UK P&I CLUB

Container lashing and stowage

In general terms, by a process of evolution, the lashing systems in use on small container vessels and post-panamax are very similar

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Lashing of containers on deck

The use of a computer lashing program, together with the IMO requirement for every vessel to carry onboard an approved Cargo Securing Manual, should mean a reduction in collapsed stows and losses overboard

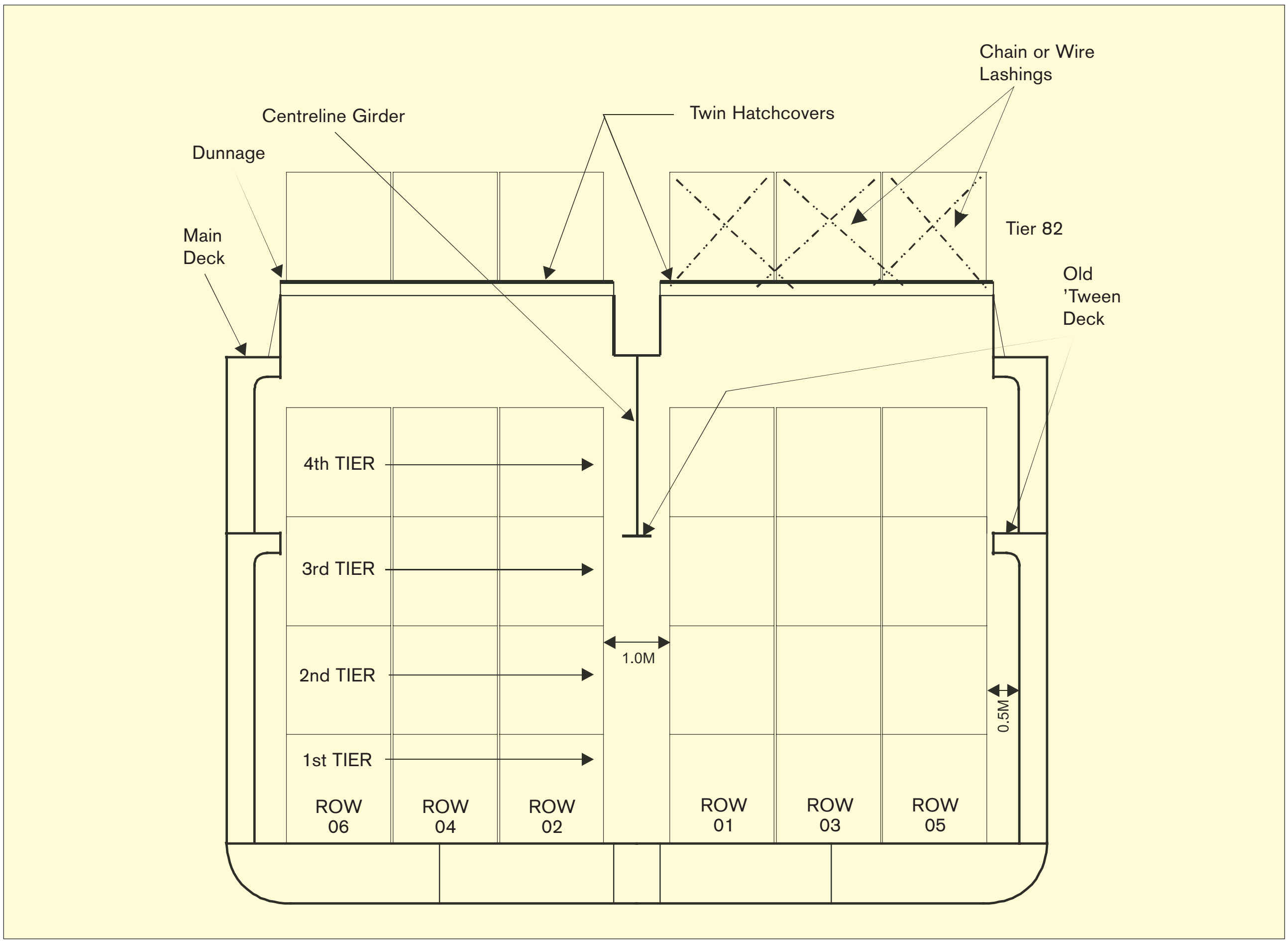
In the early years of containerisation, existing general cargo vessels were converted with the removal of 'tween decks and the addition of cell guides into the cargo holds. On deck, the hatchcovers were strengthened and fittings added for lashings. However, the containers on deck were seldom stowed above one high and so were secured to the vessel by 'traditional' cargo ship methods.

Often seen still trading today, are a few of the 'first generation' vessels built during the late sixties and early seventies. These ships were the first to be designed and built as pure container carriers. The holds and hatchcovers were as wide as possible, and container posts were fitted on deck to facilitate loading of deck-stowed containers out to the ship's side (see Figure 2).

For this generation of vessel, two systems of securing the cargo were common. One relied on the use of twistlocks in conjunction with lashing bars or chains, and the second relied on the use of stacking cones and bridge pieces in conjunction with lashing bars or chains. Gradually, due to the increased utilisation of differing height containers, the second method became redundant and it became common practice to use twistlocks throughout the stow. This method normally allowed containers to be stacked three high and, in some cases, four high if the fourth tier was light in weight or empty.

For first generation vessels, computer technology was not available onboard to speedily calculate dynamic loads acting on container lashings and frames. The shipboard computer (if any) was only used to calculate

Figure 1: Typical midship section of an early vessel conversion



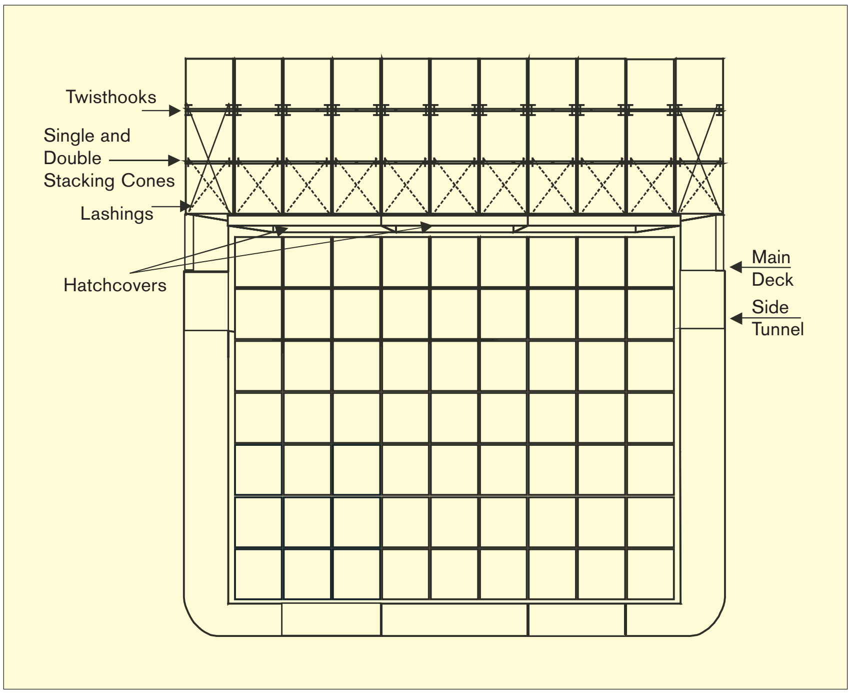


Figure 2: Typical midship section through an early generation cellular container vessel

stresses and stability for the ship itself. Therefore, the shipboard staff would ensure the vessel was lashed according to a lashing plan taken from the lashing equipment manufacturer's manual, which appeared to assume an ideal stow with respect to the distribution of weight in each stack (the homogenous stack).

With further development in the industry during the 1970s and 80s, the size of containerships continued to grow, with 9-high stowage in holds and 4-high stowage on deck becoming commonplace and the industry began to wake up to the fact that standards in lashing were required. Ships were, at this stage, still supplied with loading computers that continued to calculate a ship's stability, shear forces, bending and, occasionally, torsion moments. Very few had the capability to calculate dynamic loads on container frames and lashing systems caused by ship motions and wind forces. And so the lashings were still applied throughout the stow in accordance with the manufacturer's manual. Cargo was being lost overboard even though a properly designed securing system was in place and the cargo was correctly stowed. It became apparent that there was a great deal of ignorance concerning the combined static and dynamic loads acting on a securing system when adverse weather was causing severe ship motions, particularly rolling.

Today, large container ships are being built – known as the 'post-panamax' class (too large to transit the Panama Canal) – capable of carrying up to 8,500 TEUs, and small container ships down to coaster/feeder vessels of a few hundred TEUs. But in general terms, by a process of evolution, the lashing systems in use on both types of vessels are very similar. Both have adopted the twistlock and lashing bar/turnbuckle system.

On post-panamax vessels – where among other features the vessel's large beam results in an unavoidable, relatively large GM (metacentric height), and 6-high stowage on deck is common – the modern practice is for the vessel to be fitted with a lashing bridge; a substantial steel structure running athwartships between each forty foot container bay. This allows the second and third tiers of containers to be secured to the bridge using lashing rods and turnbuckles, whilst the whole stow is secured throughout with twistlocks (see Figure 3). The lashing bridge allows the anchoring points for each stack to be moved higher up the stack, which allows the lashings to be more effective in reducing the tipping moments acting on a stack when a vessel is rolling heavily. However, the practice of fitting the bridges between forty foot bays means that the twenty foot containers can only take advantage of the lashing bridges at one end. So, in effect, the twenty foot stacks have to revert to the limits of a conventional lashing system. This is the case, because the practice of estimating the forces acting on a stack divides the container weight equally between each end of the container. So the weight in each twenty foot container is limited by the capacity of the lashing system at the container end, which does not have the advantage of being secured by a lashing bridge.

On smaller vessels, the whole stow is also secured throughout with twistlocks, and the lowest three tiers are secured to the hatchcover or support post using the lashing bar/turnbuckle combination (see Figure 4).

Lashing bridge

However, since the mid 1980s, naval architects have produced computer programs to calculate the dynamic loads acting on container stacks. Such programs have been designed for use by ships' officers and container planners. On modern vessels, 5-high and 6-high stowage on deck is common; the use of onboard computers to check the dynamics of the stow in all weather conditions is vitally important for the safe carriage of the cargo. The use of a computer lashing program, together with the IMO requirement for every vessel to carry onboard an approved Cargo Securing Manual, should mean a reduction in collapsed stows and losses overboard, provided the operators maintain the lashing equipment and comply with the requirements of the Manual. The vigilance of ships' staff is therefore vital to ensure that lashings are applied correctly.

Requirements of lashing systems

In 1985, the advent of IMO SOLAS resolution A.489(XII) required vessels to carry onboard a Cargo Securing Manual drawn up to a standard contained in MSC/Circular 385, such that on 1st July 1996. This was extended to new container ships and to existing vessels on 1st January 1998. Such Cargo Securing Manuals need to be approved by the relevant Classification Society. The IMO published guidelines on the standard required of the Cargo Securing Manual in the form of MSC/Circular 745, which superseded the earlier MSC/Circular 385, and has been published as IMO 298E *Guidelines for the preparation of the Cargo Securing Manual.*

Typical 'on lid' loading

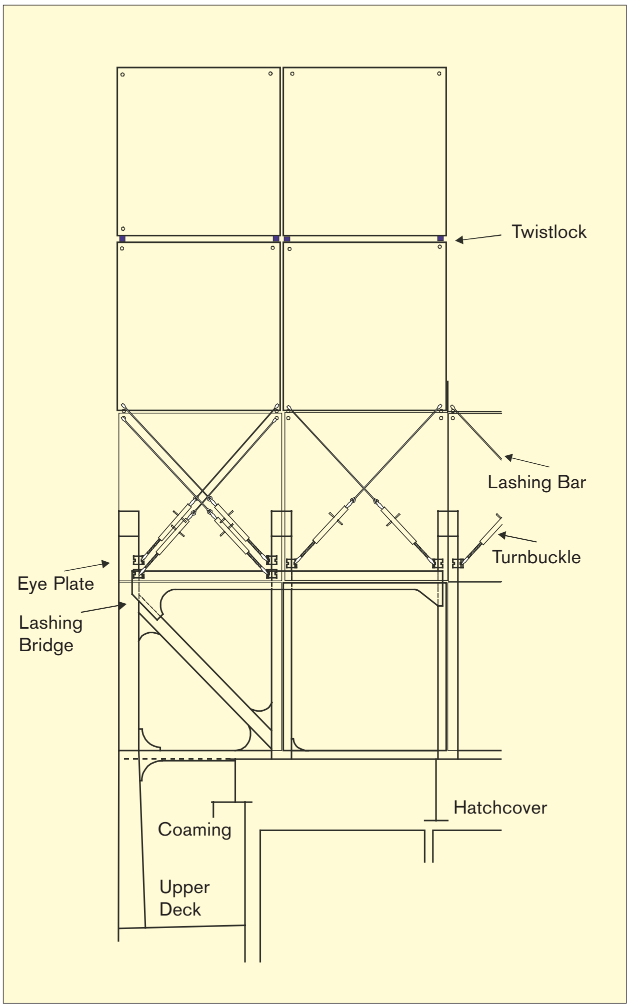


Figure 3: Typical post-panamax lashing bridge arrangement (shown 4-high)

The amended SOLAS Chapter VI: Regulation 5, *Stowage and Securing* states:

"*Cargo and cargo units carried on or under deck shall be so loaded, stowed and secured to prevent as far as is practicable, throughout the voyage, damage or hazard to the ship and the persons onboard, and loss of cargo overboard.*"

It goes on to say that:

"*Cargo units, including containers, shall be loaded, stowed and secured throughout the voyage in accordance with the Cargo Securing Manual approved by the Administration... The Cargo Securing Manual shall be drawn up to a standard at least equivalent to the guidelines developed by the Organisation*" (IMO).

Therefore, following MSC/Circular 745, any Classification Society which approves a Cargo Securing Manual will need to ensure the following:

- The information in the Manual is consistent with the requirements of the vessel's trim/stability and hull strength manual, International Load Line (1966)

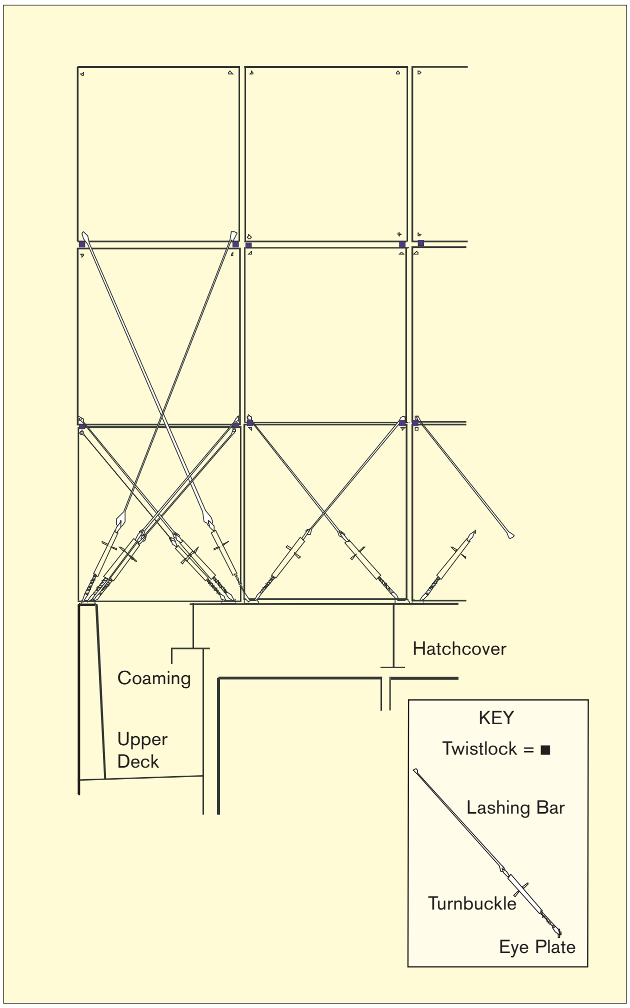


Figure 4: Typical container vessel's hatchcover lashing arrangement

requirements, and the International Maritime Dangerous Goods Code (IMDG), where applicable.

- The Manual specifies arrangements and cargo securing devices provided onboard for the correct application to the containers, based on transverse, longitudinal, and vertical forces, which may arise during adverse weather and sea conditions.
- Such securing arrangements and devices, mentioned above, shall be suitable and adapted to the nature of the cargo to be carried.
- There is sufficient quantity of reserve cargo securing devices onboard the ship.
- The Manual contains information on the strength and instructions for the use and maintenance of each specific type of cargo securing device.
- The Manual should consist of a comprehensive, and understandable, plan providing an overview of the maximum stack weights and permissible vertical distribution of weight in stacks.
- The Manual should present the distribution of accelerations on which the stowage and securing system is based, and specify the underlying condition of stability.
- The Manual should provide information on forces induced by wind and sea on deck cargo, and contain information on the nominal increase of forces or accelerations with an increase in GM.
- The Manual should contain recommendations for reducing the risk of cargo losses from deck stows, by applying restrictions to stack weights or heights where high stability cannot be avoided.

IMO Circular 745 also states that the cargo securing devices should be maintained in a satisfactory condition, and that items worn or damaged to such an extent that their quality is impaired should be replaced. It is commonly accepted that obligatory survey of portable fittings is not generally pursued by the Classification Society, and so inspection and replacement should be the responsibility of the operators. When replacement securing devices are placed onboard, they should be provided with appropriate certification.

Portable fittings should be certified by some form of type-approval system, usually coming from the manufacturer (when approved), a Classification Society, or other accepted testing body.

Ship managers may request a Classification Society to approve their particular lashing system and the lashing program software, in addition to the requirement of approving the Cargo Securing Manual.

Until the Cargo Securing Manual and the computer lashing program are produced and approved 'hand in glove' in the same way as the ships stability loading computer and Stability/Loading Manual are already used, there is bound to be confusion with respect to the safe capabilities of the ondeck container lashing system for each ship.

One note of caution: the different Classification Societies have set their own standards for the minimum SWLs of lashing gear and maximum allowable forces acting on a container, and the roll angle which any calculations should include.

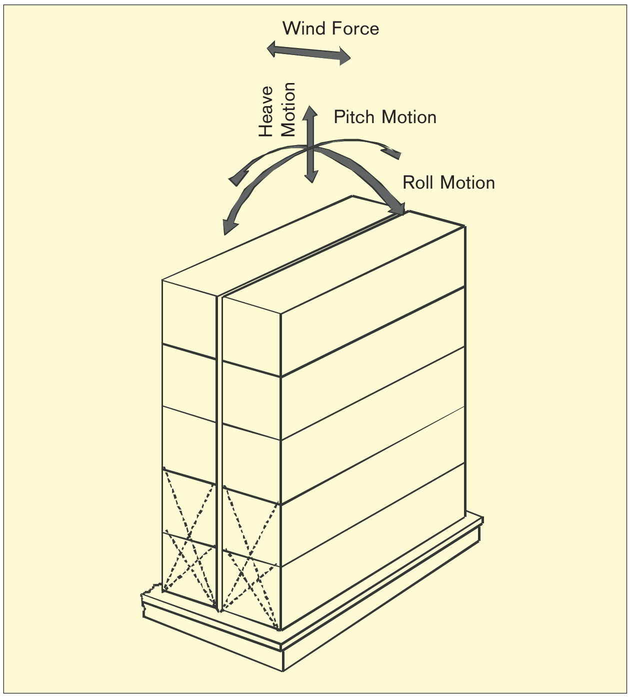
Types of lashing failure

In general terms, whenever a vessel is 'working' in a seaway it will incur three main movements which are described as rolling, pitching, and heaving. These give rise to accelerations, and therefore forces, which act on the container frames and lashing system in use. Figure 5 illustrates the ship motions experienced by a container stack.

Of the forces acting upon an individual container and its lashings as a result of these movements, the separation force is the tipping force which is acting to 'pull out' or separate the corner fittings or twistlocks.

When the vessel is rolling heavily, if the separation force is excessive, it may pull the twistlocks out of the corner castings of the container, break the twistlocks at their weakest point, or separate the corner castings from the main body of the container.

Figure 5: The accelerations acting on a container in a seaway



When the vessel is rolling heavily, and containers stowed on higher tiers are heavy, a racking force will be set up in the frame of the lowest containers. The larger the roll of the vessel, the larger the racking force will be.

A large GM – particularly when coupled with a short roll period – increases the dynamic loadings caused by rolling, and all of the loads previously mentioned, will increase the compression and tension forces acting at the corner posts of the containers and at the twistlocks between them. If excessive, they may result in structural failure of one or more of the corner posts (see Figure 8).

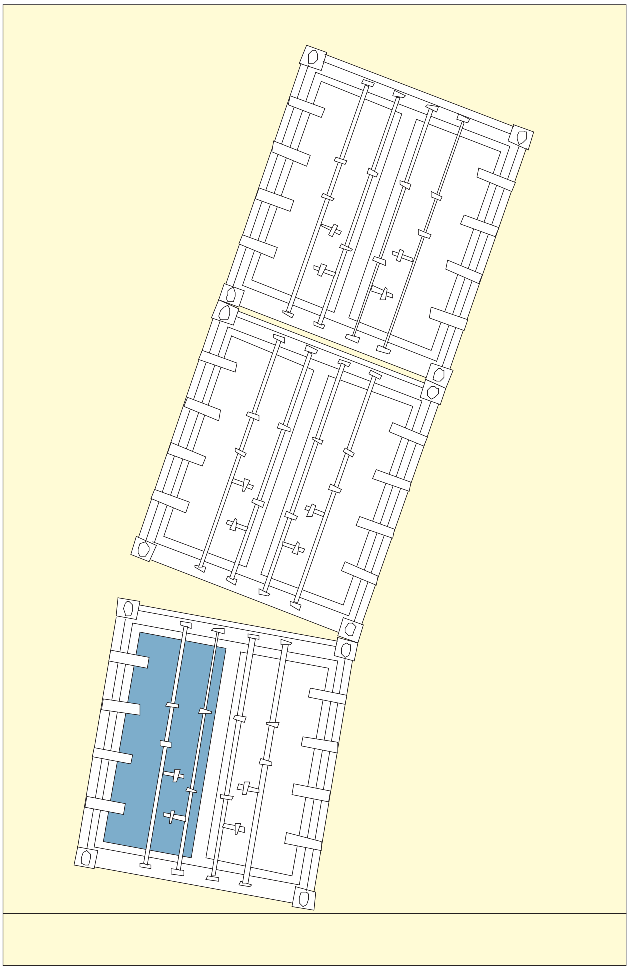
Application of computer software

Having identified that containers were being lost overboard – despite apparently having a properly designed and implemented securing system in place and that cargo was correctly stowed – analysis showed that there was much ignorance concerning the combined static and dynamic loads that were present in adverse weather. In such cases, the bad weather being encountered had caused severe ship motions, in particular a rolling motion. The result of this analysis is that, of all the ships motions, rolling is the most likely cause of overloading the container frames and lashings.

It is interesting to note that the same difficulties were being experienced in the mid 1980s. The solutions, in principle, are also similar. A number of computer programs are available – such as *Seamaster*, *Seacos* and *Loadstar* to name but a few – that calculate not only the vessel's stability, but the forces experienced within a container stack.

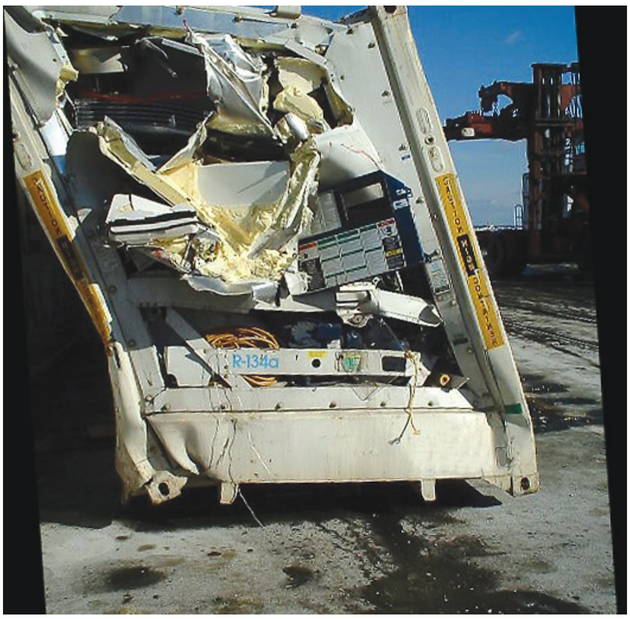
A note of caution: many ports supply the chief officer with a disk containing a *Bayplan* file of the preload plan, which should include all the relevant container data – it is important to check that the correct container height has been entered, as this affects the vessel's stability and any calculation of the forces experienced within the stack.

Figure 6: Excessive tipping moment or separation force on corner fittings



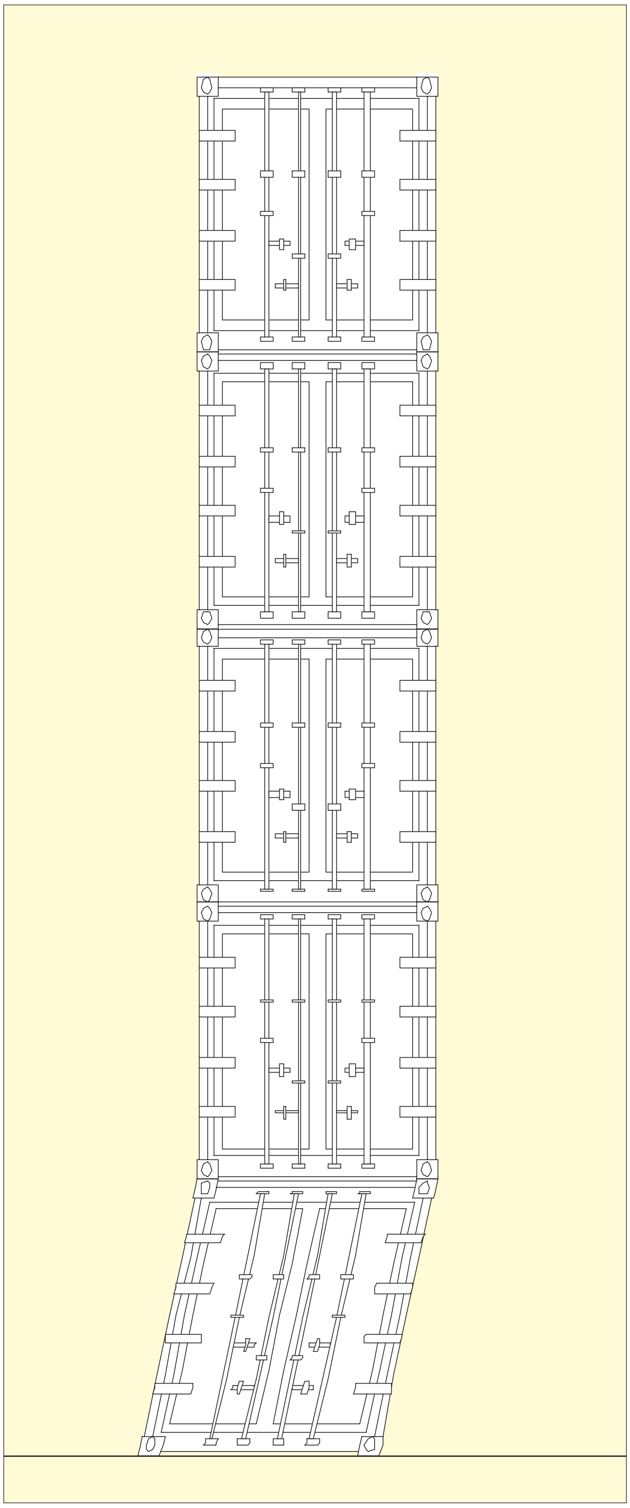
Page 9 shows excerpts of printouts from the *Seamaster* program representing the force analysis of an actual cargo carried by a post-panamax container vessel and the applied lashings, utilising a lashing bridge and with a ‘conventional’ lashing system (parallel lashings only in both cases). The vessel experienced heavy weather and, as a result, containers were either lost overboard or severely damaged. The printouts show how much a container stack can be overloaded in severe weather taking into account ships’ motions due to wave action and wind. It can be seen that the stack weights and individual container weights are not excessive, but when subjected to heavy rolling and wind, the container frames and lashings become overloaded; particularly the transverse racking forces and the tension/compression forces which are primarily caused by heavy rolling and wind action on the outside stacks.

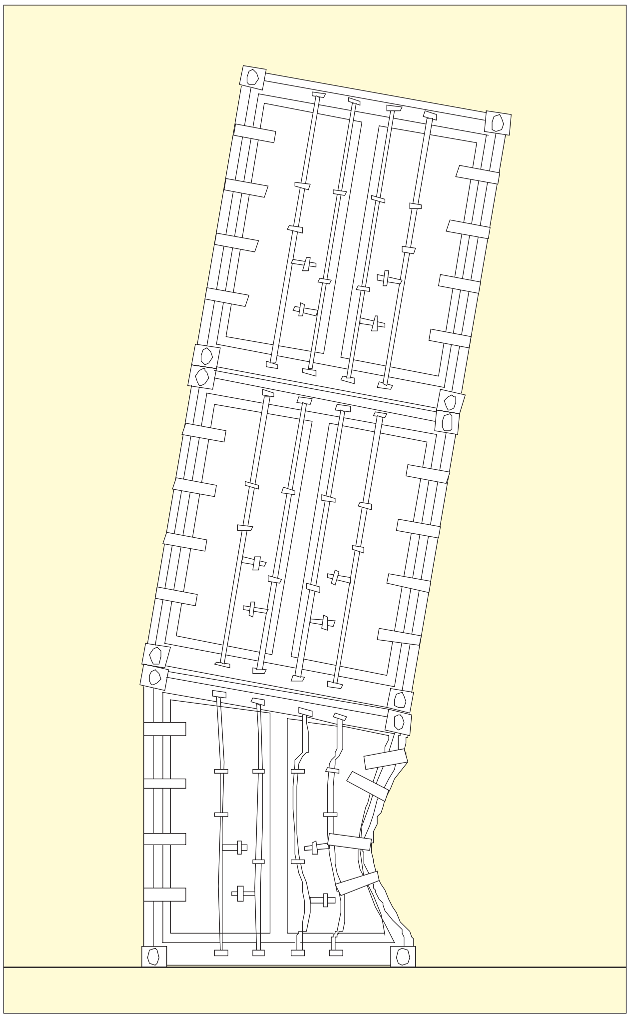
The benefits of using a program such as this can be summarised, therefore, as helping to ensure a safer carriage of deck-stowed containers, a saving on lashing requirements both in terms of usage and employment of lashing gangs, and the possibility of loading more cargo (depending on the voyage). Because so much high value cargo is containerised and carried on deck, it is essential that each vessel has onboard a computer program capable of assessing the forces acting on container stacks during a voyage, allowing for adverse weather. It goes without saying, of course, that lashing equipment also has to be in good condition, and certified as suitable. However, use of these programs could lead the user into a false sense of security. Forces calculated assume that all containers are in good condition – no damage to corner posts and castings, that all lashings are correctly applied, with equal tension on lashing bars, etc. These programs also calculate to a theoretical angle of roll that the ship shouldn’t exceed, but in many cases, does.



Forces within a stack are affected by all ship motions, but the angle of roll is normally the most critical. Classification Society regulations assume values, which are the default values in these programs. They calculate the forces acting on each non-cellular stack, using the environmental and lashing data already set. The lashing data is set up on a row-by-row basis, allowing for lashing bridges, etc. The natural period of

Figure 7 and photo (below left): Excessive racking force on a container end wall, causing the frame of the lower container to deform (rack)





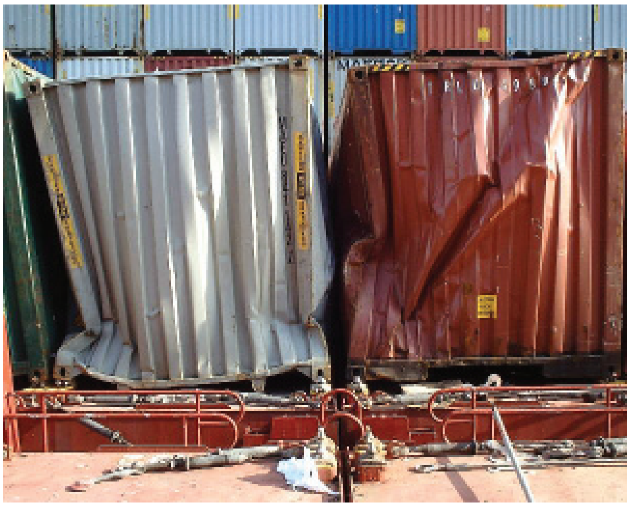


Figure 8 and photo above right: Excessive compression force on container corner post, leading to failure of the post

roll can be determined using the following rule-of-thumb formula:

$$Period\ (T_R) = \frac{0.7\ Beam}{\sqrt{GM}}$$

The case illustrated, with a GM of 0.9m, leads to a natural roll period of 16 seconds. This would lead to quite a long roll, with the loadings increasing to the maximum, and then reducing until the vessel becomes upright, and then rolls back the other way.

A detailed breakdown of the forces in each stack is obtained, displaying the relevant forces acting on each container. The programs assume, as a default, that all containers are stowed with their door ends aft, but this can be altered by the user. As an example, an excerpt of a printout from the *Seamaster* program is shown opposite. The bottom line for each row of containers indicates the maximum allowable forces (MAF) for the forces identified in the column directly above, highlighted in blue. If a force exceeds the MAF it is highlighted in red.

Racking force: The first two columns are the transverse forces tending to distort the container ends, primarily due to a rolling action. This should not exceed a MAF of 15t. If a lashing is applied, the force varies between the forward and aft ends of the container because of the different ‘stiffness’ of the door and closed ends.

Corner shear: This is closely related to racking, but is the force tending to shear off the twistlocks. It should not exceed a SWL of 15t for a standard twistlock.

Compressive force: This is the force acting on the container corner posts and fittings, and is the result of tilting the stack and the vertical acceleration. It should not exceed 45t for a standard 20’ container corner post, or 67.5t for a 40’ container’s corner post. Larger compression forces are allowed for corner castings at the base of a stack (83.8t).

Separation force: This is the tipping force which is acting to ‘pull out’, or separate the corner fittings and should not exceed 15t for the top fitting, and 20t for the bottom. It is shown as a negative value in the force table. This force does not refer to the tensile loadings on the twistlocks.

Lashing tension: This is the tension in the applied lashings. Lashing rods should only ever be applied hand tight, not over-tightened with large spanners, as this induces unnecessary tension in the lashing rod, reducing the angle of roll at which the SWL would be exceeded. The Germanischer Lloyd (GL) limit for lashing rods is 23t SWL; turnbuckles are rated at 18t. *Seamaster* uses the LRS 1999 rules for reporting (see excerpt from a printout opposite).

The examples of the *Seamaster* printout are from an actual incident involving container loss in heavy weather. They illustrate the advantages of using a

WITH LASHING BRIDGE – Report for Deck Bay 54 on the basis of LRS 1999 Rules

(with 78 kn wind & 24.9° roll, assuming draught = 12.6 & GM = 0.90m)

Row 12 Deck Bay 54

Tier	Ht(ft)	Wt(t)	Wind(t)	Cl	Door	Fwd < LASHINGS length	type	> Aft length	type
88	9.5	19.5	4.3		Aft				
86	9.5	26.2	4.3		Aft				
84	9.5	21.4	4.3		Aft	3.92	St 30	3.92	St 30
82	9.5	26.2	4.3		Aft				

Rolling: Tier	Racking Force Fwd	Aft	Side	Corner Shear Fwd	Aft	Compression Forces Fwd	Aft	Fwd	Aft	Lash Tension Fwd	Aft
88	2.9	2.9	0.0	4.2	4.2	9.2	9.2	0.3	0.3		
86	11.2	11.2	0.0	2.1	-2.9	49.9	62.8	-6.5	-6.5		
84	6.8	-2.3	0.0	6.5	1.5	64.7	65.9	-9.7	-0.6	**23.2**	**38.9**
82	**15.2**	6.1	0.0	11.6	6.6	**91.6**	81.2	**-20.3**	-2.2		
(MAF)	(15)	(15)	(10)	(15)	(15)	(67.5/83.8)		(-15.0/-20.0)			

Row 11 Deck Bay 54

Tier	Ht(ft)	Wt(t)	Wind(t)	Cl	Door	Fwd < LASHINGS length	type	> Aft length	type
88	9.5	21.2	4.3		Aft				
86	9.5	22.0	4.3		Aft				
84	9.5	26.3	4.3		Aft	3.92	St 30	3.92	St 30
82	9.5	26.3	4.3		Aft				

Rolling: Tier	Racking Force Fwd	Aft	Side	Corner Shear Fwd	Aft	Compression Forces Fwd	Aft	Fwd	Aft	Lash Tension Fwd	Aft
88	3.1	3.1	0.0	4.5	4.5	9.9	9.9	0.4	0.4		
86	11.3	11.3	0.0	1.6	-3.4	49.7	62.6	-7.2	-7.2		
84	6.5	-2.7	0.0	6.8	1.8	65.4	66.6	-9.2	-0.1	**23.3**	**39.2**
82	**15.8**	6.7	0.0	11.9	6.9	**93.1**	82.6	**-20.4**	-2.2		
(MAF)	(15)	(15)	(10)	(15)	(15)	(67.5/83.8)		(-15.0/-20.0)			

NO LASHING BRIDGE – Report for Deck Bay 54 on the basis of LRS 1999 Rules

(with 78 kn wind & 24.9° roll, assuming draught = 12.6 & GM = 0.90m)

Row 12 Deck Bay 54

Tier	Ht(ft)	Wt(t)	Wind(t)	Cl	Door	Fwd < LASHINGS length	type	> Aft length	type
88	9.5	19.5	4.3		Aft				
86	9.5	26.2	4.3		Aft				
84	9.5	21.4	4.3		Aft				
82	9.5	26.2	4.3		Aft	3.68	St 30		

Rolling: Tier	Racking Force Fwd	Aft	Side	Corner Shear Fwd	Aft	Compression Forces Fwd	Aft	Fwd	Aft	Lash Tension Fwd	Aft
88	2.9	2.9	0.0	4.2	4.2	9.3	9.3	0.3	0.3		
86	11.2	11.2	0.0	9.5	9.5	31.1	31.1	-6.6	-6.6		
84	**20.3**	**20.3**	0.0	7.6	13.9	**77.8**	63.1	**-25.1**	**-25.1**		
82	**17.3**	**28.7**	0.0	12.7	**19.0**	**107.4**	**107.3**	**-39.8**	**-54.4**	**18.6**	
(MAF)	(15)	(15)	(10)	(15)	(15)	(67.5/83.8)		(-15.0/-20.0)			

Row 11 Deck Bay 54

Tier	Ht(ft)	Wt(t)	Wind(t)	Cl	Door	Fwd < LASHINGS length	type	> Aft length	type
88	9.5	21.2	4.3		Aft				
86	9.5	22.0	4.3		Aft				
84	9.5	26.3	4.3		Aft				
82	9.5	26.3	4.3		Aft	3.68	St 30		

Rolling: Tier	Racking Force Fwd	Aft	Side	Corner Shear Fwd	Aft	Compression Forces Fwd	Aft	Fwd	Aft	Lash Tension Fwd	Aft
88	3.1	3.1	0.0	4.5	4.5	10.0	10.0	0.4	0.4		
86	11.3	11.3	0.0	9.1	9.1	30.7	30.7	-7.3	-7.3		
84	**20.0**	**20.0**	0.0	7.9	14.3	**78.8**	63.8	**-24.4**	**-24.4**		
82	**17.7**	**29.4**	0.0	13.0	**19.4**	**109.0**	**108.9**	**-39.7**	**-54.6**	**19.0**	
(MAF)	(15)	(15)	(10)	(15)	(15)	(67.5/83.8)		(-15.0/-20.0)			

lashing bridge arrangement for securing containers. Both the number of instances of forces in excess of the Class limits (figures in red), and the degree of those excesses, is reduced with a lashing bridge. However, compressive forces are transferred higher up the stack as the lashing bars are attached at the base of the tier 86 containers.

Just because a container, or item of lashing equipment, has exceeded its safe working load / maximum allowable force, does not automatically lead to the conclusion that that item will fail. SWLs are mostly set at 50% of the breaking load. The use of a SWL is to give a safety margin, allowing for occasional over-stressing. A container that has been highlighted as having exceeded the Class limits will not automatically be lost when the vessel rolls to 24.9°. Indeed, many container stacks remain onboard after having suffered greater loadings than some of those lost. The calculations cannot allow for the domino effect of an inboard stack collapsing, falling against its neighbour thereby inducing far greater forces upon it, which in turn collapses, etc.

The correct application of the lashing equipment is also important; one example of incorrect application of semi-automatic base twistlocks occurs when there is an element of fore and aft movement of the container immediately prior to landing it onboard; the base locks tend to be placed in the deck fitting rather than the base of the container prior to loading. Any fore and aft movement of the container, as it is aligned over the base lock, risks the actuating wire being caught under the container, rendering the twistlock inoperable unless the container is lifted and landed correctly. This highlights the necessity of continual vigilance on behalf of ship's staff during the loading process.

Twistlock failure

Unlocked twistlock

Heavy weather seamanship for container vessels

The actions required to be taken by the master, upon encountering heavy weather, vary according to the size of the container vessel, but some actions have a common thread:

- **Intelligence:** It is vital the master uses all available means to forecast the possibility of experiencing heavy weather, so that early preparations can be completed and any options for avoidance examined. This would be in the form of a passage plan, weather bulletins, weather faxes, routeing chart and pilot book information, weather routeing, and past experience.

- **Familiarity:** The master should also be familiar with his own vessel, its handling characteristics and allowable engine settings in heavy weather. This can only be gained by experience.

- **Preparation:** Once it is known that heavy weather conditions will be experienced, it is imperative that proper preparation is carried out. This would entail the completion of numerous tasks in all departments and an *aide-memoire* checklist is commonly used. Fundamentally, the vessel should be put to its best sea-keeping condition possible in terms of stress, stability, watertight integrity, security of cargo, security of equipment, and reliability of machinery.

- **Handling:** When heavy weather is expected it is important that the outside conditions are monitored and recorded in greater detail and with best accuracy. This will provide data to ensure the master reduces speed in good time. (Too often the first reduction in speed occurs after the first damage has happened). For example, on modern, large containerships the sea and wind conditions should be observed from main deck level. With modern engine-monitoring equipment, the main engine load value, the exhaust gas temperatures, and the turbo charger revolutions should be carefully monitored, as these values can be used as a precursor to indicate when speed should be reduced.

- **Handling:** The standard tactic of 'heaving to', by keeping the main conditions two points on the bow with the vessel at reduced speed, is often still the best action to take. Keep the vessel in hand, steering at all times, and endeavour to maintain the best lookout, both visually and by radar. If the vessel is rolling excessively (assuming she has already been put into the best stability condition) alteration of course towards a 'hove to' type of heading followed by a reduction of speed, should be carried out as soon as possible. Care should be taken when carrying out this course adjustment, ensuring the turn is not violent or coinciding with the roll period.

- **Record keeping:** At all times regular weather and sea-state information, positions, courses steered, engine settings, should be recorded, and all received weather information should be retained onboard.

As well as the points already mentioned, the master will be faced with a number of considerations pertinent to his own vessel, such as:

- If fitted, at what speed do the vessel's stabilisers cease to have an effect?

- When running before heavy weather, what is the potential for damage aft caused by a boarding sea – reefer sockets, steering gear vents, etc?

These recommendations are not intended to be definitive – each incident being judged on its own merits. However, through years of experience, these factors have been found to come in to play in most heavy weather incidents.

There is no doubt that defensive navigation may increase the time on passage, but when navigating in, or near, heavy weather, being cautious may prevent an accident, saving both time and money.

Heavy containers over light

One of the most persistent problems experienced onboard containerships is bad stowage. This can take many different forms, but the most potentially damaging example occurs when heavyweight containers find their way into the upper tiers of container bays on deck.

The problem can occur with any containership, if the permissible stack/tier weights are ignored for a specific securing arrangement. As an example, containerships of the latest generations feature deck stows comprising six or seven tiers of units which, to the casual observer, represent a huge carrying capacity. The better informed, namely the ship's officers and ship planners, have a different appreciation, as they should be aware that weight limits apply and, in the upper tiers (sixth and seventh layers) only empty containers can be carried.

Background

In containership liner operations there are normally three individuals who play an important part in the planning and/or loading operations, they are:

- The ship planning co-ordinator;

- The loading terminal's ship planner; and

- The ship's loading officer.

With modern communication systems, and the exchange of preliminary and final stowage plans, at least two of these important individuals, if not all three, should be in a position to verify whether stack and/or tier weights are within the permissible limits for the securing system being used. Problems can occur, given the complexity of modern Cargo Securing Manuals and this can result in mistakes and poor co-ordination.

Irrespective of whether it is an one-off voyage charter or a regular caller, the ship planning co-ordinator has the very important job, firstly, of ensuring that he has available the necessary particulars of the vessel that will enable the stowage planning, loading operation and securing of containers to be undertaken in a proper and seamanlike manner. He must, secondly, ensure that each loading terminal has the same information readily to hand.

Cargo Securing Manuals have become very complex, with numerous securing arrangements each having their own permissible stack and tier weight limits. This creates a requirement for the ship planning co-ordinator, in conjunction with the ship's staff, to make sure that the loading terminal planner is aware of the securing arrangement(s) to be used and their applicable permissible stack and tier weights.

The operating principle is that the weights of containers should not exceed the prescribed limits for slots in which they are stowed. These limits should be set according to stack weight, tier position and the securing arrangement being used. In modern container handling systems the loading model for a particular class of vessel is usually sufficiently well detailed so as to 'prevent' an operator from planning the loading of a heavy container in a light slot. In a more sophisticated approach, the loading computer will calculate, on an individual stack basis, the resultant forces acting upon the containers and the lashing system. A maximum container weight will be determined for each position, and it is possible that a heavy container could be received over a unit of lesser weight, provided that securing loads are acceptable. In both examples, however, if the weight is excessive for the specified position, then the computer program will simply reject the container.

As far as ship operations are concerned, however, the container industry covers a broad spectrum. Vessels which incorporate the very latest technology run side-by-side with others from older generations. There are many services which rely upon chartered tonnage, either wholly for short or long terms, or from time to time to supplement an existing established service. In all cases, it is the responsibility of the ship planning co-ordinator and/or the loading terminal ship planner to stow the containers into the proper and appropriate positions on the ship.

As a result of a diverse service structure, and the utilisation of different classes and designs of vessels, it is inevitable that ship planners may, on occasions, find themselves working without detailed knowledge of the technical data for a particular vessel. However, in such cases, the ship planning co-ordinator and/or the loading terminal ship planner should look to attend the vessel to obtain the necessary information. Planners should not apply their own interpretation, as what may be applicable for one vessel may not be for another.

The requirement for detailed technical knowledge is crucial. Individuals must resist the temptation to overlook basic stowage rules on the assumption that margins of safety exist.

The causes

Whatever the background, the problem of heavy containers being loaded in high tier positions above light containers has been around for years and has been responsible for many very serious and expensive casualties.

The role of the ship planner in the operation is crucial. He or she is required to plan the stowage of large numbers of containers onto a vessel in a loading operation, which must take place quickly and efficiently.

The planner must cope with uncertainty in the loading information and in the time of arrival of units at the port.

It is assumed that a ship planner has knowledge of some basic principles in container stowage; i.e. keeping heavy weight items at the base. In practice, however, many ship planners simply rely upon the limit, which exists for the total weight of units that can be carried in a particular stack. This is simply insufficient, and there must be additional awareness of the limit existing for the weights of individual containers carried in different tiers.

Bad stowage can occur as a result of a mistake, or it can be deliberate. The following are the principal reasons why heavy containers are sometimes placed in the wrong slots:

- **Inexperience**
  By mistake, an inexperienced planner faced with a problem of container distribution might simply allocate stowage on 'the best possible' basis ignoring good stowage principles and the vessel's stowage and securing criteria.

- **Insufficient knowledge**
  A planner who lacks specific knowledge of the tier limits for a particular vessel, or class of vessel, will not know whether a particular plan he/she has composed meets with the criteria of the vessel's lashing system. For example, he or she may assume tier positions for empty units are suitable for laden containers.

- **Deliberate bad stowage**
  An experienced planner may come across the 'impossible' stowage dilemma – too many heavy boxes and not enough suitable slots. In such cases, there is always a temptation to take a chance that an indiscretion in the loading distribution will pass unnoticed and the problem will simply 'sail away'. There have even been many examples, involving relatively sophisticated planning systems, in which planners have changed the weight information on containers so that they are not rejected by the computer when placed in particular positions.

- **Late arrivals**
  A most common reason for errors occurs when containers are received for shipment late, for whatever reason. The vessel may be part loaded, and stevedores may have abandoned a scheduled loading plan in place of a hybrid, for reason that cargo was not available when the vessel arrived. When the containers arrive late, it may be the case that only relatively high positions are left available.

How can these errors be addressed onboard ship?

Without having to-hand the proposed stowage plan, detecting a weight problem in a container stow is not an easy task. A container has the ominous characteristic of looking exactly the same when laden with lead ingots as it does when filled with rattan furniture. Ships' staff should not allow loading operations to commence until they have received a copy of the proposed stowage plan. It may be the case that a full stowage plan has not been completed, but a loading terminal should be able to give the plan for the bays about to be worked. A relatively quick inspection should show whether heavy containers have been planned over light ones; and whether the stack and tier weights are within the permissible limits.

A reason for this is that the system for container loading is entirely driven from ashore by the planner, who creates a stowage plan and has the ability to vary and modify right up to the moment a particular unit is picked up by a crane. It is frequently the case the final bay plan, received after work that has been completed, bears only passing resemblance to the pre-load plan which was received just as work was commencing.

Vigilance is the key and ships' staff should be aware that mistakes are often accompanied by departures from plan. Accordingly, duty officers must not hesitate to report to the chief officer on any occasion when stevedores advise there is a change to the original plan. The chief officer should look carefully at any change which is proposed.

Containerships work around the clock, but it is during the night cargo watches that most deviations from the plan are experienced. This is also the time when a less scrupulous terminal may try to 'pull a fast one' and allow indiscretion to creep into the loading operation.

Ships' staff should always check the pre-loading plan for 'heavy' container stacks. These should be identified and, if possible, the container numbers in these stacks checked during loading. If a different container appears in the upper tier then it may be a heavy unit stowed by mistake and of sufficient weight to overload the stack and the lashing system.

Containership operators must instruct terminals to check weight against stowage slot, before allowing a unit to be shipped late in a position other than that originally planned. In most cases the plan will be sufficiently flexible to accommodate late loading, but in some instances it will not. Potential problems must be identified, and remedied, before sailing – DON'T LET IT GO BY!

How the problem is all too often discovered

The most common method by which a stowage error of this type is discovered is when the chief officer updates his loading plan using the final plan, normally provided on a CD. The update should tell him if there are any changes from the pre-load plan. Frequently, however, there are significant differences flashed up on the computer screen.

In more extreme cases, the discovery is made when the vessel encounters moderate weather and starts to roll and pitch. The safety margins in lashing systems are very small, and an excessively heavy stack will soon begin to challenge the integrity of the securing arrangements. Container structures are overloaded, fittings fail and movement occurs.

On a modern vessel, the breakdown of the stowage usually commences in lower tiers, possibly at second tier level, where racking loads might cause failure of the door end structure. Alternatively, the compressive forces may cause buckling of a post. There may be excessive pull out loads on twistlocks or baselocks. Once fittings have begun to fail, movement of the stack occurs and load is transferred to adjacent stacked containers.

This type of problem can assume significant proportions, and in most cases an entire bay of containers is at risk. Examples where heavy containers have been loaded in high positions have involved:

- The loss overboard and a subsequent compulsory recovery of dangerous chemicals in 200 metre water depths.
- The capsize of ships alongside a berth.
- The collapse of stacks and spillage of hazardous chemicals on deck.

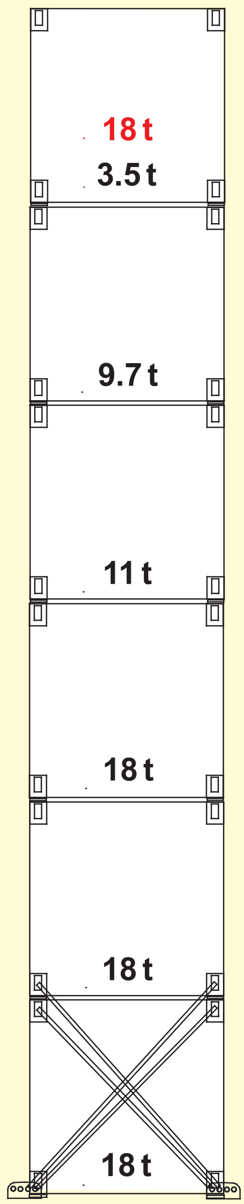
For illustrative purposes, it is appropriate to review a numerical example.

In the theoretical case illustrated (right), we have a 6-high internal (i.e. no wind load) stack of 40ft units in an aft located bay onboard a 230 metre long containership. The vessel has good stability with a GM of 1.5 metres. In ascending order the container weights planned are 18/18/18/11/9.7/3.5 tonnes. The stack weight is 78.2 tonnes, which is well below a nominal limit of 100 tonnes which applies to the vessel.

In a seaway experiencing rolling of 26° the lashing loads would be under a tension load in the order of 14.5 tonnes at the 'door ends' in a parallel lashing system.

If, because of last minute arrivals at the container terminal, a unit of 18 tonnes were placed in the sixth tier then the situation would be quite different. The stack weight would have risen to 93 tonnes, still well below the limit, but forces in the stack would increase as well.

For the conditions outlined, i.e. a roll angle of 26°, the lashing tensions would rise to about 17.5/18.5 tonnes. Compression forces in container corner posts at tier 1 level would rise to about 800 kN, exceeding higher strength standard limits, and tension forces in posts would also be high. The racking forces at tier 3 would be close to the allowable limits for a standard container.



The example shows a marginal case where slightly more stressful conditions could cause the stack to collapse. Ship motions would be important and even the over-tensioning the lashings might be sufficient to bring about failure.

This demonstrates that if the rules of good stowage are broken even with relatively modest loads then there are potentially serious consequences. If the stack included heavier containers, i.e. units of 20 tonnes and greater, then bad stowage would probably, if not certainly, cause collapse if the vessel were to meet adverse conditions.

It would be wrong to assume that bad stowage will cause a container collapse. There are other components to the equation. In addition, the vessel will have to encounter heavy weather and experience ship motions of amplitudes approaching design working limits. There are additional factors, which can influence events. Containerships can be very large vessels and lashing systems are of very substantial scale. Such large arrangements can easily conceal defects, both in lashings themselves and their manner of application. The safest condition is one, which has complied with the basic stowage rules.

A containership master must be prepared to use all available tools in the ISM system in order to report defective stowage to the vessel operators and designated person ashore. It is a fundamental requirement of ISM that defects of this type are reported.

There have been examples of vessels performing multiple chartered voyages, with overloaded and defective stowage conditions, and with no record of any protest by the master to charterers through owners. A containership master should remember to use all the tools available, in order to check stowage and security. Modern vessels have computer programs to enable lashing integrity to be checked at the push of a button. These facilities must not be overlooked.

Container lashing and stowage:
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