between 5m to 6m in height, it was the master's intention to keep the swell ahead.

The master and chief officer discussed options for adjusting the ballast configuration to increase the GM and help reduce the roll. At 1635, the chief officer commenced pumping ballast into number 5 port and starboard double bottom tanks. A total of 1104 tonnes was loaded, which had the effect of increasing the fluid GM from 0.77m to 1.13m. Ballasting was completed at 1700 and the stability of the vessel verified.

At about 1715, the wind strength increased momentarily to 68 knots and a succession of larger than average swell waves approached from both the port and starboard bows. The vessel took a series of five large rolls, the first four rolls were estimated by the crew to be in the region of 25 to 30 degrees.

At 1718, prior to the fifth roll, the master and chief officer both reported sighting a much larger, steep sided swell wave, estimated to be between 10m to 12m in height, approaching from 30 degrees on the port bow. The wave hit the vessel on the port shoulder in the vicinity of bay 14 just as she was commencing her return to the upright, from port. The wave created a significant increase in acceleration forces, which caused the vessel to return quickly to the upright and the ship's head to swing rapidly to starboard.

The master was concerned that the change in ship's heading left the vessel at risk from the swell on the port bow, and responded by putting the wheel hard to port and increasing speed. As the vessel returned to the upright, there was a loud 'cracking' noise, followed by the chief officer reporting to the master that the ship had suffered a container collapse in bay 34, directly in front of the bridge. Simultaneously, the ship's head returned to a course of 180°.

1.2.5 Post accident events

Both master and chief officer reported that immediately after the stack had collapsed the wind decreased to about 40 knots.

The master ordered that a full emergency muster be conducted to check the wellbeing of all crew members. All crew were accounted for, and none were injured. The master informed MRCC Halifax of the incident, and broadcast a 'Securité' message on GMDSS to warn other vessels in the vicinity of the accident and the associated danger to navigation.

At 1751 the master contacted the DPA and informed him of the incident. The master confirmed that all personnel had been accounted for and that no personal injuries had been sustained.

At 2000, the weather conditions allowed an alteration of course to be made to 195°. Speed remained at 5 knots. By 2100, as the weather conditions continued to moderate, the master was able to alter course to 220. By 2336, a succession of small increases in speed, up to 57 rpm, had the vessel making good about 11.5 knots. Weather conditions remained south easterly Beaufort force 7 until midnight when the wind decreased to force 5.

At 0230 the course was adjusted to 250 in accordance with the original passage plan.

At 1000 on 28 January, the lull in weather conditions allowed an inspection of damage. Remaining cargo lashings were checked, and structural damage in way of bay 34 examined. The environment in the vicinity of bay 34 was deemed by the master and the mate to be too dangerous for the crew to carry out any re-securing of the cargo that had broken loose.

Examination of bay 34 showed that 27 forty foot deck containers were lost overboard, and 28 forty foot deck containers had collapsed. Only 9 forty foot deck containers from bay 34 remained secured in position **(Figure 1)**. A steel pedestal, designed to support the port outboard extremity of the containers in row 12, suffered catastrophic failure **(Figures 2 and 3)**. Closer inspection of the remaining deck cargo showed that four containers on the bottom tier of bay 14, port side, had also been damaged by compression forces. All of the lashings in bay 14 had remained intact.

Between the morning of 28 January 2006, and arrival of the vessel at Ambrose anchorage, Newark in the early hours of 1 February 2006, the master made several adjustments to the vessel's course and speed, commensurate with the prevailing weather conditions and to prevent further loss of the loose deck containers **(Figure 4)**.

Figure 1

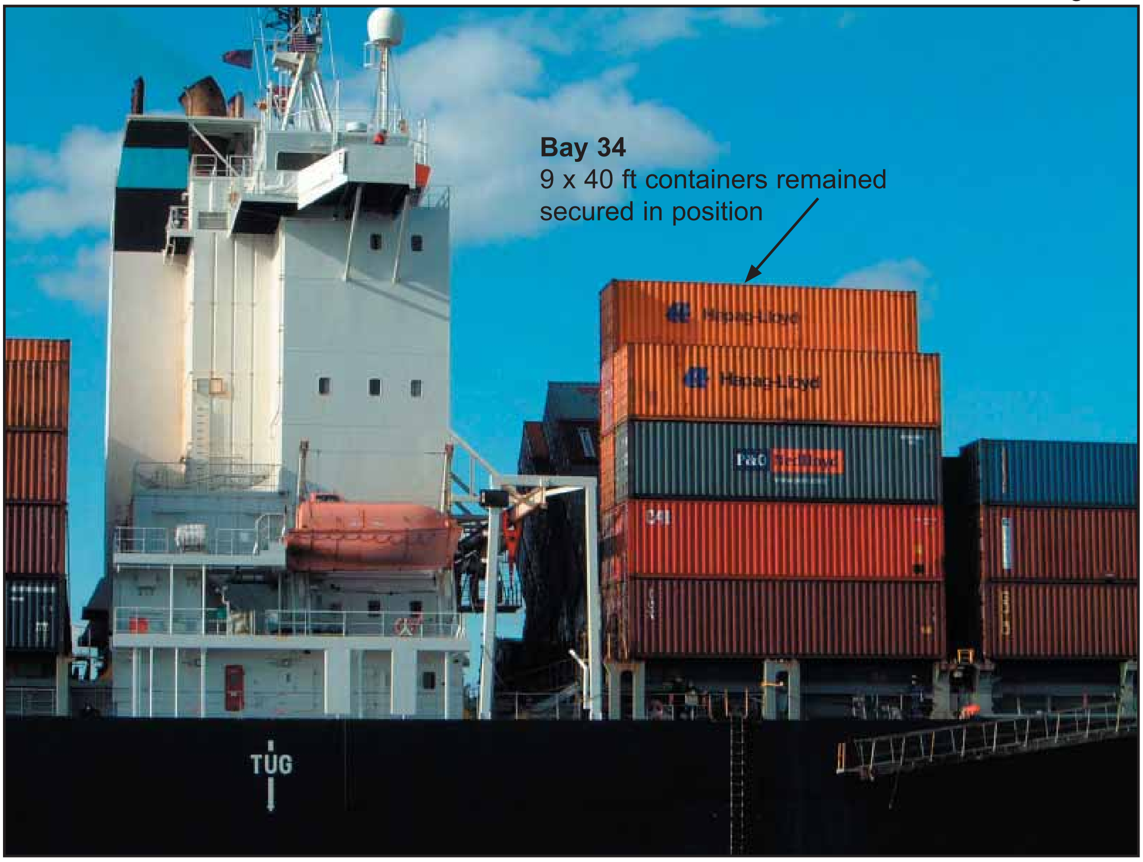


Figure 2

Pedestal support pre-accident

Figure 3

Pedestal support post-accident

Figure 4

Remaining containers in bay 34

1.2.6 Damage sustained

When a container collapses, as a result of either structural or lashing failure, the resultant action is for the containers directly above to topple sideways. The reaction is a ‘domino effect’, that causes adjacent rows to topple sideways, until the ship’s side is reached and cargo is lost overboard.

The general nature of damage in bay 34 made it impossible to ascertain the exact cause of the initial failure, however the following observations were made:

- Broken semi automatic twist locks.
- Parted lashing bars with fork end splays.
- Fractured hatch top container feet.
- Compression damage to containers.
- Corner castings ripped from container.

Structural damage to the vessel was contained to bay 34, and consisted of damage to the hatch top securing arrangements and collapse of the outboard row pedestal support.

The lashings of the collapsed stacks were disrupted and damaged in the accident such that no assessment could be made of their original disposition. However, a general examination of lashings in other bays around the vessel showed a number of inconsistencies, including:

- Missing lashing bars.
- Additional lashing bars.
- Bars secured to incorrect container.
- Insufficient securing arrangements to lash out of gauge containers.

1.3 MANNING

1.3.1 The master

Aged 54, the British master had 36 years experience at sea and had been employed by the same company throughout. With the exception of three voyages on general cargo vessels, all 36 years had been spent sailing on container ships. The master first assumed command in 1995, and commenced sailing on the North Atlantic service in 1999. Conditions of employment allowed the master to work an 8 weeks on / 8 weeks off routine with the vessel's other master. After a slightly extended tour of duty, negotiated with the company, he was due to leave the vessel 3 weeks after the accident.

1.3.2 The chief officer

Aged 45, the Filipino chief officer began his career at sea in 1976, and was in possession of a class II/2 certificate of competency. He had worked his way up through the ranks starting as a junior seaman, and was promoted to chief officer with Blue Star Ship Management in 1993. The chief officer had 13 years experience on container ships, although this was his first voyage on the North Atlantic service. He had joined the vessel 6 days before the accident, on 21 January.

1.3.3 Ship's complement

The safe manning certificate required the vessel to carry a minimum of 15 crew members; Blue Star Ship Management manned the vessel with a total complement of 22. The vessel was manned with a British master and chief engineer, the remaining officers and ratings were Filipino. The complement allowed the vessel to implement a bridge watchkeeping organisation that consisted of the master plus three watchkeeping officers.

In port, during cargo operations, the third and second watchkeeping officers worked cargo watches that consisted of 6 hours on watch followed by 6 hours off watch; the chief officer was available as required.

1.4 METEOROLOGICAL CONSIDERATIONS

Blue Star Ship Management provided vessels engaged on the North Atlantic service with the premium 'Orion' weather routing package, produced by 'Weather News'. The facility was praised by the master of *P&O Nedlloyd Genoa*, as providing consistent, reliable, and accurate information. It assisted the master to plan passages using the latest meteorological weather routing and forecasting data available. If necessary, the 'Orion' package allowed the master to obtain weather guidance, via telephone, from a shore based operative.

It was Blue Star Ship Management's policy to provide the master with the latest meteorological information and let him decide upon the optimum route for the intended crossing.

1.4.1 Planning

The master was acutely aware of the adverse effect of swell on the vessel, particularly a head swell approaching within an envelope 30 degrees either side of the bow. The master reported that the vessel was far more susceptible to slamming and that rolling in excess of 15 degrees, due to beam swell, was unusual. On departure from Le Havre, the master downloaded the latest 'Orion' weather forecast which showed two low pressure area systems moving east between Latitudes 40 and 45 degrees north and, a low pressure system to the east of Newfoundland which was moving rapidly north-east clear of the proposed track.

In making the decision whether to take the northern most great circle route or a southerly rhumb line route via the Azores, the master's principal concern was the direction of the prevailing swell. He interpreted that the forecast indicated a predominance of westerly (head-on) swell on the southerly rhumb line route, potentially with wave heights in excess of 9 metres **(Figure 5)**.

He also assessed that the northern great circle route provided better scope for adapting the vessel's course and speed, and avoiding swell on the bow. In theory, this option would provide sufficient time for the vessel to avoid the low pressure system developing over Newfoundland, and provide the best passage time.

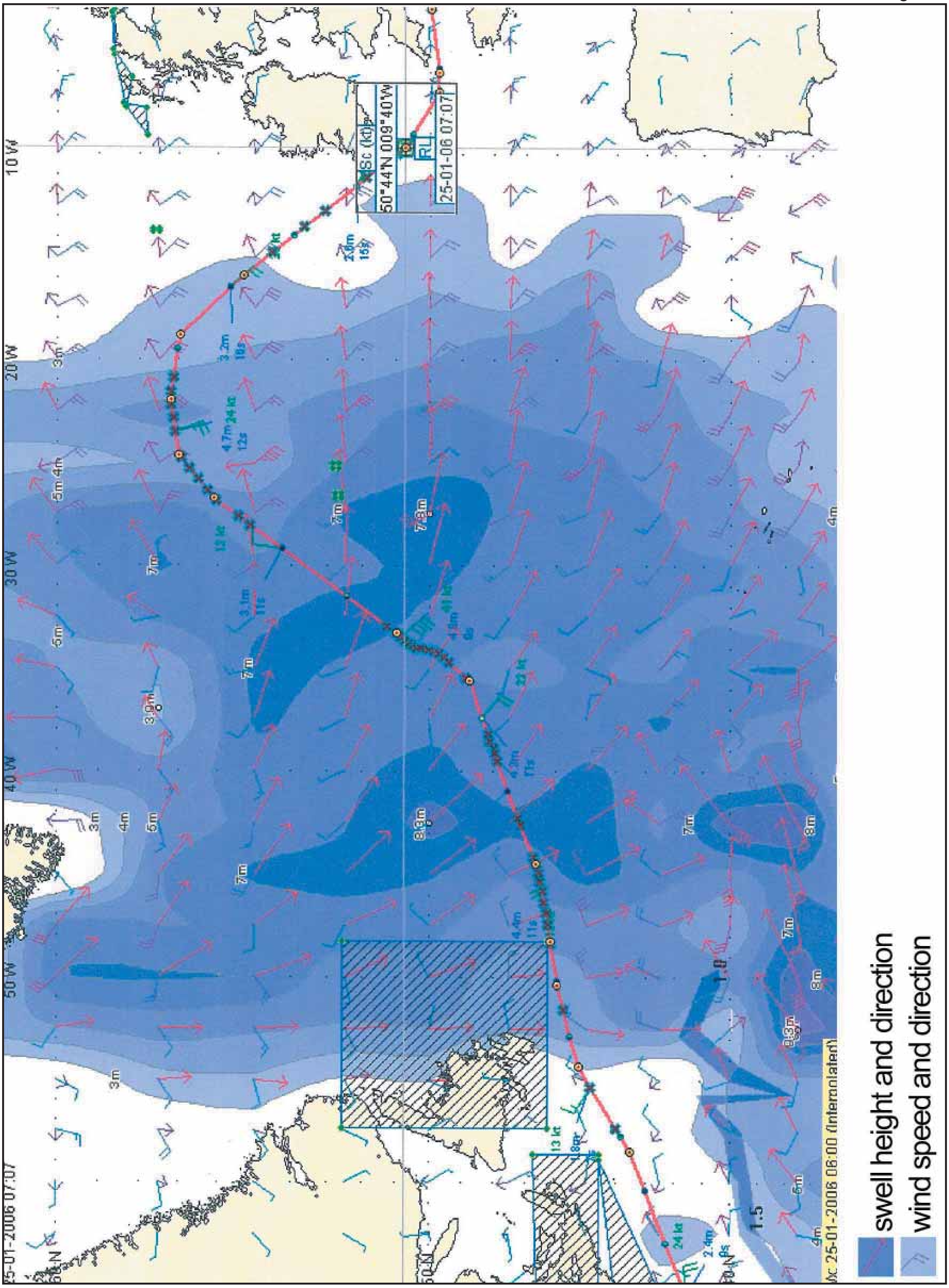
The meteorological information obtained by the master is confirmed by the Meteorological Office charts for the same period, which can be found at **Annex A**. The 26 January chart shows a low pressure system 984mb and deepening developing over Newfoundland, and a high pressure system 1021mb, to the east. This was the master's first sighting of the 984mb low.

1.4.2 Conditions at the time of the accident

Computer generated charts depicting the conditions encountered by the vessel at the time of the accident can be found at **Annex B**. The data shows the vessel encountering primary wave heights of 5.4 metres from a relative direction of 30 degrees on the port bow, with the wind approaching from a relative direction of 10 degrees on the starboard bow.

The wind speed data chart and the relative wind direction chart, support the OOW's meteorological entries in the bridge logbook. However, the computer data is unable to account for, or predict, abnormal conditions (eg extra strong gusts, or high waves). The master was clear that the wave that struck on the port bow was exceptional; approximately double the average swell height at the time.

Figure 5



25 January 2006 - 0707 weather download (wind and swell)

1.5 CARGO SECURING MANUAL

1.5.1 Guidance provided for the master

The cargo securing manual had been compiled by the lashing manufacturer, Ship's Equipment Centre (SEC), and was approved by the classification society on behalf of the flag state.

The classification society considers that the tolerances allowed for when calculating the lashing system arrangement were adequate, but only when the ship is loaded in accordance with the approved manual.

A. Heavy weather considerations

The manual was comprehensive and included guidance in the event of the vessel entering heavy weather, specifically:

- Avoid excessive accelerations.
- Alter course and or speed to reduce ship motion.
- Heave to.
- Avoid areas of adverse weather and sea conditions.
- Ballast in good time to improve the behaviour of the ship.
- Voyage plan to avoid adverse weather.
- Ensure cargoes are secured in the most effective and efficient manner.

The manual was clear in advising that the crew must carry out visual checks on lashing arrangements during loading, as well as adjusting lashings once the vessel had sailed.

B. Cargo checks on passage

The manual provided advice to the crew on the inspection and adjustment of securing arrangements during the voyage. The advice included:

- The need to maintain a visual check on cargo securing devices during loading.
- The need to adjust cargo securing arrangements when heavy weather or swell was expected, moreover when it had passed.
- The need to adjust ballast in order to change the motion of roll.
- The risk of wave resonance between the period of natural roll and the period of the attacking sea. Roll angles might reach values from 30 to 50 degrees. Resonance could be avoided by changing course, and thereby changing the period of roll.
- That heading into seas at high speed could produce slamming shocks, which might exceed longitudinal and vertical accelerations. This would be hazardous to cargo units, and an appropriate reduction in speed should be considered.

C. Cargo shift considerations

The manual provided further guidance to the master on actions that might be taken once a cargo shift had occurred:

- Alter course and or speed to reduce accelerations.
- Restow the cargo where possible.
- Divert course to seek shelter.
- Carry out ballasting if the vessel has adequate stability.

D. Container weights on deck

The manual displayed, in a clear diagrammatic form for each bay:

- The maximum permissible number of containers in each stack.
- The maximum permissible weight of each stack.
- The lashing configuration for each bay.
- The vessel's maximum permissible GM.

1.6 CARGO STOWAGE PLAN – BAY 34

1.6.1 General stowage plan

All containers in bay 34 were loaded at the ports of Hamburg, Antwerp, and Rotterdam.

The stowage plan for bay 34 at the time of the accident **(Figure 6)** shows a homogeneous section of 40 foot containers stowed 5 high, with the exception of row 11 which was only stowed 4 high.

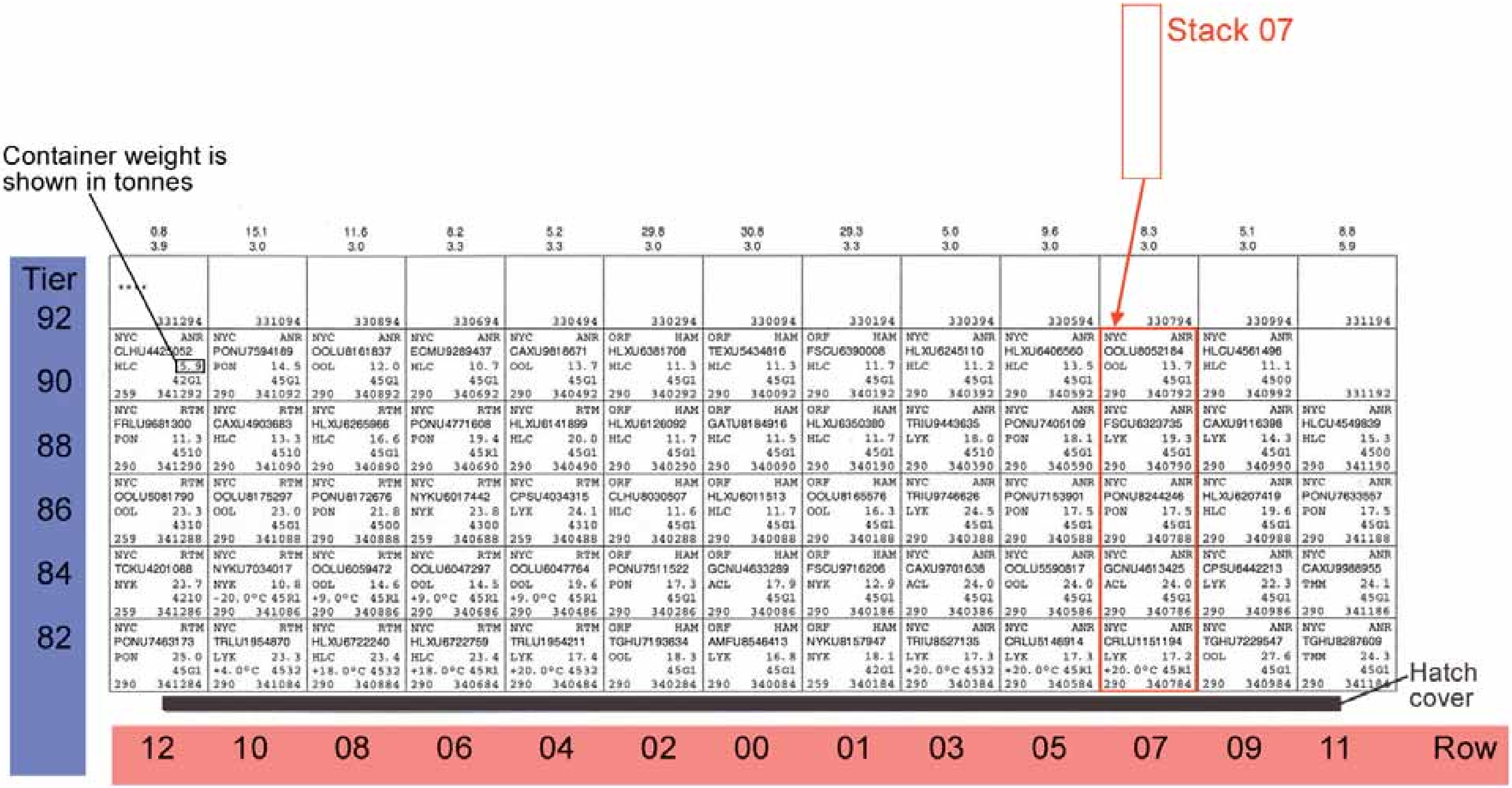
There was a total of 11 refrigerated containers stowed in tiers 82 and 84. All but 6 of the containers stowed in bay 34 were 'hi cubes' with a designed height of 9' 6", one foot more than the standard container height of 8' 6". **Annex C** shows the relative positions of the 8'6" containers within the stack.

There were no designated dangerous cargo containers stowed in bay 34.

Annex D shows the locations of the containers that were lost overboard, broke loose, and remained secured in position.

1.6.2 Stack weights

The manual showed that in bay 34, which suffered the cargo shift, the maximum number of containers that could be stacked vertically was six. Each stack (excluding stacks in outboard rows 11 and 12) was allowed a maximum total weight of 100 tonnes, the two outboard stacks were each allowed a maximum total weight of 82.5 tonnes. The maximum permissible GM was 1.315 metres.



Cargo stow plan - bay 34 (viewed from aft)
Departure: Le Havre

A fax amendment to the securing manual showed a modified arrangement for containers 9' 6" in height. Effectively, the amendment increased the maximum permissible weight allowed in each outboard stack by 2.5 tonnes, but reduced the maximum number of containers in each stack, across the bay, to five high. Each outboard stack had a maximum permissible weight of 85 tonnes.

Tier	8'6" (2590mm) high standard containers		9'6" (2900mm) high Hi-Cube containers (fax amendment)	
	outboard rows (tonnes)	inboard rows (tonnes)	inboard rows (tonnes)	outboard rows (tonnes)
92	3.5	3.5		
90	3.5	8.5	11	4
88	3.5	10	15	4
86	11	20	17	16
84	30.5	28	26.5	30.5
82	30.5	30	30.5	30.5
H A T C H C O V E R				
Total	**82.5**	**100**	**100**	**85**

*P&O Nedlloyd Genoa'*s bay 34 stowage plan for the voyage from Le Havre to Newark **(Annex C)**, indicated a mix of container heights, particularly in row 12, which contained 3 x 8'6" units and 2 x 9'6" units. Other mixes can be seen in rows 6, 4, and 1.

Using the cargo securing manual, fax amended, criteria for 9'6" units, the shaded sections of **Annex E** show the containers considered to be loaded in excess of the cargo securing manual maximum permissible weight, at the time of the accident. Comparison of the actual total stack weights, against the fax amended maximum permissible, shows that the port outboard stack number 12, had been overloaded by 4.2 tonnes.

1.6.3 Company instructions

A memorandum, issued by Blue Star Ship Management after three incidents of lost or damaged containers had occurred, is shown at **Annex F**. The memorandum explains:

'*modern lashing systems today rely on complex forces and leave little room for manoeuvre, but rely upon the principle of NO heavy over lights*[1]*. However the practicality of this is known therefore differences of up to ten percent between boxes can be considered acceptable'*

The bay 34 stow plan shown at **Annex G**, highlights 14 cases where heavier containers had been loaded over lighter ones. The shading shows where the weight discrepancy was in excess of the 10% difference allowed by shore management.

[1] Not to load a heavier container over lighter container

1.6.4 Actual weights

To assist the investigation, Blue Star Ship Management arranged for the damaged containers remaining on deck to be weighed. The results are shown below and can be crossed referenced to **Annex E**.

Container Number	Actual Wt	Declared Wt	Error Wt
GATU 8184916	11.36	11.5	- 0.14
TEXU 5434816	11.00	11.3	- 0.30
OOLU 8165576	16.50	16.3	+0.20
HLXU 6350380	10.50	10.5	0.0
FSCU 6390008	11.00	11.7	-0.70
OOLU 5590817	18.90	24.0	-5.10
PONU 7153901	16.13	17.5	-1.37
PONU 7405109	16.31	18.1	-1.79
GCNU 4613425	27.78	24.0	+3.78
OOLU 8052184	16.00	13.7	+2.30

The results show that the remaining containers were close to their declared weights. The two overweight containers were both stowed in row 07, OOLU 8052184 at tier 90 and GCNU 4613425 at tier 84. The additional weight in the stack increased the total weight to 97.8 tonnes, 2.2 tonnes below the maximum permissible. The additional weight further breached the ‘no heavy over lights’ rule.

1.7 LASHING ARRANGEMENT

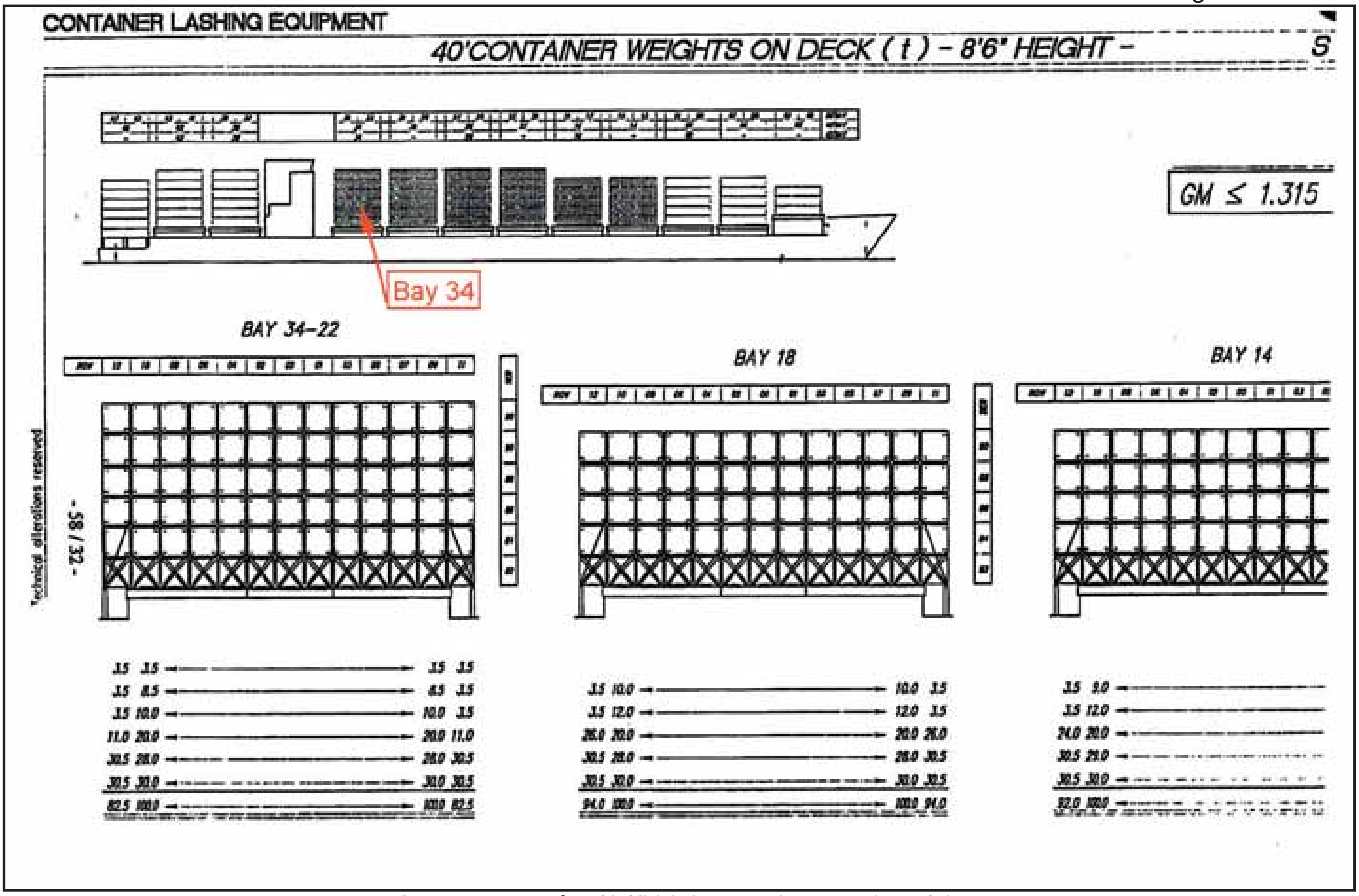
1.7.1 Instructions contained within the cargo securing manual

During the investigation, the cargo securing manual was examined with the assistance of the chief officer, specifically the securing arrangements for bay 34. The manual contained two illustrations depicting the conditions and arrangements for securing 40’ containers that were 8’ 6” in height **(Figure 7)**, and the hi-cube 9’ 6” high units **(Figure 8)**.

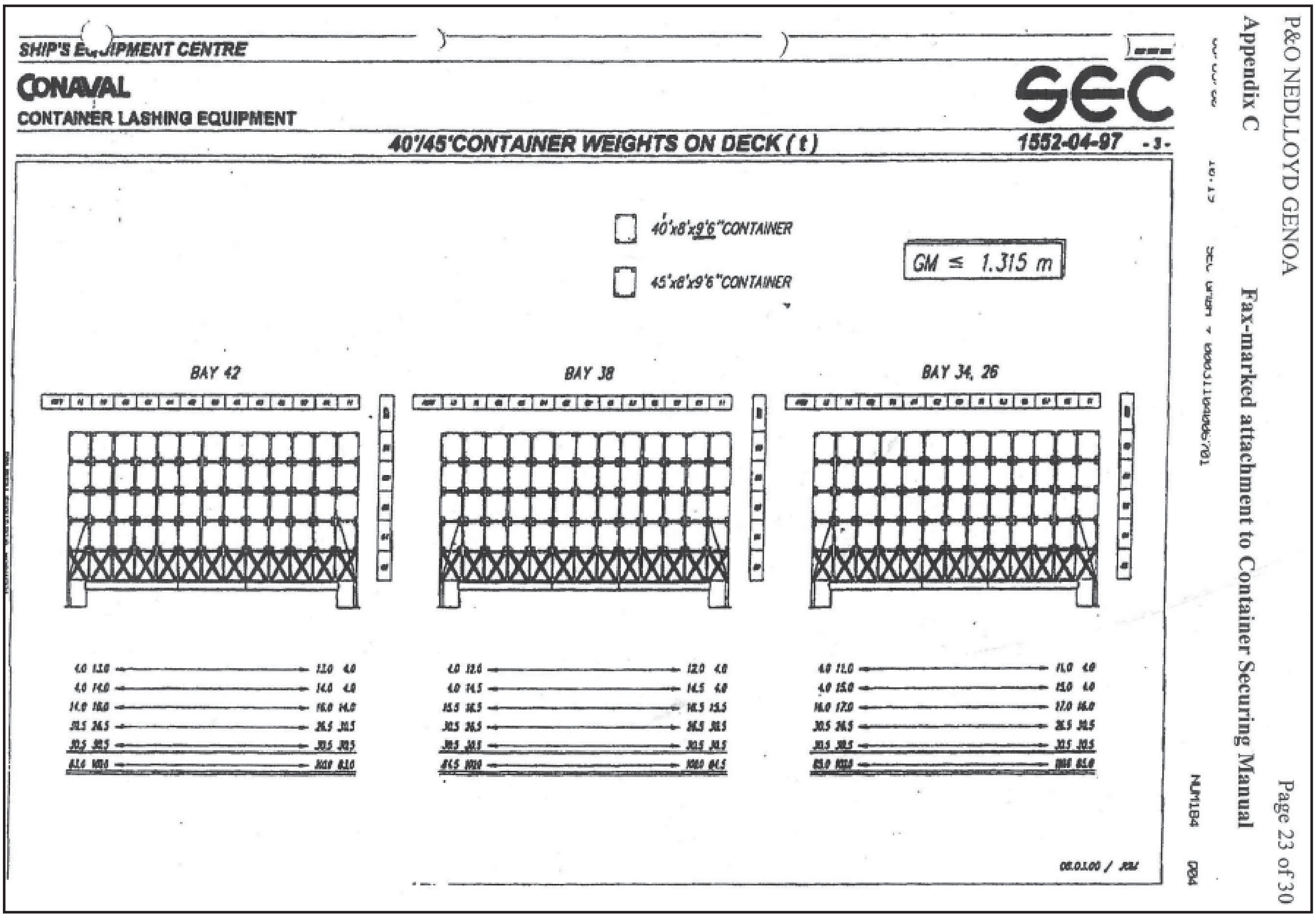
The lashing arrangement was the same for both configurations, and consisted of:

- Double diagonal lashings to the top of the bottom tier, and to the bottom of the second tier.
- The outboard stack was fitted with a diagonal lashing from the bottom outboard corner (bottom tier) to the bottom corner of the third tier.
- A vertical lashing from the bottom outboard corner, to the top outboard corner in tier two.

No reference could be found within the manual that drew the crew’s attention to alternative lashing arrangements for containers stowed in different configurations.



Arrangement for 8' 6" high containers at bay 34



Arrangement for 9' 6" high containers at bay 34

1.7.2 Local lashing diagrams

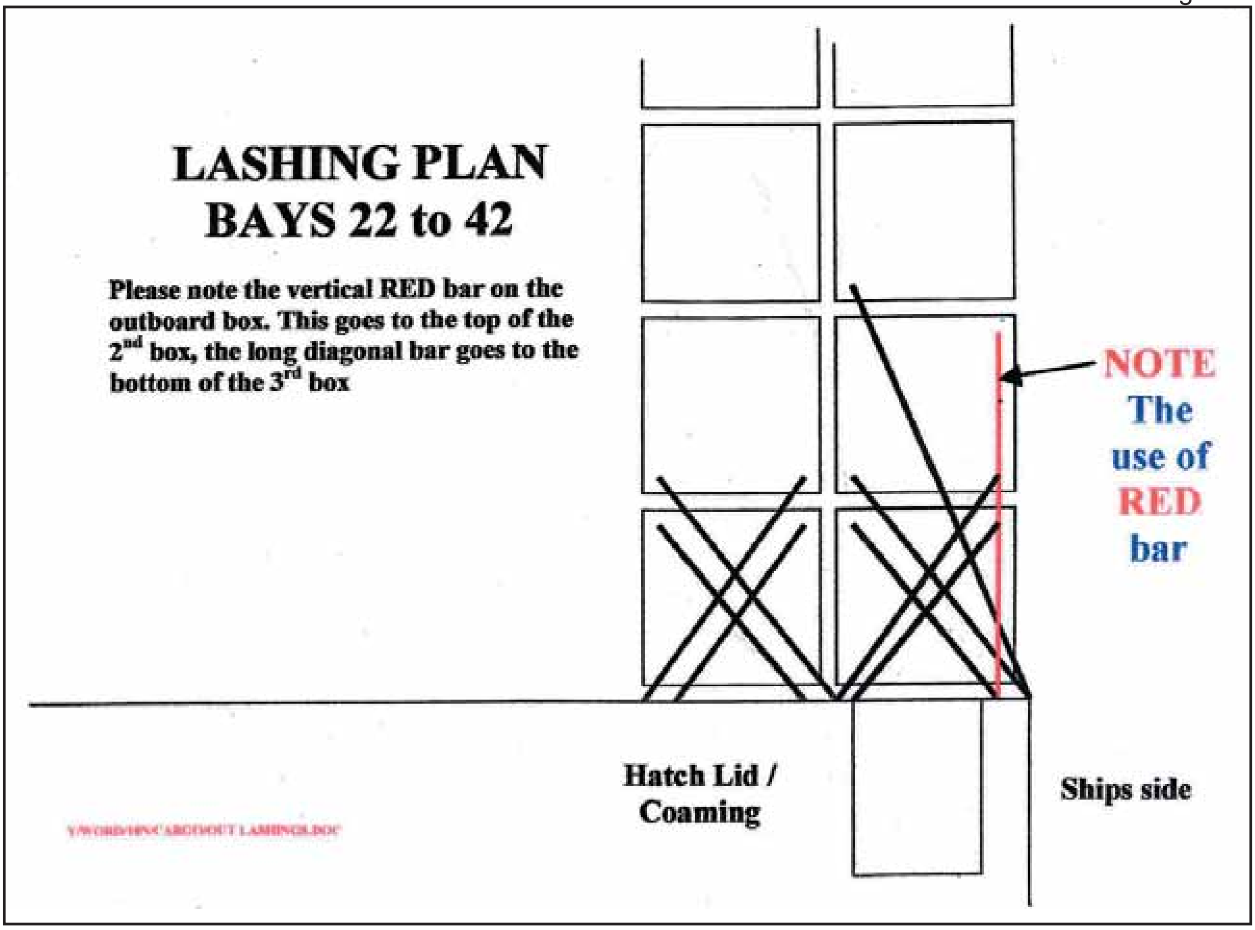
Clear, unambiguous diagrams **(Figure 9)** were posted along the port and starboard walkways, adjacent to the bays, to assist both the ship's crew and the shore stevedores identify the correct lashing configuration.

Each diagram was accompanied by a written explanation of the lashing requirement. The explanation made no reference to any variation in lashing configurations that may be required due to individual unit height or the number of containers in the outboard stacks.

1.7.3 Lashing equipment

All of the lashing equipment onboard the vessel was class approved. Red colour coding of the vertical outboard lashings assisted stevedores to ensure that the correct equipment was fitted in the correct location. The chief officer was unsure as to why some lashing bars were painted red, believing that possibly they were supplied from another vessel. Bi-annual inspection of all cargo securing equipment, including the vessel's supply of Semi Automatic Twist Locks, was supported by onboard planned maintenance documentation.

Figure 9



Lashing diagram displayed adjacent to relevent bays

1.7.4 Cargo checks

The cargo log confirmed that the cargo officer carried out regular checks of lashings during the loading period. The cargo officer was also responsible for checking every container against the stow plan, and checking all twist locks were locked once a bay had been completed. Just prior to completion of cargo operations, the chief officer and the cargo officer commenced rounds of the deck cargo checking securing arrangements. When the chief officer was satisfied with the standard of lashing, he signed the stevedore documentation accordingly.

Interviews conducted with the ship's officers and terminal operators indicated that the standard of lashings by stevedores varied depending upon the terminal, the stevedore's familiarity with the vessel, and the standards demanded by the ship's officers.

At sea, the second officer conducted daily checks of the lashings in company with the deck crew.

1.8 STABILITY

1.8.1 Parametric rolling

Parametric rolling can be a particular problem on ships, such as *P&O Nedlloyd Genoa,* designed with a flat transom and with large bow flare. This is a common design, found on many modern container ships, which maximises deck cargo capacity while minimising water resistance with fine hull lines.

The stability of a vessel is dependent on its water-plane area and especially the breadth of that area. When a ship is in calm water, its water-plane area will provide a certain metacentric height, GM, which is a measure of the vessel's initial stability. It also provides an indication of the vessel's roll behaviour; a high GM causing a stiff or quick roll motion, a low GM causing a slower rolling action. In calm water, for a given loading condition and hence GM, the ship will also have a natural roll period about which the ship will oscillate if given an impulse in roll.

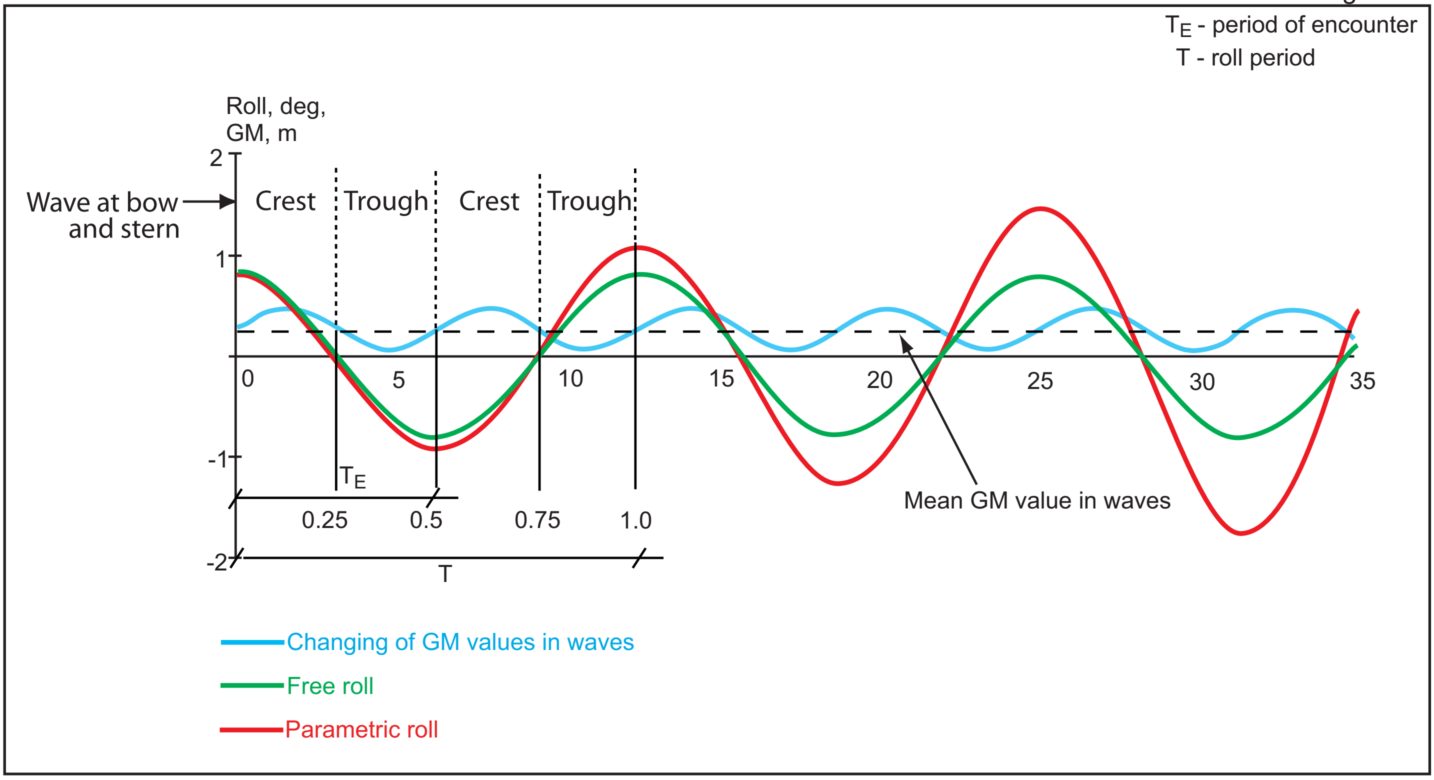
Figure 10 shows a free, un-damped roll motion. If a ship finds herself in head or near head seas (also applies in following seas) and encounters waves with a wavelength similar to the ship's length, it is possible for the bow and stern to rest on the crests, while amidships is in the trough of a wave. In this condition, given the bow flare and flat transom, the water-plane area is increased (when compared to a level waterline) resulting in a higher GM.

As the wave crest moves down the vessel's side, it will arrive amidships, leaving the bow and stern in troughs. At this point, the water-plane area is decreased and the GM is much lower. **Figure 10** also shows the oscillating nature of GM.

If the encountered wave period is half the ship's natural roll period, a resonant roll motion occurs as the varying GM provides impetus to the rolling action at both extremes of the motion. In these conditions, angles of roll of over 30° can develop within four or five roll cycles.

Synchronous rolling, when the encountered wave period is close to the ship's natural roll period, is a similar phenomenon but not as serious, since impetus is only added to the roll cycle once each roll. Often, a ship's natural roll damping is sufficient to ensure synchronous rolling is not a significant problem.

Figure 10



Development of parametric roll

1.8.2 Acceleration forces

The cargo securing manual laid down the vessel's maximum permissible GM, applicable to each bay. When the vessel entered heavy weather, compliance with the GM requirements would ensure that the acceleration forces acting due to ship motion were within the limits used by the lashing manufacturer when ascertaining the number, size, and configuration of lashings required. The maximum permissible GM for bay 34 was equal to, but not greater than, 1.315m. This was based upon a stack of six 40 foot containers 8'6" high or, the amended fax version, a stack of five 40 foot containers 9'6" high.

The master had considered the effects of the heavy weather and, after consultation with the chief officer, decided to add 1104 tonnes of sea water ballast to number 5 port and starboard double bottom tanks. On completion of ballasting, both tanks were full. The ballasting operation was intended to reduce the angle of roll in the heavy weather.

When the ballasting operation commenced at 1635 the vessel had a fluid GM of 0.77m. The minimum fluid GM of 0.6m was experienced shortly after commencement, when approximately 25 tonnes had been loaded.

On completion of the operation, the fluid GM was calculated as 1.13m, which was still 0.185m less than the maximum permissible at bay 34. The operation had increased the fluid GM by 0.36m, and at no point during the operation had the maximum permissible GM been exceeded.

1.8.3 Stability calculations

The proposed stow plan was initially drawn up by the company's cargo planning team. This plan was, in turn, passed to the relevant operations staff within the container terminals, and refined or adapted to better suit the cargo operation.

When the vessel arrived alongside the terminal, staff presented the chief officer with a 3.5 inch floppy disc, which contained the proposed cargo operation for that port. After examining the disc on the stability computer, the chief officer was given the opportunity to make changes to the plan if they were deemed necessary.

The stability programme had a mimic diagram of all bays and holds. As the container weights were input, the computer would alarm if maximum stack weights were exceeded. The chief officer had, on previous vessels, used an operating system which not only alarmed if the stack weight was exceeded, but also alarmed if a wrong container weight was entered into the stack.

One of the chief officer's main checks was to assess the accuracy of the container weights onboard. This he achieved by comparison of the observed and calculated draughts, which on departure from Le Havre was described as 'very close'.

1.9 CONTAINER CONSTRUCTION

1.9.1 Age

Close inspection of 12 heavily damaged containers showed that eight of the 12 containers were manufactured post 2000, three in 1999, and one in 1995. The refrigerated container at the bottom of row 07, which is believed to have triggered the collapse in bay 34, was manufactured in January 2001.

1.9.2 Container inspection

The requirement for the approval and subsequent maintenance of freight containers is laid down in the International Convention for Safe Containers 1972(CSC). Contracting states have agreed to implement the requirements in the convention for the testing, inspection, approval and maintenance of containers. The convention was implemented in Great Britain by the Freight Container (Safety Convention) Regulations 1984. The HSE is the enforcing authority for the regulations, and acts as the approving authority for companies who approve new and re-conditioned containers. The HSE also approves the proposed arrangements for examination schemes and programmes.

The initial approval and certification of a container is carried out by a classification society surveyor. Pending a satisfactory inspection, the container will then be affixed with a safety approval plate, as required by the CSC. The safety approval plate is designed such that subsequent periodic inspections can be recorded on the same plate. Approximately one in 50 newly manufactured containers will undergo a jig test and be subjected to racking force loads. However, after this initial test, at no point in the container's life is it assessed for structural strength and rigidity.

The CSC allows for containers to be operated under a Periodic Examination Programme, when the first examination occurs no fewer than 5 years from the date of manufacture. Subsequent examinations should not exceed 30 months periodicity.

The CSC also allows for containers to be operated under an Approved Continuous Examination Programme, when the examination should be carried out in connection with a major repair, refurbishment or on/off hire interchange. In any event, the interval without examination should not exceed 30 months.

All examinations must be carried out by a competent person, who must possess sufficient knowledge and experience of containers to determine whether the container has defects that could place any person in danger. The factors to be considered during inspection are shown at **Annex H**.

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 FATIGUE

Ten days prior to the accident, *P&O Nedlloyd Genoa* had arrived in European waters after completing a North Atlantic passage. She carried out cargo operations at five ports within a 7 day period, before sailing from Le Havre for the return North Atlantic crossing.

The vessel had been deep sea, working a bridge watchkeeping routine with three deck officers for 3 days prior to the accident. The master was not a watchkeeping officer, and had the flexibility to work, and be on call, as required. Manning scales were adequate and the officers were appropriately qualified.

Hours of rest records confirmed that the bridge watchkeeping officers and the master had all received rest in excess of the statutory minimum requirement.

Although heavy weather had reduced the quality of rest on 27 January, fatigue is not considered a contributory factor in this accident.

2.3 SIMILAR ACCIDENTS

The total number of containers lost overboard in heavy weather is unknown; reports in the shipping press vary from 2000 to 10,000 containers per year. Potentially such losses represent a significant hazard to the safety of navigation, and can inflict significant harm upon the marine environment. However, when the presumed number of lost containers is compared to the total number shipped worldwide in one year, the percentage loss is extremely small.

The loss of containers from *P&O Nedlloyd Genoa* in January 2006, was the first of five high profile accidents involving the loss of containers overboard in the first two months of 2006. The other incidents involved:

Date	Name	Capacity	Flag	Approx Loss	Location
Feb 06	*P&O Nedlloyd Mondriaan*	8,500 teu	Liberian	58	Netherlands Coast
Feb 06	*P&O Nedlloyd Mondriaan*	8,500 teu	Liberian	50	Bay of Biscay
Feb 06	*CMA CGM Otello*	8,500 teu	French Antarctic Territories	50	Bay of Biscay
Feb 06	*CMA CGM Verdi*	5782 teu	Bahamas	80	Cape Finiesterre

At the time of this investigation, the French and Bahamian flag states were investigating the accidents involving the *CMA CGM Otello* and *CMA CGM Verdi* respectively.

Further, in June 2006, seven containers stowed at bay 74 on board *Maersk Santana*, (a sister ship of *P&O Nedlloyd Mondriaan*) suffered structural failure of container corner posts during heavy weather in the southwest monsoon. None of the containers was lost overboard and there was no collapse of the stow.

2.4 CAUSE OF THE ACCIDENT

The nature of the accident, lack of precise dynamic information on *P&O Nedlloyd Genoa*'s actual pitch and roll accelerations and the damage sustained by the effected containers and lashings, has meant that an exact cause of accident could not be determined with certainty.

However, the investigation has found that the requirements of the cargo loading manual were not followed, such that the weight distribution in bay 34 was out of tolerance. The lashings on the affected containers in bay 34 were destroyed, but it is considered probable that the stow was sufficiently out of tolerance such that the accelerations caused by excessive heavy rolling caused the refrigerated container lowest in row 07 to buckle and collapse, resulting in a progressive collapse of the rows to port.

The investigation also found that:

- The current container inspection requirements do not assess structural strength and rigidity.
- The process of lashing containers is physically highly demanding and potentially dangerous, and if the process is not closely supervised then shortfalls are likely to occur.
- The cargo planning programme used by Blue Star Ship Management met statutory requirements, but it did not provide the chief officer with all the information necessary to identify weaknesses in the loading plan.
- No mechanism existed for verifying declared container weights.
- The actions taken to counter the effects of heavy weather, had the effect of generating the pre-conditions for parametric rolling.

In sum, these factors generated the pre-conditions for collapse which allowed the stimulus of a few heavy rolls to cause the accident.

2.5 PRE CONDITION 1 – CARGO PLANNING AND SECURING

2.5.1 Stow plan

Preparation of the cargo stow plan is the responsibility of dedicated cargo planning staff who are familiar with the requirements of the cargo securing manual. The shipping company's planners liaise closely with container terminal planning staff to finalise cargo stow and programme logistical requirements.

Producing a container vessel's stow plan is a very complex equation as there are a considerable number of variable components, some driven by statutory requirement, others driven by customer needs. The stow plan for bay 34 had to consider the need to place refrigerated containers in the bottom two tiers to be close to a power source; but also, as a priority, it should have considered the requirement not to exceed maximum stack weights or individual tier weights, and ensure that heavier containers were not placed over the top of lighter containers. The requirement to place refrigerated containers, especially light ones, in the bottom two tiers, restricts the planner from placing heavier containers on top. If all the rules are obeyed, the weight of a refrigerated container in tier 82 could significantly constrain the weight of other containers above it – with obvious commercial implications.

It was evident from the bay 34 stow plan, that planning had exceeded the maximum stack weight limit in the port outboard stack (row 12), disregarded the principle of 'no heavy over lights', exceeded the cargo securing manual weight limits, and also exceeded in several places the company's self imposed 10% overload limit. The plan was flawed, but was allowed to proceed.

That the errors were not identified by the company's own planning staff, or the terminal, or the last line of defence – the chief officer, is a concern. There is a possibility that commercial pressures to accept the cargo, possibly at short notice, took priority over the need to achieve a stow plan that complied with the requirements of the cargo securing manual.

Implementation of the plan resulted in greater load forces acting upon containers lower down in the stacks and, decisively, greater than calculated load forces applied to the container lashing arrangement. The classification society believed that the calculations used to obtain the data contained within the securing manual left little room for error. Tolerances are fine; it is therefore crucial that in bad weather conditions, when all forces are approaching maximum values, securing manual instructions are fully adhered to.

The proposed stow plan was handed to the chief officer on the ship's arrival in port. With the equipment he had available, there was probably insufficient time for him to analyse a complex loading programme before loading commenced. Once cargo operations were underway, there was little realistic chance of the chief officer imposing his own requirements.

2.5.2 Onboard loading computer

The onboard loading computer programme provided an automatic facility for monitoring total stack weight, and included an alarm when the stack exceeded the cargo securing manual's stated maximum stack weight. The computer could not, however, differentiate between container heights, and therefore was unable to provide a stack height alarm when 9'6" containers, which had different maximum stack weight criteria, were loaded. Similarly, it was unable to monitor for overloaded tier weights; provide information on the forces likely to be exerted on the lashing system; or, advise on the suitability of the lashing system to cope with such forces.

Although the loading computer met flag state requirements, it provided limited facilities to the chief officer who was expected to conduct a full analysis on the proposed stow in accordance with the company's ISM system, and subsequently advise on any problems that had been identified.

2.5.3 Lashing arrangements - requirements

Lashing configuration is a fundamental aspect of safe container ship operations, details of which are contained within the cargo securing manual. In an attempt to ensure that the correct lashing configuration was followed by contracted stevedores, and to serve as a standard operating procedure for cargo officers, a clear and concise colour coded lashing plan for relevant bays was displayed along the port and starboard walkways.

This investigation discovered several examples of incorrect use of lashing bars. Specifically, lashing bars were missing; located in the wrong container; within the correct container but the incorrect securing point; and, in some cases, lashings had been fitted surplus to requirements. Semi-automatic twist lock arrangements, however, appeared satisfactory.

That inconsistencies were identified in the lashing configuration highlights a misunderstanding by ship and shore staff of the fundamental importance of lashing correctly in accordance with the cargo securing manual. The same misunderstanding fails to recognise the fine tolerances embedded within the securing manual calculations, leaving little or no room for error, particularly when operating in heavy weather and facing maximum load forces, as was the case with *P&O Nedlloyd Genoa*.

Lashing equipment manufacturers, designing to classification society standards, are required to design and manufacture equipment based upon forces generated by an angle of heel greater than 22 degrees and equal to but not greater than 30 degrees. A safety factor is incorporated into the design equation to guard against angles of heel greater than 30 degrees, but the effectiveness of the allowance is not quantified.

The number of lashings required to be removed for discharge, and replaced again before sailing, has a significant time, and therefore cost, implication for the ship operator. Although cargo security will always remain paramount for the operator, the need to minimise port costs and to increase operational effectiveness removes the incentive towards greater safety margins using conventional lashing methods.

2.5.4 Lashing arrangements - practicalities

There are a number of reasons why the correct lashing configuration is not always achieved:

- Heavy, cumbersome equipment

  Lashing requires heavy steel lashing bars to be located in relatively small apertures within the container corner casting, up to and including third tier containers. Manhandling lashings to the container securing point is difficult, sometimes made worse by damaged corner fittings. The number of lashings per port that are required to be removed and then re-secured is considerable. The work is tiring and repetitive (potentially leading to a lack of attention to detail and a routine acceptance that lashings may be incorrectly positioned).

- Safe Access

  It can be difficult for a stevedore to obtain safe access between container bays and the ends of outboard stacks. Working with heavy lashings in such areas can be hazardous, often resulting in the application of lashings as close as possible to their designated location. During hours of darkness, the problem is further exacerbated by the lack of adequate lighting, which can further hinder correct positioning of lashings.

- Time pressure

  Turnaround times of container ships leave little room for error. The carefully planned operation integrates several components from the logistic chain. It applies pressure, perceived or otherwise, on ship and shore staff to work to maximum efficiency. This pressure may manifest itself in staff not having the time available to thoroughly check lashing configurations.

- Standard demanded

  The quality and accuracy of the final lashing configuration is dependent upon the standards demanded by the ship's crew, and the stevedoring company's own quality control. Given the cultural differences that existed between the crew and the stevedores, the influence of the latter might have determined the quality of the final lash, even though final approval of this was provided by ship's staff.

- The future

  Given the circumstances of this accident, the trend towards increased container ship size (and the consequent increase in the lashing requirement) may, if turnaround times are proportional and manning levels remain the same, increase the risk of cargo securing discrepancies.

2.6 PRE CONDITION 2 – STACK COMPRESSION

2.6.1 Inspection regime

P&O Nedlloyd, like many of the major container companies, has a system in place that enables the interrogation of container inspection records for any company owned container. It is widely recognised by the industry that there are opportunities for leased or shipper-owned containers to by-pass the inspection process and enter the logistic chain. Second hand containers in various states of repair, sold worldwide, may well re-enter the shipping chain at a later stage.

The task of inspecting millions of containers worldwide should not be underestimated. The International Convention for Safe Containers specifies the procedures to be adopted, but, the reality in parts of the industry is a system based upon trust and the acknowledgement that sub-standard containers could, on occasions, be omitted from the inspection process.

A sub-standard container could have a serious impact on the security of the cargo stow. Although the container at the bottom of row 07 was only 5 years old, its integrity could not be assured. The lowest container in the stack bears the greatest top weight and is most at risk of collapse from the effects of the racking, compression and acceleration forces applied to it.

2.6.2 Cause of the collapse

The cause of the collapse of the container stacks in bay 34 was probably due to a significant increase in downward compression and racking forces exerted on the bottom container in row 07 by the acceleration forces imposed on the deck cargo by the ship's motion in heavy weather; the stow plan in row 07 incorporated heavy over lights; and, tiers 88 and 90 exceeded maximum permissible weights.

The problem was made worse, in that the actual weight of the containers stowed in row 07, tiers 84 and 90, was 6 tonnes over their declared weight.

It is possible that excessive compression forces were exacted by overtightening the lashing bars. However, as these were broken in the collapse, the investigation was not able to prove this theory.

2.6.3 Declaration of weight

Although a container may pass over a weigh-bridge for the purpose of satisfying road transport requirements, there is presently no requirement for it to be weighed prior to shipping. At a container terminal, the gantry crane confirms a total lifted weight for the purposes of safe working load requirements, but neither this information nor the weigh-bridge information is available to the carrier. This appears a missed opportunity for computer integration of weight data into the stow planning process.

The declared weight of a container provided by the shipper and used for all stow planning and onboard stability purposes can, if inaccurate, cause major discrepancies between actual and declared weights. Furthermore, incorrect weight can result in stack overload and the application of excessive compression and racking forces on containers and their lashings.

Although there are no financial gains to be made by the shipper who declares less than actual weight, the industry acknowledges that over-weight containers are a problem. However, as yet this has not justified a requirement for compulsory weighing of containers prior to loading.

2.7 ACCIDENT STIMULUS

2.7.1 Parametric rolling

P&O Nedlloyd Genoa's master was aware of the hazards of parametric and synchronous rolling. However, his primary concern was that of heading into large swell waves, which could lead to slamming. The passage plan was therefore designed to keep the predominant head swell outside the envelope 3 points either side of the bow.

When the roll amplitude became untenable in the deteriorating weather, a course which placed the ship's head more into the swell was adopted, together with a reduction in speed to prevent slamming. Also, 1104 tonnes of water ballast was loaded into the double bottom, which increased the ship's GM from 0.77m to 1.13m.

Shortly before the accident, Transas records show *P&O Nedlloyd Genoa* making an average SOG of 6.2 knots. With swell waves similar in length to the ship's length, and seas predominately on the bow, the encountered wave period would have been approximately 10 seconds **(Annex I)**. Reducing speed to 4 knots would have increased the encountered wave period to 10.5 seconds. Calculations show that the approximate natural roll period for *P&O Nedlloyd Genoa* was 28.5 seconds for a GM of 0.77m, and 24 seconds for GM of 1.13m.

By increasing the GM, the master decreased the roll amplitude, but the natural roll period was getting closer to twice the encountered wave period, and therefore the risk of parametric rolling would have been increased. Slowing down increased the encountered wave period bringing it even closer to half the vessel's natural roll period.

Regardless of whether or not parametric rolling was the cause of the four large amplitude rolls prior to the loss of the containers from bay 34, the large abnormal wave which hit the vessel's port shoulder appears to have stopped the roll amplitude from increasing any further. The confused seas experienced immediately before the accident would also have reduced the risk of suffering parametric rolling; as a steady swell pattern is required to start and maintain the resonant roll motion.

In this incident, the sea conditions do not appear to have been steady enough to induce parametric rolling. Additionally the ship's natural roll period appears at the time to have been just outside the limits for parametric rolling to occur. However, the master's actions were generating the pre-conditions for parametric rolling – something he could have avoided had ship specific advice on the phenomenon been available to him.

2.7.2 Abnormal wave

The existence of abnormal waves has been the subject of much research. Most recently their existence has received greater credibility following the successful *Maxwave* project undertaken by the European Union. The project was able to prove that abnormal waves exist, and that they occur much more frequently than had been previously expected. Important to the case of *P&O Nedlloyd Genoa,* the study concluded that abnormal waves are typically non-linear and break very quickly; in doing so, they unleash a tremendous amount of energy. However, because abnormal waves are fairly infrequent, and because they last for such a short time, the chances of a vessel encountering such a wave are small. Despite this, the witnesses' accounts of events were consistent with the vessel being subjected to the effects of an abnormal wave.

The vessel had completed a significant roll to port, and was in the process of commencing a natural acceleration back to the upright. It is probable that the energy released by the wave at the time of impact with *P&O Nedlloyd Genoa* in the vicinity of bay 14, significantly increased the acceleration force back to the upright. Although the maximum GM for bay 34 had not been exceeded by the ballasting operation, the resultant acceleration force caused by the vessel's natural return to the upright, boosted by the external force of the wave, was far greater than that which, under normal operating circumstances, the vessel could have reasonably been expected to encounter.

Consequently, the resultant forces exerted on the lashings probably exceeded those used for determining the strength and numbers of lashings required by the cargo securing manual. Furthermore, the increase in acceleration forces, combined with container weight distribution, probably caused structural failure of a container.

2.7.3 Passive countermeasures

Although the master had considered the implications of parametric rolling, his uncertainty about the countermeasures required, and the potential delay in analysing the situation and taking preventative action, might have had catastrophic results. It is essential for deck officers serving on container ships sensitive to parametric rolling, to have an awareness of the circumstances and conditions that lead to parametric rolling and be familiar with the preventative actions relevant to their vessel.

Classification societies have the ability to establish how susceptible a particular ship design is to parametric rolling. The data can be displayed in the form of polar plot diagrams for individual hull forms, which provide 'no go' areas in various sea states. The information contained on the plot provides the crew with practical guidance on the measures needed to avoid parametric rolling, and should be specifically targeted at susceptible ship designs.

The effects of abnormal waves, however, must be balanced against the frequency of encounter. Continued research will guide designers, classification societies, and flag states to examine equipment safety factors and whether or not increased safety margins are required. At the present time, good seamanship and heavy weather avoidance measures remain the most effective actions in countering the effects of abnormal waves.

2.7.4 Design countermeasures

Built in 1998, with a minimum freeboard of 3.72m and without stabilisation, *P&O Nedlloyd Genoa* had been safely operating on the North Atlantic trading route for several years. However, subsequent vessels with minimum freeboards in excess of 6.0m now operate the route. When a comparison is made between the two vessel types, the latter design offers proportionately better protection from heavy seas. Further, the vessel was not designed with, nor retrospectively fitted with, any form of passive or active stabilisation system. Such systems significantly assist a vessel's sea keeping abilities, a priority for vessels carrying large quantities of deck cargo trading in areas renowned for heavy weather.

As was P&O Nedlloyd's intention before the accident happened, *P&O Nedlloyd Genoa* has now been removed from the North Atlantic service.

2.8 ISM

The Blue Star Ship Management safety management system – Fleet Instructions Handbook level C and D, addresses the requirements for stability and cargo operations. The instructions are comprehensive and provide adequate guidance for those involved in cargo stability operations.

Instructions contained in safety management systems are often well considered and intentioned, but full compliance with such instructions can sometimes be difficult for staff to achieve in practice. The discrepancies found in *P&O Nedlloyd Genoa*'s lashing arrangements and the stow plan, suggest that while the onboard paper audit trail was being completed, in reality, the cargo officer might have been unable to fulfil his duties to the standard required by the SMS. The chief officer's obligations to assess the cargo stowage plan, and be the ultimate checker of cargo securing arrangements, were also not achieved.

The failures to satisfactorily check the stow plan and lashings, contributed to this accident. Blue Star Ship Management, as part of its ISM internal audit regime, should check not only that their instructions are understood, but also that they are achievable with the manpower available in the turn round times allotted.

Such an assessment would assist the company to identify training requirements and ultimately improve ISM procedures.

SECTION 3 - CONCLUSIONS

3.1 FINDINGS

The following safety issues have been identified by the investigation. They are not listed in any order of priority:

1. Although heavy weather had reduced the quality of rest on 27 January, fatigue is not considered a contributory factor in this accident. [2.2]

2. The nature of the accident, lack of precise dynamic information on the vessel's actual pitch and roll accelerations, and the damage sustained by the affected containers and lashings has meant that an exact cause of accident could not be determined with certainty. [2.4]

3. The bay 34 stow plan showed that planning had exceeded the maximum stack weight limit in the port outboard stack (row 12), disregarded the principle of 'no heavy over lights', and exceeded in several places the company's self imposed ten per cent overload limit. The stow plan was flawed, but was allowed to proceed. [2.5.1]

4. That the errors in the stow plan were not identified by the company's own planning staff, or the terminal, or the last line of defence – the chief officer, is a concern. [2.5.1]

5. Cargo securing tolerances are fine, it is therefore crucial that in bad weather conditions when all forces are approaching maximum values, securing manual instructions are fully adhered to. [2.5.1]

6. Although the loading computer met flag state requirements, it provided limited facilities to the chief officer, who was expected to conduct a full analysis of the proposed stow in accordance with the company's ISM system, and subsequently advise on any problems that had been identified. [2.5.2]

7. That inconsistencies were identified in the lashing configuration highlights a misunderstanding by ship and shore staff of the fundamental importance of achieving a correct lashing configuration in accordance with the securing manual. [2.5.3]

8. In the design and manufacture of container ship lashing equipment, a safety factor is incorporated into the design equation to guard against angles of heel greater than 30 degrees, but the effectiveness of the allowance is not quantified. [2.5.3]

9. Although the container at the bottom of row 07 was only 5 years old, its integrity could not be assured. The lowest container in the stack bears the greatest top weight and is most at risk of collapse from the effects of the racking, compression and the acceleration forces applied to it. [2.6.1]

10. The cause of this collapse was probably due to a significant increase in downward compression and racking forces exerted on the bottom container in bay 34, row 07. [2.6.2]

11. The sea conditions do not appear to have been steady enough to induce parametric rolling, and the ship's natural roll period appears to have been just outside the limits for parametric rolling to occur. [2.7.1]

12. The resultant acceleration force caused by the vessel's natural return to the upright and the external force imparted by an abnormal wave, was probably far greater than that which, under normal operating circumstances, the vessel could have reasonably been expected to encounter. [2.7.2]

13. An awareness of the circumstances and conditions that lead to parametric rolling and familiarity with types of preventative action is a necessary prerequisite for deck officers serving on container ships sensitive to parametric rolling. [2.7.3]

14. The vessel was not designed with, nor retrospectively fitted with, any form of passive or active stabilisation system. Such systems assist a vessel's sea keeping abilities, a priority for vessels carrying large quantities of deck cargo trading in areas renowned for heavy weather. [2.7.4]

15. Blue Star Ship Management, as part of its ISM internal audit regime, should check not only that its instructions are understood, but also that they are achievable with the manpower available in the turn round times allotted. [2.8]

SECTION 4 - ACTION TAKEN

Blue Star Ship Management has:

- Recognised the need to provide its vessels with improved stability computers capable of fully analysing a proposed stow plan. The new software is capable of making a comparison between the cargo securing manual lashing arrangement and the maximum forces likely to be encountered within the proposed stow, adapting the lashing configuration accordingly. The operator is alerted to any discrepancies including stack weights, tier weights, and heavy over light.
- Begun installing IBM Loadstar stability software to all of its vessels. The shore-based cargo planning staff will continue to utilise Powerstow cargo planning software, and they will also be provided with Loadstar stability software which will be used to run a last check on the final loading condition prior to distribution to the loading terminal and the ship's command.
- Ensured all deck officers have now received formal training, undertaken by IBM, on the method of operation of the *IBM Loadstar* stability computer.
- Undertaken to train all masters in the actions to be taken in the event of heavy weather, and the techniques used to avoid it.

MARIN has:

- Initiated The *Lashing At Sea Project*, aiming to bring together key components of the logistic chain. It is intended that the study will examine the physics involved in lashing loads and develop future guidance for the lashing of container ship deck cargoes. Shipping companies, lashing manufacturers, Protection and Indemnity clubs, classification societies, flag states, and national governments will participate in discussing and tackling the issues relating to lashing equipment and procedures onboard ships.

  The project will:

  - Review previous accidents.
  - Review present-day lashing equipment.
  - Acquire data of actual occurring load forces.
  - Examine current design assumptions.
  - Recommend changes to operational procedures, and the necessary international rules underpinning such procedures.

  Blue Star Ship Management will participate in the study which will begin in June 2006, and complete in June 2008.

MCA and HSE have:

- Prior to the accident, agreed to carry out a joint study to determine the seriousness of structural deficiencies in containers. The study will examine a random selection of containers located at various United Kingdom ports.
- Issued to their surveyors and HSE port inspectors instructions for the inspection of containers, based upon current IMO guidance on serious structural deficiencies in containers, and appropriate photographs to accompany the text. The guidelines will be circulated to the ports industry and the Chamber of Shipping.
- Plans to audit a random selection of companies who use the Approved Continuous Examination Programme.

  The study is expected to complete at the end of 2006.

SECTION 5 - RECOMMENDATIONS

Blue Star Ship Management is recommended to:

2006/196 Undertake a risk assessment on the vulnerability of its vessels to parametric rolling. Should significant risk exist, implement control measures to include vessel specific guidance to masters on when parametric rolling may be encountered, and instructions on how to avoid it.

2006/197 Emphasise to its crews the importance of lashing checks to ensure compliance with the cargo securing manual and, when correct lashing can not be achieved, identify alternative arrangements or impose limitations as necessary to ensure the safety of the cargo.

2006/198 Introduce an independent check of lashing arrangements on all vessels, as part of its internal ship specific ISM audit regime.

The Maritime and Coastguard Agency is recommended to:

2006/199 Consult with the United Kingdom Chamber of Shipping and representatives from the marine insurance industry, with the objective of including in ships' stability information, for the use by the ship's crew, vessel specific parametric rolling data.

2006/200 Use the data from the current MCA/HSE study into container damage, to review:

- container structural strength and rigidity standards; and
- the need to improve container inspection regimes.

2006/201 In consultation with MARIN, review the contents of container vessel cargo securing manuals and, if appropriate, issue further guidance on their minimum required content.

Marine Accident Investigation Branch
August 2006

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