



The Shipowners' Protection Limited
St Clare House
30-33 Minories
London
EC3N 1BP

Tel: +44 (0)20 7488 0911
Fax: +44 (0)20 7480 5806
Email: info@shipowners.co.uk

www.shipownersclub.com

Basic Stability for Small Vessels

Index

2	Introduction
4	Lack of Understanding of Stability Criteria
6	Stability Requirements
14	Failure to Observe Basic Principles
16	Pre Load Requirements
16	Free Surface Effect
17	Estimating Centre of Gravity
17	Container Heights
17	Container Weights
18	Draft
19	Cranes and Derricks
20	Overloading
20	Reductions in Freeboard
21	Failure to Confirm the Vessel's Condition
22	Errors in Calculations
24	Computers
27	Conclusion
28	Appendices
30	Appendix 1: Proforma Calculation Sheet (VCG)
31	Appendix 2: Examples of Calculating Stability Conditions
42	Case Studies

Introduction

Many different types of vessels are entered in the Club, each possessing their own unique stability requirements.

Generally speaking tankers, bulk carriers and passenger vessels retain more than sufficient stability to ensure compliance with the regulations when fully loaded. Dry cargo ships, container carriers and barges are subject to large reductions in stability when loaded therefore care must be taken to ensure the condition of the vessel complies with the regulations which lay down the minimum stability requirements. If these are not complied with, then the safety of the vessel, her crew and cargo will be compromised.

Over the years the Club has dealt with a number of claims involving general cargo vessels and container ships that have been caused by the vessel having inadequate stability and being allowed to undertake a voyage in that condition. There have also been a large number of similar incidents involving flat top barges loaded with break bulk, containers, scrap metal or combinations of all three. In most cases the lack of sufficient stability has not been made apparent until an external force has acted on the vessel caused by heavy sea conditions, a sharp alteration of course or the pushing of an assisting tug.

Prompted by these claims, the Club has published this booklet on basic stability aimed primarily at Members and crews of dry cargo vessels. The purpose of the booklet is to explain the fundamentals of stability and explanations as to how it can be determined which is not always readily understood by crews and personnel responsible for loading vessels. All too often the GM is taken to be the measure of a vessel's stability and this is an incorrect assumption.

Appendix 2 contains a number of stability calculation examples and the Case Studies describe the circumstances leading to actual related claims dealt with by the Club.

Notwithstanding the type of dry cargo vessel or barge, the predominant cause of claims we see is a lack of adequate transverse stability on vessels carrying containers. Although the majority of incidents occurred either on specific container vessels or cargo vessels carrying containers, stability issues are equally important on all types of vessels. Fortunately most incidents have not resulted in a total loss. This is mainly because as the vessels listed over, the cargo has fallen overboard and positive stability was regained, allowing the vessel to return to near upright. In other cases, the vessels developed an angle of loll and upon arrival in port, with the assistance of the authorities, the upper tiers of containers were removed and positive stability was regained by lowering the overall KG. If a vessel were to experience the serious effects of insufficient stability whilst in a heavy sea where dynamic stability is crucial, the results may not be so fortunate with loss of the vessel and life a real possibility.

The Club has also dealt with claims arising from flat barges carrying scrap metal. In each case the vessel capsized but did not sink, but in all probability the cause was inadequate stability compounded by the shifting of cargo.

Causes

We have found it rare that an unsatisfactory situation regarding the vessel's stability develops through a single cause. In our experience it usually arises through a collection of one or more of the following factors:-

- Lack of understanding of the stability criteria
- A failure to observe basic principles
- Arithmetical errors in calculations



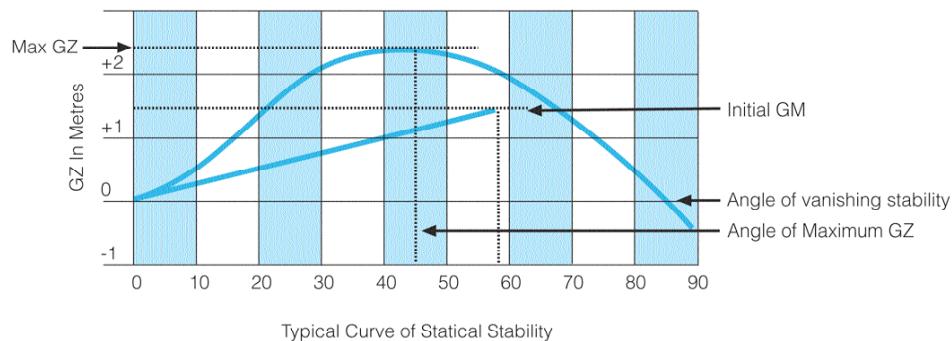
Lack of Understanding
of Stability Criteria

During investigations into claims, we have found that there have been occasions when the senior officers responsible for cargo operations were not familiar with the vessel's stability manuals, or the onboard Class approved stability/loading instrument program. Members and Masters must ensure that all personnel involved in cargo operations make themselves thoroughly familiar with the contents of the stability manual and the operating parameters therein.

Stability Requirements

The IMO has issued minimum stability criteria for different types of vessel and these criteria are taken into account at the vessel's design stage and when calculating the data for the stability book.

Sea staff and shore personnel involved with marine operations are usually aware of the minimum permitted height for the GM and can mistakenly use this as the sole measure of a vessel's stability. However, this is only one single criterion, and compliance with this alone is not enough to guarantee adequate stability. There are other equally or more important factors which have to be taken into account to ensure that the vessel has sufficient positive stability for the voyage. In the Club's experience these other limitations are not always fully understood or taken into account.



Utilising the vessel's stability data, the Curve of Statical Stability can be drawn and from this the vessel's dynamical stability can be determined. Dynamic stability is the ability of a vessel to resist or overcome external heeling forces and is directly proportional to the area underneath the curve of statical stability. Thus the more dynamic stability a vessel has, the greater the ability to resist external forces.

The IMO sets down minimum requirements for a vessel's stability (which vary according to ship type) stipulating:-

- Area under the curve from 0 to 30 degrees
- Area under the curve from 0 to 40 degrees or the angle at which flooding commences
- Area under the curve from 30 to 40 degrees or the angle at which flooding commences
- Minimum Righting Arm at 30 degrees
- Angle from 0 degrees to maximum righting arm
- Minimum GM at equilibrium.

When undertaking manual calculations, the GM can be calculated with relative ease but the other criteria involve long and complex calculations. To overcome this, the requirement is for the stability book to provide the Master with an easy means to obtain a quick check to ascertain whether or not the vessel's stability complies with all the minimum requirements.

This information normally takes the form of either a table and/or a graph indicating the maximum Vertical Centre of Gravity (KG) permitted for a particular displacement. Providing the vertical centre of gravity lies within the parameters laid down in the vessel's stability book, the vessel's stability complies with the minimum requirements stipulated by the IMO/Flag State for that type of vessel. (Note: Standard Loading conditions are usually included in the stability book as guidelines).

Depending on the vessel type and the naval architect, the stability information can be presented in differing formats. It is therefore important that the persons responsible for the stability of the vessel are fully familiar with the information and how it is presented for their vessel.

The following is an example of a table found within the stability book for a barge type vessel.

Displacement (Metric Tonnes)	Max VCG	LIM1	LIM 2	LIM3	LIM4	LIM5	LIM6
2800.00	9.164m	656%	768%	0%	264%	3d	3559%
2900.00	8.989m	636%	789%	0%	256%	2d	3448%
3000.00	8.814m	616%**	700%	0%	248%	2d	3353%
3100.00	8.638m	597%	650%	0%	240%	2d	3273%
3300.00	8.460m	579%	600%	0%	232%	2d	3207%
3400.00	8.282m	561%	588%	0%	224%	2d	3153%
3500.00	8.103m	544%	570%	0%	216%	2d	3113%
3600.00	7.922m	527%	529%	0%	208%	2d	3085%

Limit	Description	Minimum Requirement
LIM 1	Area under the curve from 0 degrees to 30 degrees	> 0.550 m- rad*
LIM 2	Area under the curve from 0 degrees to 40 degrees or the angle at which flooding commences	> 0.0900 m-rad*
LIM 3	Area under the curve from 30 degrees to 40 degrees or the angle at which flooding commences	> 0.0300 m-rad*
LIM 4	Minimum Righting Arm at 30 degrees	> 0.200m*
LIM 5	Angle from 0 degrees to maximum righting arm	25.00 deg*
LIM 6	Minimum GM at equilibrium.	0.150m*

*The limits used in this example are for illustration purposes only. The vessel's stability book should be consulted in order to determine the limits that apply to the vessel in question.

**The figures in the table indicate the percentage of the limits set down by IMO. For example in the above table LIM 1 is exceeded by 616% - actual area under the curve is 3.608 m-rad.

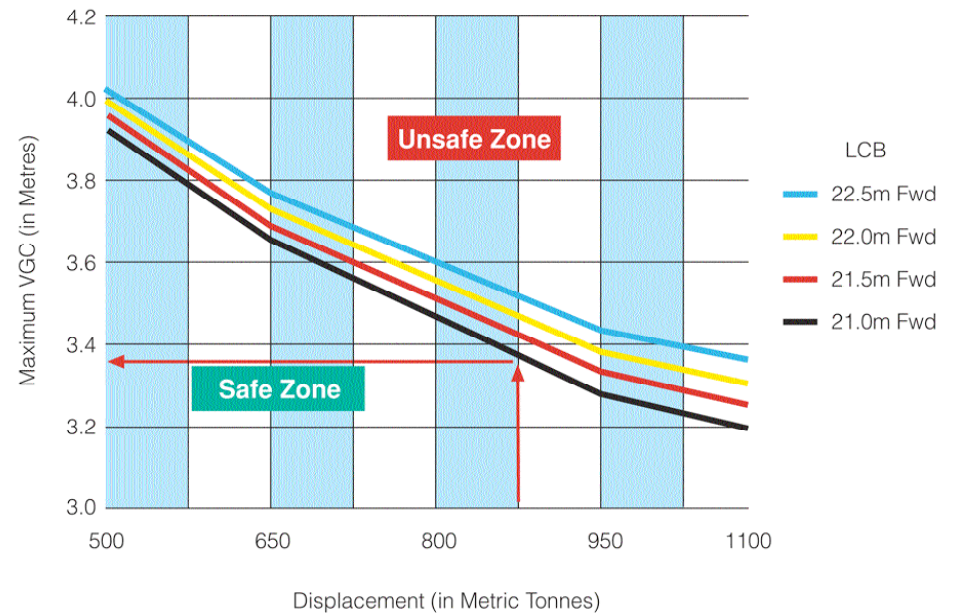
Example

With a displacement of 3350 metric tonnes, this vessel is permitted to have a maximum

$$\text{VCG of } 8.460 - \left(\frac{8.460 + 8.282}{2} \right) = 8.371 \text{ metres.}$$

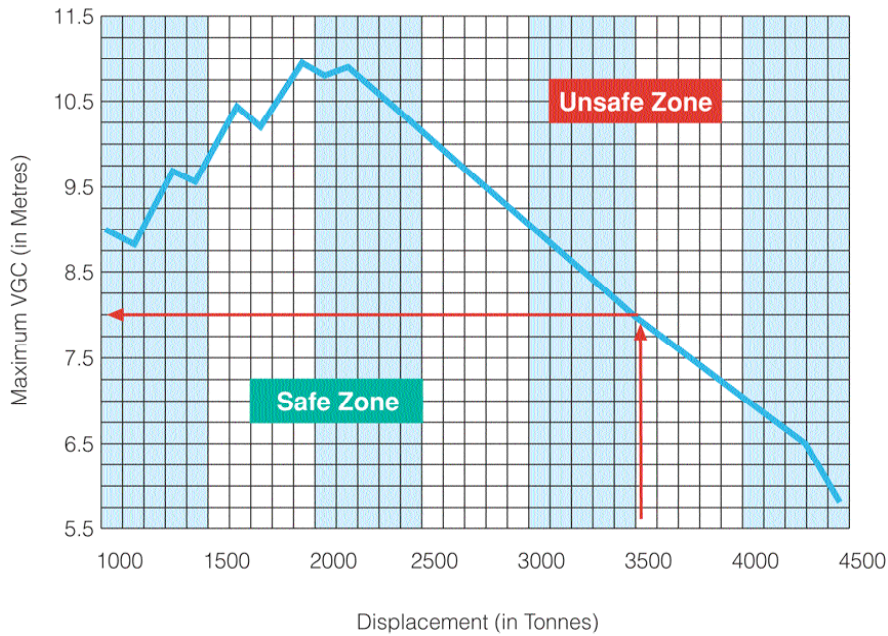
In this example the limiting factor is LIM3 which is at the minimum requirement for all displacements. Providing the vessel's VCG (KG) does not exceed the stated value for the relevant displacement (interpolating as necessary), the vessel's intact stability lies within the acceptable limits.

The following graph shows the maximum VCG versus Displacement for a ship shape vessel when the Longitudinal Centre of Buoyancy (LCB) has to be taken into consideration. Providing the vessel's VCG lies within the graph, the stability complies with the minimum requirements.



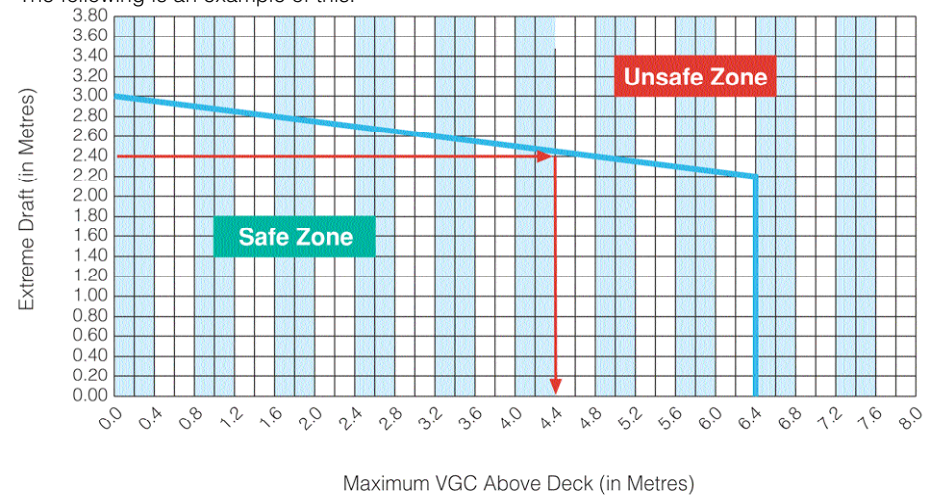
In this example, a vessel with an LCB of 21m forward of midships and with a displacement of 875mt, the maximum permitted Verticle Centre of Gravity (VGC) is 3.39m

This graph shows the maximum permitted VCG against displacement for a barge. As with the previous graph, providing the vessel's condition lies below the graph line, all the stability requirements are complied with.



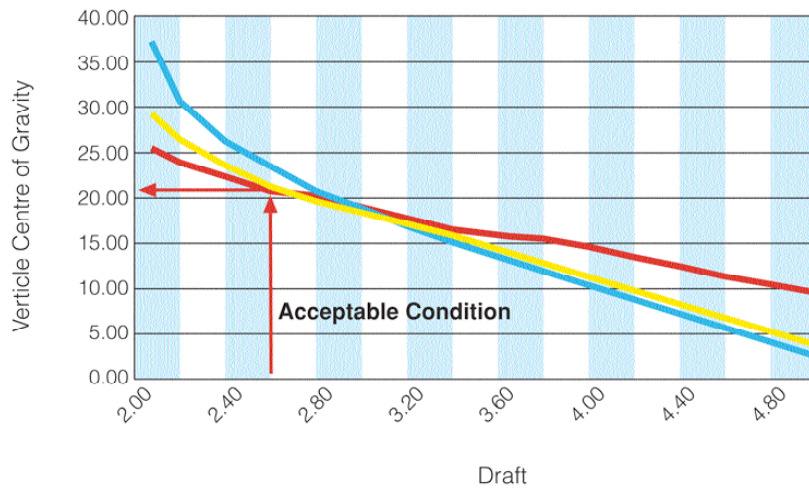
In this example, for a displacement of 3550mt, the maximum permitted VCG (KG) is 8.0m.

For some vessels, the criteria is shown relative to the vertical centre of gravity of the cargo above the main deck and not the VCG of the vessel (the vessel's KG related to the baseline). The following is an example of this.



In this example, for a draft of 2.40m the maximum verticle centre of gravity of the cargo above the main deck is 4.4m

In the following graph the governing limits for area under the GZ Curve, angle of heel due to wind and minimum range of stability are plotted individually. When the information is presented in this way, confusion can exist but in every case the **minimum** VCG must be complied with i.e. for some drafts one criterion might govern the maximum KG and for others it might be one of the other two criteria.



- █ CR1 = Area under GZ Curve up to the angle of maximum righting lever
- █ CR2 = Static angle of heel due to wind load
- █ CR3 = Minimum Range of stability

Example

With a draft of 2.60 metres this vessel is permitted a maximum VCG of 21.0 metres.



Failure to Observe
Basic Principles

Pre Load Requirements

Persons responsible for loading a vessel or barge, must ensure that they are made aware of the cargo weights to be loaded and the height of their centres of gravity. This information, wherever possible should be determined before loading operations are commenced, so that a safe load sequence can be calculated beforehand and that no nasty surprises are encountered at the last minute.

Notwithstanding any pressure placed on the vessel by the shore terminal, the responsibility for loading remains with the Master alone.

Free Surface Effect (FSE)

The free surface effect of any liquids on board has a marked impact on the vessel's stability by reducing the effective GM (or conversely by effectively increasing the KG). Some of the claims the Club has dealt with have highlighted the fact that either no account of FSE had been taken, or if it had, the data was incorrectly applied.

Ideally, ballast tanks should either be pressed up full or completely empty so there is no free surface effect to consider. However, when this is not possible, it is best practice to initially allow the maximum FSE for each and every slack tank in the stability calculations. If the stability condition is then noted to be critical for any stage of the voyage, the actual free surface moments can be applied to the calculation in order to obtain an accurate assessment of the vessel's condition.

It is essential that the FSE is always calculated and applied correctly and Masters should be given clear guidance on the Member's requirement in this regard. It should also be borne in mind that free water on the decks has the same effect and when the stability condition is critical it can have a major impact.

Estimating Centre of Gravity

Masters are reminded of the need for accurate estimation of a cargo's centre of gravity. Errors can accumulate if incorrect assumptions are made which can then compromise a vessel's stability. Estimations should always err on the side of safety (i.e. it is better to estimate too high rather than too low). The centre of gravity of a container should always be assumed to be at mid height unless it is known to be different (some Classification Societies use 0.4 x container height).

Container Heights

Consideration should be given to ensuring the correct container heights are used when calculating the VCG. Whilst the actual difference between an 8' 00", 8' 06", 9' 00" or 9' 06" (Hi Cube) high container is not significant when considered individually, a large number of incorrect heights can have an adverse effect on the final VCG if not allowed for, particularly on smaller vessels.

Container Weights

The incorrect declaration of container weights is a problem encountered throughout the container shipping world and can manifest itself more in the local trades that our Members operate in rather than the main line trade.

Unfortunately this problem is one that is generally outside the control of Masters and shipowners. Visually there is no means to assess the weight of a container and the Master has to take the manifest or bill of lading at face value. This cannot be totally relied on, it places more emphasis on the need to monitor the vessels actual drafts during loading. If discrepancies arise they can be investigated further or allowed for by assuming the worst case scenarios.

Another problem with not knowing the weights of containers loaded, is the possibility that

heavier units can be loaded on top of lighter ones with the subsequent reduction in stability. This problem may also occur when for the sake of economy and time, the number of container lifts are kept to a minimum and heavier containers are placed in an unsuitable location i.e. on top of lighter ones.

The Club has dealt with one claim where it was found that the overall difference between actual and declared weights was 10%. In the extreme, containers declared as being empty were found weighing in excess of 20 tonnes.

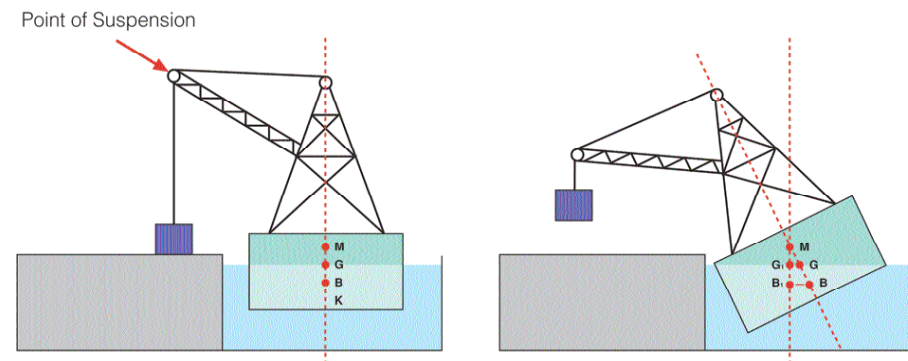
Although this problem can cause unacceptable situations, it is largely out of the control of the Master, however the potential for associated problems should always be kept in mind.

Draft

During cargo operations, it is important that the draft is observed visually, forward, aft and amidships on both sides at regular intervals and a comparison made to the calculated or expected draft. Any variances must be investigated. We have dealt with claims where little attention has been paid to the draft and vessels have subsequently been found overloaded which has contributed to a reduction in stability.

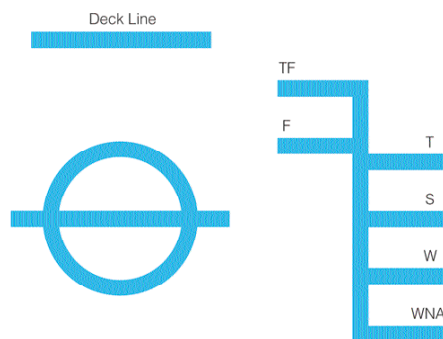
Cranes and Derricks

When ship's gear is being used for cargo operations, the vessel's centre of gravity always moves towards the weight loaded, away from a weight discharged or in the direction the weight is moved. When ship's gear is used, the instant at which the container is clear of the deck, quay or wherever it rests, the weight is transferred to the point of suspension on the crane or derrick. As a result, the vessel's vertical centre of gravity will be raised and moved in a direction towards the weight, effectively reducing the vessel's stability. This can be a crucial factor during the final stages of loading and early stages of discharging when stability could be critical. Care must be taken when calculating the stability at such times and in particular, attention should be paid to the **Free Surface Effect**. It might be necessary to ballast the double bottom tanks in order to ensure adequate stability during the lifting operation.



Overloading

Following plan approval and periodic loadline surveys, all vessels are issued with a Loadline Certificate by the Flag State (or issued by a Classification Society on behalf of the Administration). This document alone is the overriding authority governing the minimum freeboard a vessel is permitted to load to. The Club has known cases whereby information from an unapproved stability manual was used for loadline purposes and this was found to be incorrect.



A vessel is automatically considered unseaworthy if she puts to sea with a freeboard less than that permitted. Masters should be made aware of the fact that if a vessel is overloaded the P&I cover may well be invalidated.

Reductions in Freeboard

The Club is aware of instances whereby the freeboard of a vessel has been reduced (with the agreement of the local Authorities) because it is trading in coastal or local waters. If a reduction is being considered then it is **imperative** that a study of the vessel's revised stability conditions is carried out by a Naval Architect to ensure they still comply with the regulations. A reduction in freeboard to permit a greater cargo carrying capacity for the vessel will result in a loss of reserve buoyancy and this consequently will reduce the dynamic stability of the vessel and the ability to resist external forces.

Failure to Confirm the Vessel's Condition

It is imperative that at all stages of a vessel's cargo operations the vessel maintains a stability condition that complies fully with the stability criteria for that vessel. This requirement is equally important for all stages of the voyage as well, and consideration has to be taken for the consumption of fuel, water and stores and the free surface effects this might introduce. It might be necessary to ballast the vessel to compensate for these consumables being used. If this action is necessary, then the free surface effect of water being introduced into the ballast tanks must be taken into account before any ballasting operations are carried out. It is not uncommon for ballasting a tank to initially make the situation worse before an improvement in the stability condition is achieved.

Errors in Calculations



The Club appreciates that the pressures placed on Masters when in port undergoing cargo operations means that time is often short. However such pressures do not diminish the Master's responsibilities in ensuring the vessel is in a seaworthy condition at all times. This includes correctly assessing the vessel's stability.

We have seen many instances whereby errors have been made in calculations and unfortunately they are always negative errors – vessels do not have related claims because of a positive stability condition.

If the calculations are being made by hand, then it is good practice to draw up a pro forma prior to the assessment being made. This will require fewer inputs to be made into the calculation at the time of execution and reduce the exposure to mistakes. A suggested format is contained in Appendix 1.

Computers

The Club recommends that all dry cargo vessels especially those carrying containers are provided with a computer (loading instrument) and proprietary software specific to the vessel for calculating transverse stability and if applicable, longitudinal strength. By using such software (which is Class approved) the potential for arithmetical errors is reduced as calculations are carried out automatically, data input is minimal and the results are obtained almost instantly. If the loading condition is such that the minimum stability requirements are not met, the areas of concern are highlighted to the user.

In the early days of PC use on board vessels, the computers for stability calculations were required to be "type approved", however this is not always a requirement today and Members should clarify the position with their Classification Society. A dedicated computer should be used for stability purposes and no other software should be loaded so that there is no possibility of the stability program becoming corrupted.

The following page shows a computer screen output from a stability software package developed and marketed by Shipboard Informatics Ltd. London, which is one of many software packages available.

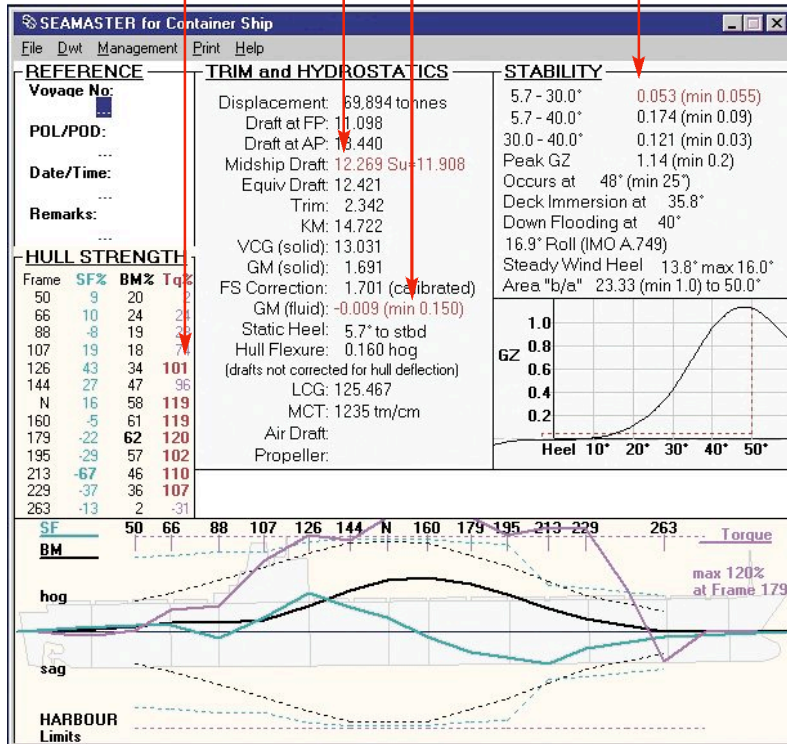
The programs are relatively easy to use as they are tailored to meet each vessel's configuration (e.g. weight and buoyancy configuration). The deadweight data for cargo and consumables is entered and the stability calculations are made immediately. If any of the minimum stability criteria is not met, the error is highlighted in red, bringing it to the attention of the user.

Such a program removes the majority of the possible errors that can occur when carrying out manual calculations. It permits more complex calculations to be carried out quickly which gives the Master all the stability (and longitudinal strength) information required in order to ensure the vessel is in an acceptable condition for departure, arrival and during all stages of the voyage.

In addition to the advantages already stated, because the programs are easy to use it enables the inevitable last minute changes to loading plans to be thoroughly investigated quickly.

The ease of use will also encourage more frequent investigations into the stability condition of the vessel.

Stability criteria outside parameters



Stability Software Screen Display

Conclusion

The Master or person responsible for the loading of the vessel should not depart a berth until the intact stability of the vessel has been calculated and it is confirmed that the statutory stability requirements, as included in the stability book approved by Class on behalf of the respective flag administration are complied with during all stages of the voyage. If it is not possible to comply, the Master should take whatever action is necessary in order to arrive at a condition that ensures the vessel is seaworthy throughout the voyage. Such action may include off loading cargo, ballasting the vessel or both.

It is good practice for Members to have clear written instructions for their Masters to cover such eventualities as stated above. It is also prudent for these instructions to cover the requirement for all stability issues to be adhered to and what action to take if they cannot be. Providing Masters know they have the backing of their operating company, there is less chance of errors being made and vessels putting to sea in an unseaworthy condition especially when pressure is brought to bear by shippers.

The aim of this booklet is to provide basic guidance to an important subject that is not always understood fully or clearly explained. A vessel's stability and loading manual is the only authorised source of stability information for a vessel and the requirements therein must always be followed – this booklet is designed to help the reader understand this information.



Appendix 1

Proforma Calculation Sheet – Vertical Centre of Gravity

(For a Cargo of Containers)

Compartment/Location		Weight	VCG	Vertical Moment	FS Moment (98% Full)
		A	B	AxB	
Cargo					
Row 1	Tier 1				
	P				
	Mid(P)				
	Mid(S)				
	S		1.22		
Row 1	Tier 2				
	P				
	Mid(P)				
	Mid(S)				
	S		2.44		
Row 1	Tier 3				
	P				
	Mid(P)				
	Mid(S)				
	S		3.66		
Row 2	Tier 1				
	P				
	Mid(P)				
	Mid(S)				
	S		1.22		
Ballast & Misc. Tanks					
Fore Peak SWB					
					145.81
No.1 SWB (P)					
					54.31
					54.32
Lt Ship					
		1156	3.2	3699.20	
Totals					

$$KG = \frac{\text{Weight Moments} + \text{Free Surface Moments}}{\text{Total Displacement}}$$

Note:

The above is only intended as an example to show the relative ease with which a vessel's Vertical Centre of Gravity can be calculated. For vessels other than barges calculations can be made including the longitudinal aspect of the vessel's condition to calculate the expected trim etc.

Appendix 2

Example of Calculating Stability Conditions

The following pages show various examples of calculating whether or not a barge's stability complies with the stability criteria contained within her stability book for different combinations of cargo. Although the examples are for a barge, the principles apply equally to all vessels.

The data used in the examples are from an actual stability book, and the limiting values in the summary table below are used in each example.

Summary Table

Deck Cargo Barge (210ft x 52ft x 12ft)

Extreme Draft (Metres)	Cargo V.C.G Above Deck (Metres)	Deadweight (Tonnes)
2.855	0.893	2171.09
2.500	4.058	1815.78
2.250	5.950	1570.03
2.000	7.548	1328.06
1.500	10.161	856.09
1.000	14.199	401.77
0.750	16.906	182.49
& below		

(Intermediate Values By Interpolation)

Notes:

1. Cargo vertical centre of gravity (C.V.C.G) include all above deck cargo support structures, deck dunnage and all lashings required to secure deck cargo.
2. Recommended maximum height of C.V.C.G above deck at corresponding mean keel draft to be incorporated in the Loadline Certificate.

Example 1

1st and 2nd tiers heavy 20ft containers (20t), 3rd and 4th tiers empty 20ft containers (2.4t).

Assumption for calculation:-

- Each tier fully stacked at 5 rows across by 8 containers fore and aft
- Vertical Centre of Gravity, VCG, of containers is half height = half 2.59m = 1.295m
- Weight of heavy container = 20t, weight of empty container = 2.4t

Taking moments about the deck to calculate the total cargo vertical centre of gravity, CVCG, above the deck

Tier	Total Weight Tonnes (W)	VCG above deck (m)	Moment (W x VCG)
1st	5 x 8 x 20 = 800	1.295	1036
2nd	5 x 8 x 20 = 800	3.885	3108
3rd	5 x 8 x 2.4 = 96	6.475	621.6
4th	5 x 8 x 2.4 = 96	9.065	870.24
	1792		5635.84

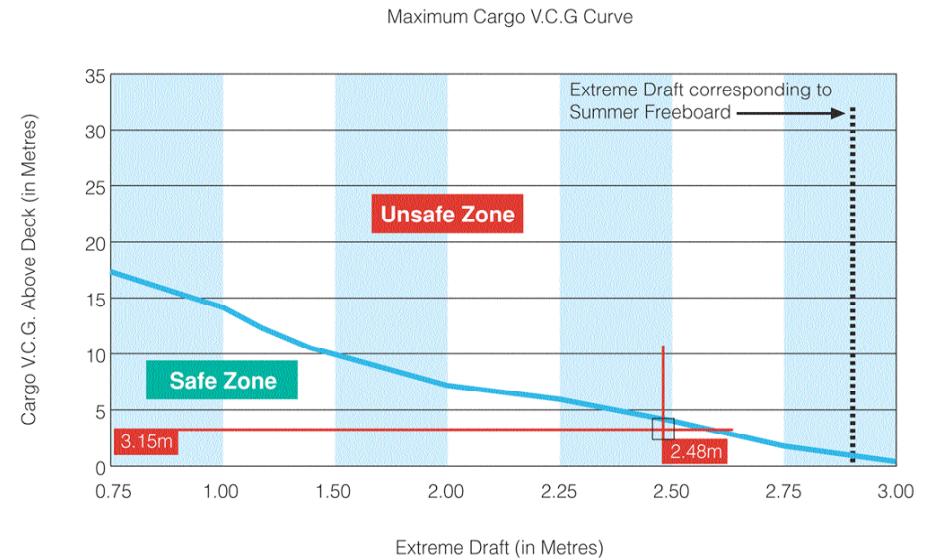
CVCG = $\frac{\text{total moment}}{\text{total cargo weight}} = \frac{5635.84}{1792}$ (total cargo weight) = **3.15m**

From the Summary Table on page 31 we derive by interpolation that for a cargo weight (deadweight) of 1792 we find that extreme draft is **2.48m** and the maximum permissible cargo VCG above deck is **4.24m**

Extreme Daft (m)	Cargo VCG (CVCG) above deck (m)	Deadweight (t)
2.500	4.058	1815.78
2.476	4.242	1792
2.250	5.950	1570.03

The calculated CVCG of 3.15m is less than the maximum permissible CVCG of 4.24m and therefore is within the permissible stability criteria and is safe.

With the extreme draft of 2.48m and the CVCG of 3.15m we can also determine using the maximum cargo VCG curve that the load plan is in the Safe Zone (see figure below).



Example 2

1st and 2nd tiers heavy 40ft containers (30t), 3rd and 4th tiers empty 40ft containers (4t).

Assumption for calculation:-

- Each tier fully stacked at 5 rows across by 4 containers fore and aft
- Vertical Centre of Gravity, VCG, of containers is half height = half 2.59m = 1.295m
- Weight of heavy container = 30T, weight of empty container = 4.0T

Taking moments about the deck to calculate the total cargo vertical centre of gravity, CVCG, above the deck

Tier	Total Weight Tonnes (W)	VCG above deck (m)	Moment (W x VCG)
1st	5 x 4 x 30 = 600	1.295	777
2nd	5 x 4 x 30 = 600	3.885	2331
3rd	5 x 4 x 4 = 80	6.475	518
4th	5 x 4 x 4 = 80	9.065	725.2
	1360		4351.2

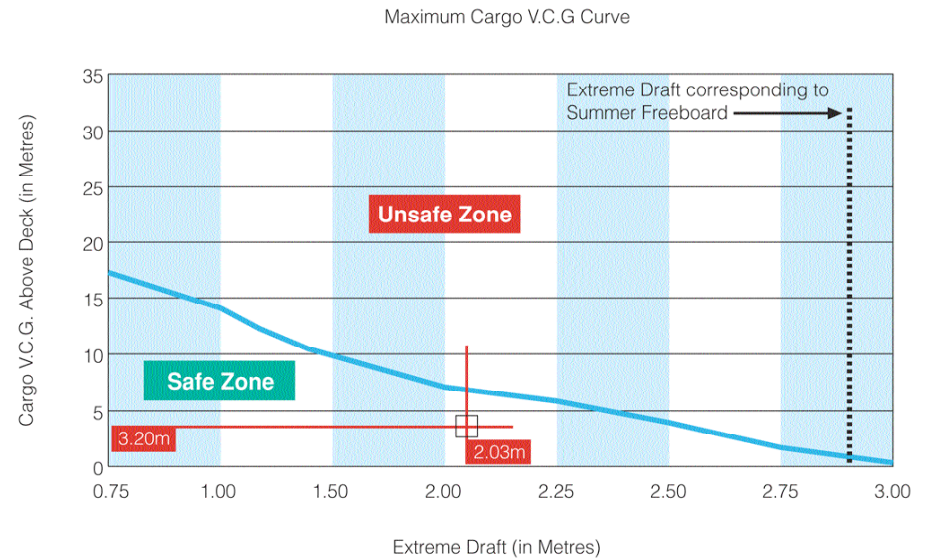
CVCG = total moment ÷ total cargo weight = 4351.2 ÷ 1360 (total cargo weight) = **3.20m**

From the Summary Table on page 31 we derive by interpolation that for a cargo weight (deadweight) of 1360 we find that extreme draft is **2.03m** and the maximum permissible cargo VCG above deck is **7.34m**.

Extreme Draft (m)	Cargo VCG above deck (m)	Deadweight (t)
2.250	5.950	1570.03
2.033	7.337	1360
2.000	7.548	1328.06

The calculated CVCG of 3.20m is less than the maximum permissible CVCG of 7.34m and therefore is within the permissible stability criteria and is safe.

With the extreme draft of 2.03m and the CVCG of 3.20m we can also determine using the maximum cargo VCG curve that the load plan is in the Safe Zone (see figure below).



Example 3

1st and 2nd tiers 20ft containers of (15t), 3rd tier 20ft containers (8t), 4th tier empty 20ft containers (2.4t).

Assumption for calculation:-

- Each tier fully stacked at 5 rows across by 8 containers fore and aft Vertical Centre of Gravity, VCG, of containers is half height = half 2.59m = 1.295m
- Weight of empty 20ft containers is 2.4t

Taking moments about the deck to calculate the total cargo vertical centre of gravity, CVCG, above the deck

Tier	Total Weight Tonnes (W)	VCG above deck (m)	Moment (W x VCG)
1st	5 x 8 x 15 = 600	1.295	777
2nd	5 x 8 x 15 = 600	3.885	2331
3rd	5 x 8 x 8 = 320	6.475	2072
4th	5 x 8 x 2.4 = 96	9.065	870.24
	1616		6050.24

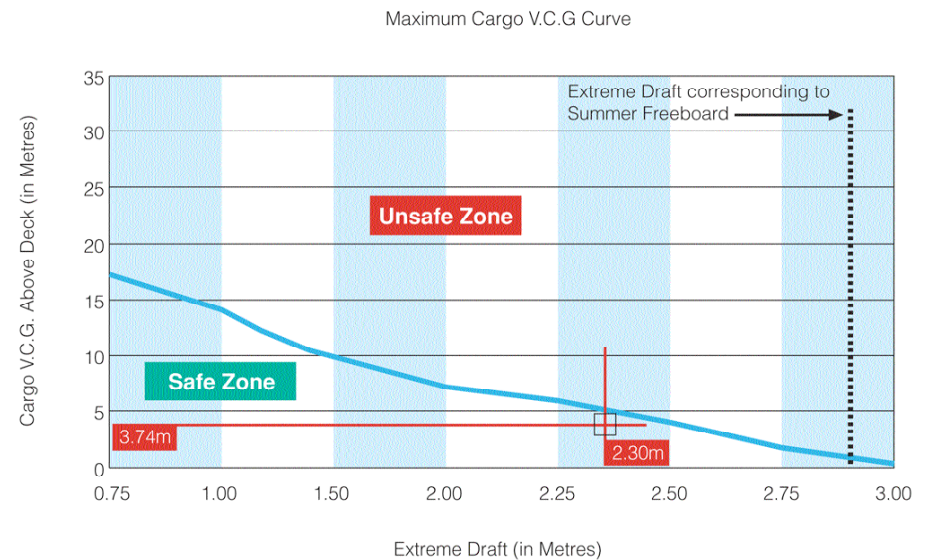
CVCG = total moment ÷ 1616 (total cargo weight) = **3.74m**

From the Summary Table on page 31 we derive by interpolation that for a cargo weight (deadweight) of 1616T we find that extreme draft is **2.30m** and the maximum permissible Cargo VCG above deck is **5.60m**

Extreme Draft (m)	Cargo VCG above deck	Deadweight (t)
2.500	4.058	1815.78
2.297	5.596	1616
2.250	5.950	1570.03

The calculated CVCG of 3.74m is less than the maximum permissible CVCG of 5.60m and therefore is within the permissible stability criteria and is safe.

With the extreme draft of 2.30m and the CVCG of 3.74m we can also determine using the maximum cargo VCG curve that the load plan is in the Safe Zone (see figure below)



Example 4

1st and 2nd tiers heavy 20ft containers (20t) and 3rd tier 20ft containers (10t).

Assumption for calculation:-

- Each tier fully stacked at 5 rows across by 8 containers fore and aft
- Vertical Centre of Gravity, VCG, of containers is half height = half 2.59m = 1.295m

Taking moments about the deck to calculate the total cargo vertical centre of gravity, CVCG, above the deck

Tier	Total Weight Tonnes (W)	VCG above deck (m)	Moment (W x VCG)
1st	5 x 8 x 20 = 800	1.295	1036
2nd	5 x 8 x 20 = 800	3.885	3108
3rd	5 x 8 x 10 = 400	6.475	2590
	2000		6734

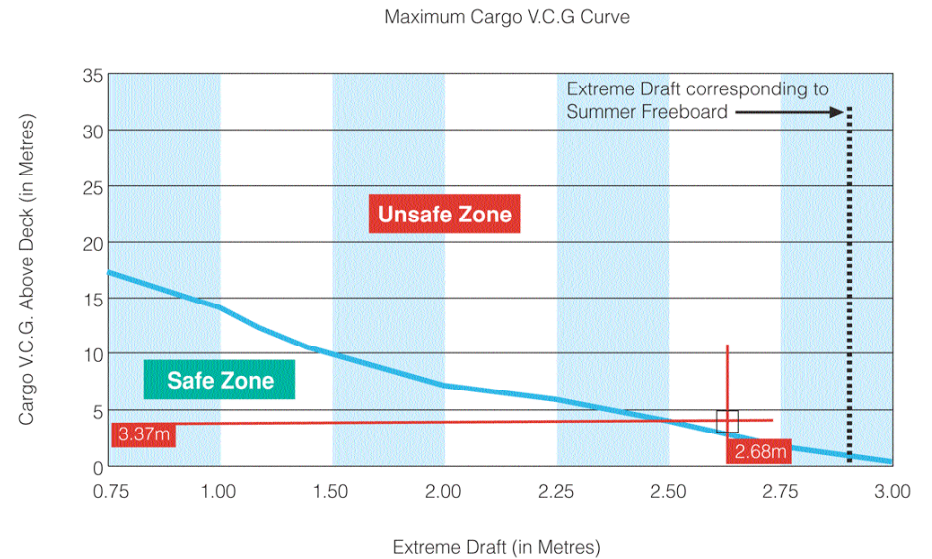
CVCG = total moment ÷ 2000 (total cargo weight) = **3.37m**

From the Summary Table on page 31 we derive by interpolation that for a cargo weight (deadweight) of 2000T we find that extreme draft is **2.68m** and the maximum permissible Cargo VCG above deck is **2.42m**

Extreme Draft (m)	Cargo VCG above deck (m)	Deadweight (t)
2.855	0.893	2171.09
2.684	2.417	2000
2.500	4.058	1815.78

The calculated CVCG of 3.37m is greater than the maximum permissible CVCG of 2.42m and therefore is outside the permissible stability criteria and is **NOT SAFE**.

With the extreme draft of 2.68m and the CVCG of 3.37m we can also determine using the maximum cargo VCG curve that the load plan is in the **UNSAFE ZONE** (see figure below).



Example 5

Mixed Cargo - Container and General Cargo Stowage: Containers, tier 1 and 2 heavy (20t), tiers 3 and 4 empty (2.4t) x 4 bays, Frames 2 – 16 Boxes, General, Stowed to 3.8m high, total 325t, Frames 16 - 20 Steel Coils, 1.5m dia x 2.4 width x 12t, stowed fore and aft 'on the roll', 3 rows x 9 coils per row, Frames 20 -24 Pipes, 40ft x 30ins dia x 7t, stowed across the barge, stacked 3 high, Frames 24 - 30.

Assumption for calculation:-

- Vertical Centre of Gravity, VCG, of containers is half height = half 2.59m = 1.295m
- Vertical Centre of Gravity, VCG, of boxes is half height = half 3.8m = 1.9m
- Vertical Centre of Gravity of coils is half diameter = half 1.5m = 0.75m
- Vertical Centre of Gravity of pipe is half diameter = half 0.762m = 0.381m

Taking moments about the deck to calculate the total cargo vertical centre of gravity, CVCG, above the deck CVCG = $\frac{\text{total moment}}{\text{total cargo weight}} = \frac{3979.79}{1818} = 2.19\text{m}$

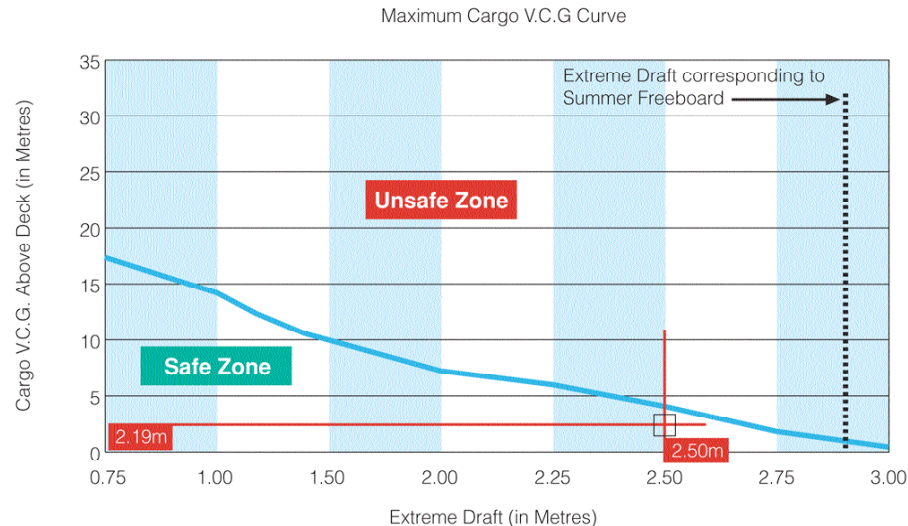
Cargo	Frames	Tier	Wt(t)	VCG(m)	Moment W x VCG
Containers	2 -16	1	5x4x20= 400	1.295	518
		2	5x4x20= 400	3.885	1554
		3	5x4x2.4= 48	6.475	310.8
		4	5x4x2.4= 48	9.065	435.12
Sub total			896		2817.92
Boxes	16 – 20	1	325	1.9	617.5
Coils	20 – 24	1	3x9x12 = 324	0.75	243
Pipes	24 – 32	1	14x7=98	0.381	37.34
		2	13x7=91	1.143	104.01
		3	12x7=84	1.905	160.02
Sub total			273		301.37
Totals			1818		3979.79

From the Summary Table on page 31 we derive by interpolation that for a cargo weight (deadweight) of 1818T we find that extreme draft is **2.50m** and the maximum permissible Cargo VCG above deck is **4.04m**.

Extreme Draft (m)	Cargo VCG above deck	Deadweight (t)
2.855	0.893	2171.09
2.504	4.038	1818
2.500	4.058	1815.78

The calculated CVCG of 2.19m is less than the maximum permissible CVCG of 4.04m and therefore is within the permissible stability criteria and is safe.

With the extreme draft of 2.50m and the CVCG of 2.19m we can also determine using the maximum cargo VCG curve that the load plan is in the Safe Zone (see figure below).



Case Studies



Case Study 1

Vessel Type: Dry Cargo

Trading Area: South Pacific

Case No: 18006

The Incident:

As the last few containers were being loaded on the deck of a 3,000 gross ton inter-island cargo vessel she capsized and sank alongside the dock, damaging the dock as she went down. The Port Authority issued a wreck removal order. The Club invited tenders for the removal operation and a contract was finally agreed with a Singapore-based salvage company. The wreck removal was effected using large sheerlegs which had to be towed over 2,000 miles to the site of the accident. The wreck was cut up into manageable sections and dumped at sea. The berth was finally cleared some five months after the ship went down. The majority of the cargo was a total loss.



Observations:

Our investigations revealed that the cause of the loss was an error in calculating the vessel's stability. The Chief Officer had failed to make proper allowance for the height of a stow of bagged cement in the lower hold when calculating the vessel's vertical centre of gravity. As a result his calculations produced an over-optimistic prediction of the vessel's stability on completion of loading. There was no established procedure on this ship for an independent check of the Chief Officer's calculation. Had there been one it is highly likely that the mistake would have been noticed and the loss of the vessel avoided.

The Financial Cost:

Cargo claims totalling over US\$3 million were submitted to the owners. By using package limitation and defences available to the owners under the Hague Rules, those claims were finally settled for less than US\$500,000. The costs of removing the wreck of the vessel approached US\$1.5 million. Claims by the Port Authority and individual crew members brought the total cost of the claim to almost US\$2.2 million.



Case Study 2

Vessel Type: Feeder Container

Trading Area: Far East

Case No: 32771

The Incident:

This incident took place on a 25 year old 370 teu feeder container ship. Shortly before arriving at the pilot station, an unexplained port list suddenly developed. The list was corrected and "sounding round" showed there to be about 100 cm of water in her hold.

Until berthed, the vessel had flopped one way or another on a number of occasions, each time corrected by moving ballast. Alongside she lay with a 15° list against the quay.

The Chief Officer carried out an assessment of the stability and deemed the vessel to be unstable. The port authority subsequently refused to give permission for cargo operations to commence until the vessel was upright, the cause of the listing was determined and stability was confirmed by the Classification Society.

Efforts to pump out the hold bilge were thwarted by choked suction. The services of a local salvage company were engaged to pump out the hold and remove the top tier of containers in order to regain positive stability. The ballast tanks were closely monitored during this operation and it became apparent that water from two ballast tanks was entering the hold. The stability calculations were reworked and showed the vessel to have positive stability. This was later confirmed by the Classification Society.

Permission for cargo operations to commence was given nearly three days after the vessel's arrival at the port.

The Cause:

The incident was caused by free water in the cargo hold. Choked hold bilge suction prevented the water being pumped out by the ship's staff.

Investigations showed that the vessel had sustained two fractures in the tank top. These were believed to have been caused by the heavy landing of containers during loading. The problem was further exacerbated by the fact that the heeling tank filling pipe had corroded through. Ironically therefore, ballast water used to correct the list increased the leakage into the hold, aggravating the problem.

Observations:

The Master was criticised for not conducting a more thorough investigation at the time of the initial listing.

A regular systematic daily sounding programme is a well established procedure of good seamanship and would give an early indication of any problem. It would do away with the need to engage in the dangerous practice of entering enclosed spaces to visually check the



hold. The difficulties in pumping out the hold once the water had entered were reportedly due to the suction being choked with debris. This highlights the need for the holds to be kept free of rubbish and the regular proving of the pumping arrangements. The provision of a hold bilge alarm would have given a very early indication of the water entering the hold.

The original erroneous stability calculation was a major contributing factor to the delay suffered by the vessel. This should have been carried out prior to leaving the load port. Third party calculations can not be relied upon.

The base of cell guides which carry the brunt of heavy container movements, should be inspected on a regular basis so that corrosion and weakness can be detected at an early stage.

The Financial Cost:

The total claim is expected to be in the region of US\$75,000 to US\$100,000.



Case Study 3

Vessel Type: Feeder Container

Trading Area: Far East

Case No: 34857

The Incident:

This incident occurred on a 316 teu feeder container vessel/bulk carrier immediately after loading had been completed.

On completion of loading the vessel had a 1° list to starboard. This slowly increased. Corrective action was taken, but despite this the list continued to increase. By the time it had reached approximately 15°, a number of containers fell off the top tier into the harbour waters. The vessel then violently rolled to port. The list increased until the water line had reached the hatch coamings and progressive flooding started to take place. Fortunately more containers fell off the top tier, reducing the list. The situation was eventually brought under control by discharging cargo and the vessel returned to an even keel.



The Cause:

This incident was caused by a poorly prepared stow plan resulting in the vessel having negative stability upon completion of loading. The onboard calculations were incorrectly executed, as they appear not to have taken the effects of free surface into account, so masking the true stability condition of the vessel.

Observations:

Feeder container vessels are renowned for their short turn round times and frequent cargo changes. Operators of these vessels should ensure procedures are in place to minimise the potential for errors. Shore prepared stow plans must be checked for accuracy, preferably by a



second person before they are issued. Means should be provided to assist ship's staff in assessing the stability condition of the vessel so as to reduce the possibilities of errors being made in hastily completed calculations. This could take the form of computers or encouragement to use prepared pro forma. Owners should satisfy themselves that the senior officers on board are fully familiar with the stability requirements of their vessel.

The Financial Cost:

This turned out to be a very expensive claim as enormous efforts had to be made to locate the sunken containers that fell overboard. The final cost was in the region of US\$580,000.



Case Study 4

Vessel Type: Dry Cargo

Trading Area: Southeast Asia

Case No: 42200

Incident:

A Feeder Container Vessel had completed cargo operations at one berth and was in the process of shifting to a second berth. A harbour tug commenced pushing the vessel towards the berth when the member's vessel began to heel over. When heeled over to approximately 10-15 degrees, containers began to fall off the vessel; the tug stopped pushing, and this action in conjunction with the loss of containers enabled the vessel to return to near upright.

Observations:

The subsequent investigations showed that poor operational practices were allowed to take place onboard with very little regard to the safety of the vessel. The centre of gravity (KG) of the vessel was determined to be well above the maximum permitted and no account had



been taken of the numerous free surfaces in the ballast tanks. To make matters worse, it was calculated that the vessel was in fact 400t over loaded, which resulted in her having a freeboard of approximately 30cms less than the minimum permitted.

These factors combined to result in a drastic reduction of transverse stability which was insufficient to withstand the forces created by the pushing tug. Ironically, the top tiers of containers had not been secured but this allowed the containers to fall off and the vessel returned to the upright. One of the contributing factors to the overloading was the under declaration of the container weights by the shipper. This case highlights the need to monitor the vessel's condition at all times. By observing the drafts, the overloading would have been noted at an early stage and the vessel's lack of adequate stability detected.

Financial Cost:

The total cost of this claim was in excess of US\$660,000; a great deal of this was accounted for in recovering containers that sank in the approach channel to the berth.

