

CARGO SECURING MANUAL

By Capt. Pawanexh Kohli

This Manual is in Accordance with Resolution A.489(XII), the Recommendation on the Safe Stowage and Securing of Cargo Units and other Entities in Ship's, as adopted by the International Maritime Organization (IMO).

M.V. -----
of Liberia.

COMPANY

(Ship and Company Name and other selected data removed by Author)

DNV APPROVED MANUAL
VESSEL DNV + 1A1, + MV, + KMC, EO, corr

THIS DOCUMENT AUTHORED BY CAPT. PAWANEXH KOHLI IN 1995 WHILE MASTER OF THE REFERENCED SHIP. THE DOCUMENT HAS REMAINED PROPRIETERY TO CAPT. KOHLI THOUGH BROUGHT INTO OFFICIAL USE.

FOCUS TOPIC: CONTAINER LASHING ON A CARGO SHIP

THIS MANUAL IS DEDICATED TO ALL THOSE WHO SAILED THE LOVELY KSECS.

INTRODUCTION

Extent of this Manual:

- To specify arrangements and securing gear provided on board the M.V. ----- for the correct application to and the securing of cargo units, based on forces that may arise during adverse weather conditions.
- To ensure, for the safety of ship and protection of cargo and personnel, that securing gear is used as specified.
- To provide information on the safe working load of any specific item of cargo securing gear provided.
- To provide information on the maintenance of such cargo securing gear.
- To provide a reference/instruction guide to the vessel's crew.

The ----- is a Reefer Cargo vessel Designed to carry refrigerated Cargo and a limited number of containers. The vessel is owned and operated by ----- (and/or subsidiaries). The Vessel carries reefer fruit cargo in loose boxes or in pallets. This Manual will discuss securing arrangements and equipment for unitized cargo (palletized cargo and containers only).

This manual is arranged in the following chapters:

i) This Introduction and Vessel's Particulars.

- Chapter 1. Location and details of fixed securing arrangements.
- Chapter 2. Location and stowage of portable securing gear.
- Chapter 3. Details of portable securing gear, inventory of items and their strength.
- Chapter 4. Correct application of portable securing gear.
- Chapter 5. An indication of the forces expected to act on cargo units.

Vessel Particulars:

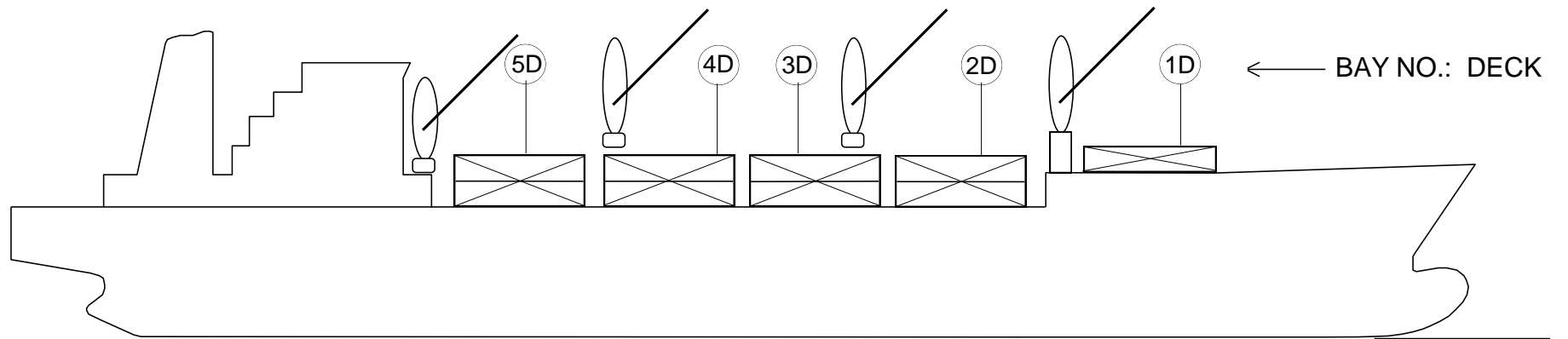
Name:	-----	Type:	Refrigerated Cargo Ship
Keel Laid:	Mar 1989	Delivered:	Dec 1989
Length Overall:	159.656 meters	Breadth (mld):	23.510 meters
Depth (mld):	14.97 meters	Displacement:	19302 tons
Block Coefficient:	0.5780	Class:	DNV +1A1, +MV, +KMC+, EO
GRT:	10749	NRT:	6841
Summer Draft:	9.957 meters	Freeboard:	3.350 meters

The vessel has four Reefer Cargo Holds, each divided into 4 decks (A, B, C, D).

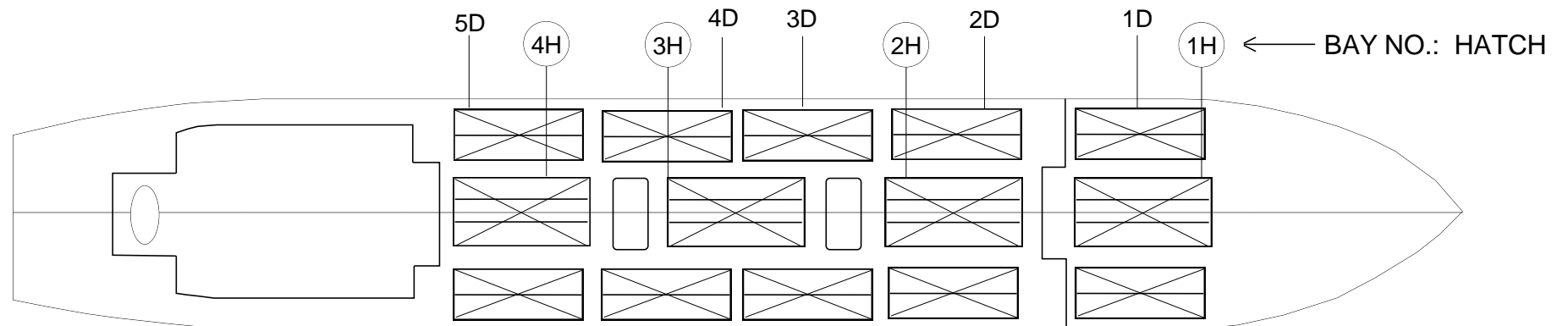
Container capacity is provided on **foe'sle deck, upper deck, hatch tops and in Hold 3**. See following Fig. 1. for General Arrangement for Deck Containers.

This vessel is provided with side boards in each Cargo hold where required for pallet stow.

The vessel can also carry small cars under deck. The air circulation holes on the deck gratings can be used as lashing points for the car lashing gear.



Drawings by Capt. Kohli



M.V. -----

Fig: 1 - Arrangement for Deck stow of Containers

Note: 4D can stow 20 feet containers also.

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CHAPTER 1: Location and details of fixed securing arrangements.

Container and fixed fitting Table :

	Quantity of Containers	Tier	Quantity of fixed Fitting	
			Conic Guides	Lashing Eyes
F'csle deck	4 FEU	1	12	nil
Upper Deck	32 FEU or 24 FEU + 16 TEU	2	60	48
Hatch Cover	12 FEU	1	32	nil
Hold 3	12 TEU	4	12 Bottom Lock Apertures	6 TP Foundations
TOTAL	48 FEU	-	104 + 12	48 + 6

Permissible Container Loads :

On Hatch Cover	32 Metric Tons per Stack for One (1) tier of 40 ft.
On Deck	25 Metric Tons per Stack for One (1) tier of 40 ft on Foc'sle Deck. 50 Metric Tons per Stack for Two (2) tiers of 40 ft on Upper Deck.
Under Deck	80 Metric Tons per Stack for Four (4) tiers of 20 ft in Hold 3.

Container Securing System :

- Only Twist Lock system without Lashing on Hatch covers and Foc'sle deck.
- Twist Lock system with Lashing on Upper deck.
- Twist Lock system with Buttresses and Bridge Fittings in Hold 3.

Permissible Deck Loads :

Deck A to D	1.70 T/M ²
Hatch A to D	1.75 T/M ²

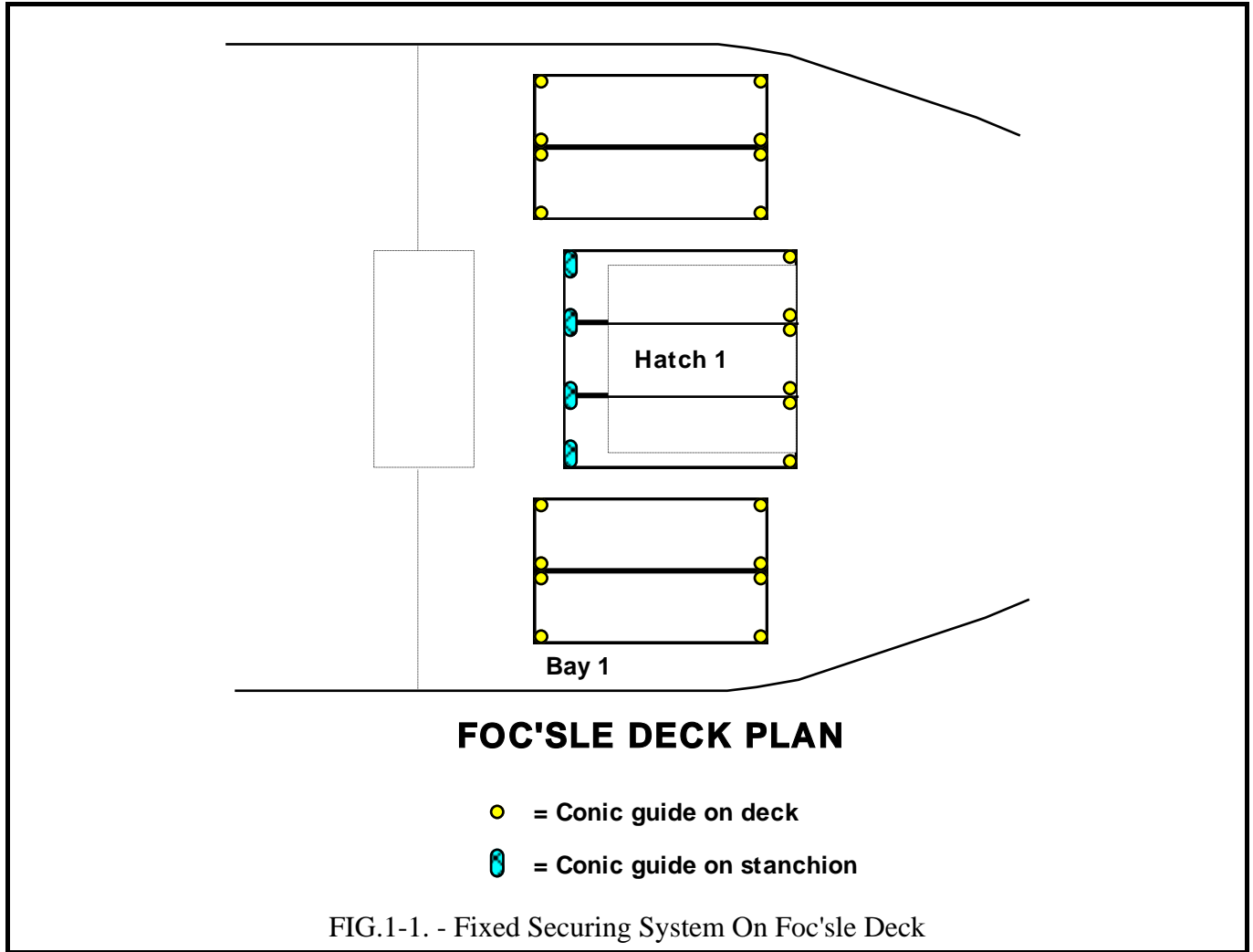
Pallet Securing System :

Hatch Side Boards and Portable Inflatable Dunnage Bags, supplemented by Wood Shoring where required.

Side Shoring (Where Fitted):

In Hold 1 = decks A, B, C and D.
 In Hold 2 = decks A, B, C and D.
 In Hold 3 = deck D.
 In Hold 4 = decks B, C, and D.

FOCSLE DECK ARRANGEMENT:-

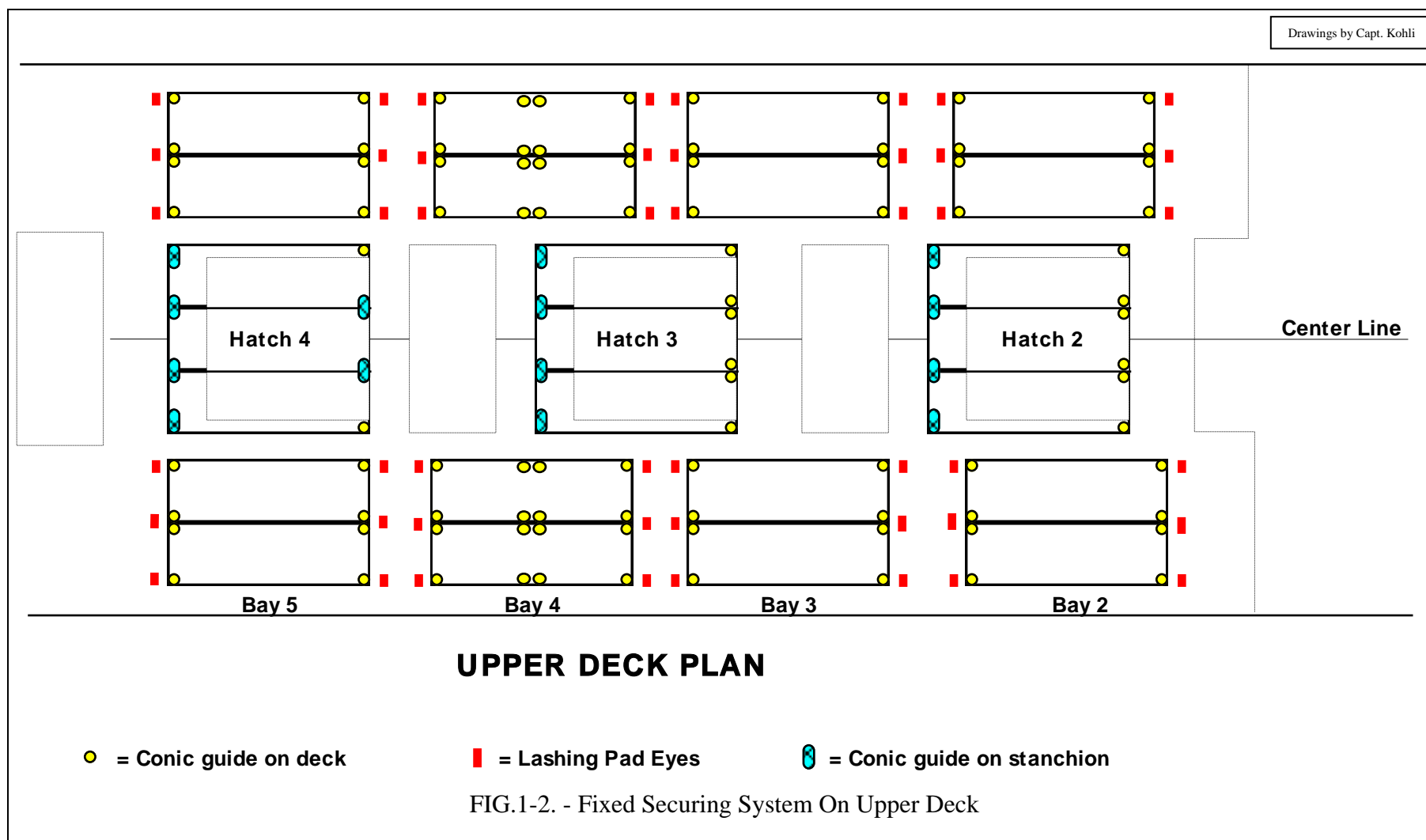


This diagram (Fig. 2.) shows the fixed securing arrangements for 40 'containers on the foc'sle deck (for stowage on Hatch top 1 and Bay 1). Note that fixed guides for the Conic Base Locks are provided for each container position. There are no eye pads for portable Lashing rods as twist locks with bridge fittings suffice.

STACK LOAD TABLE :

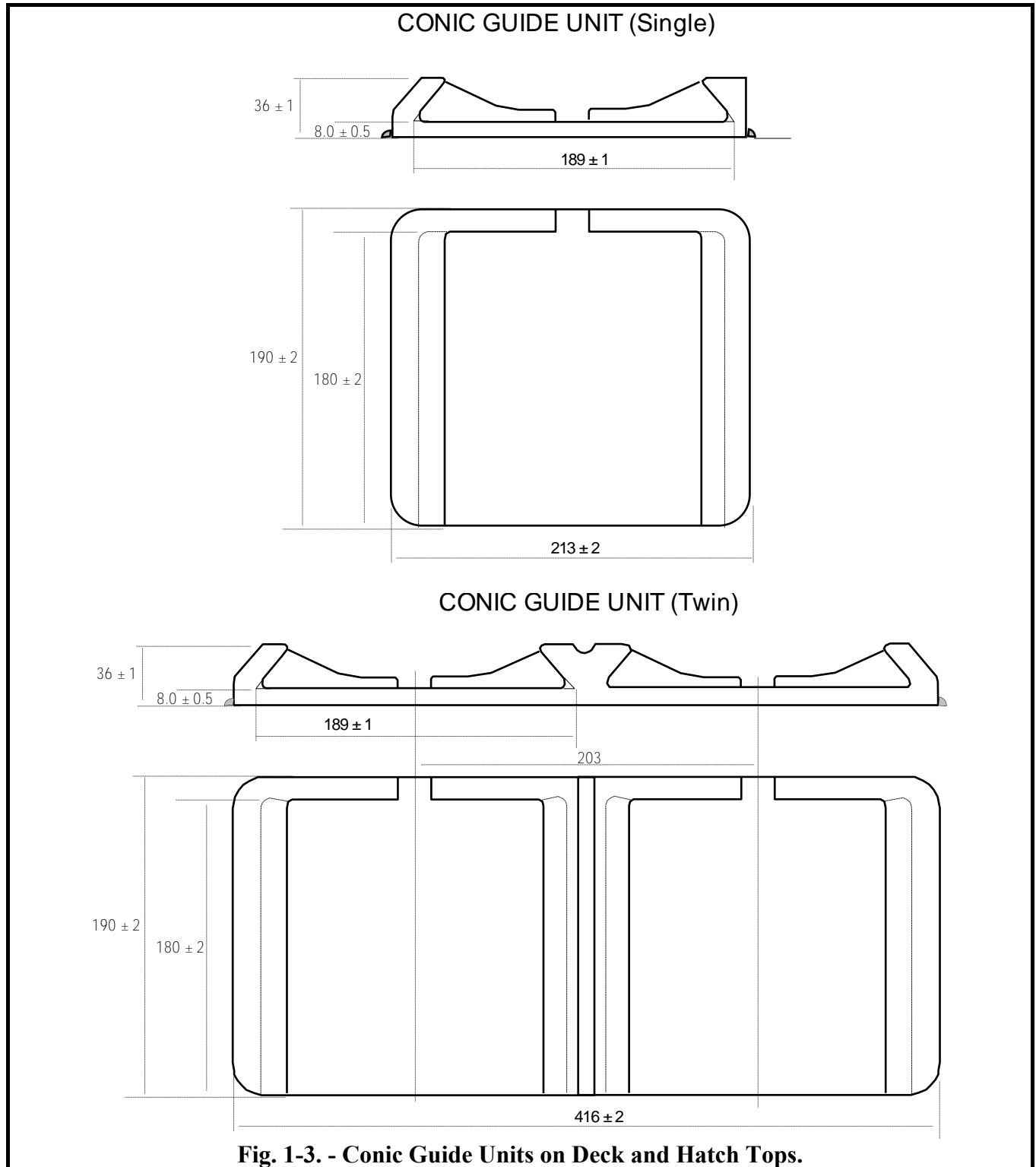
COMPARTMENT		No of Stacks	Stack Load
ON HATCH	Hatch top 1, 2, 3, 4	3 each	32 MT
ON DECK	Bay 1 (foc'sle)	4	25 MT
	Bay 2 to 5 (40' cntnrs)	4 each	50 MT
	Bay 4 (20' containers)	8	37.5 MT
IN HOLD 3	Hold 3 (20' containers)	3	80 MT

UPPER DECK ARRANGEMENT:-



This diagram (Fig. 23) shows the fixed securing arrangements for 40' containers on the upper deck (for stowage on Hatch tops 2 to 4 and Bays 2 to 5). Note that fixed guides for the Conic Base Locks are provided for each container position. Additional guides are provided for stowing 20' containers in Bay 4. There are eye pads at each 40' position in Bays 2 to 4 for portable Lashing rods.

Conic Guide Units (Single/Double): These are also known as Dovetail Shoes. They are the bottom fixed securing arrangement on all Hatch tops and Deck stow positions. The portable Bottom Locks are fitted in these units. These may be mounted on raised stools of appropriate height to compensate for camber.



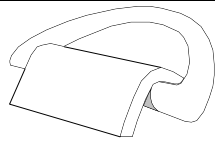


Fig. 1-3.1. - D-Ring (Lashing Eye) on Deck.

Conic Guide Units: Breaking Load -
Manufacturer- Ozean Service & Reparatur

D-Ring on Deck: Breaking Load - 49 tons
Manufacturer- Ozean Service & Reparatur

UNDER DECK ARRANGEMENT:-

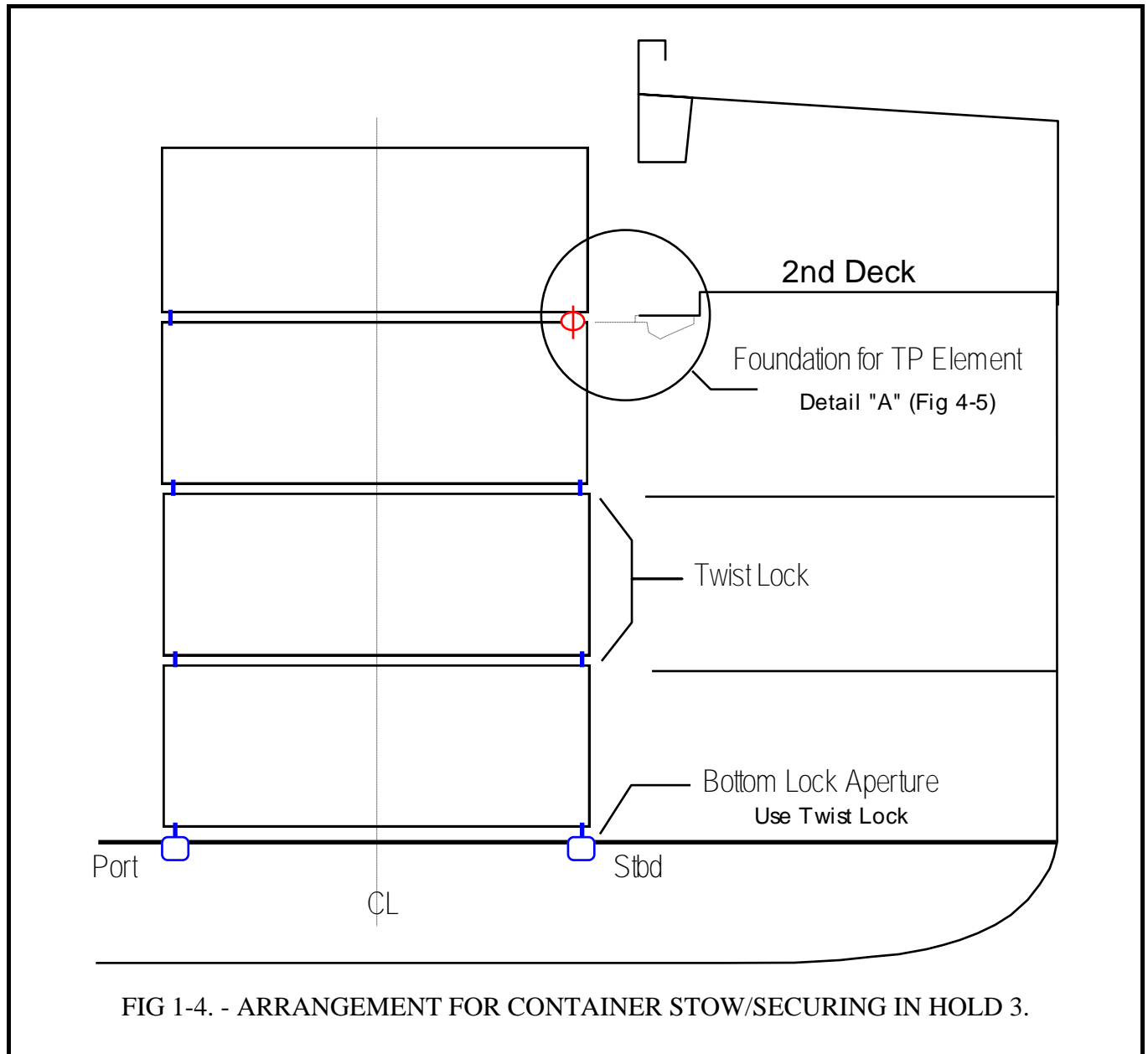
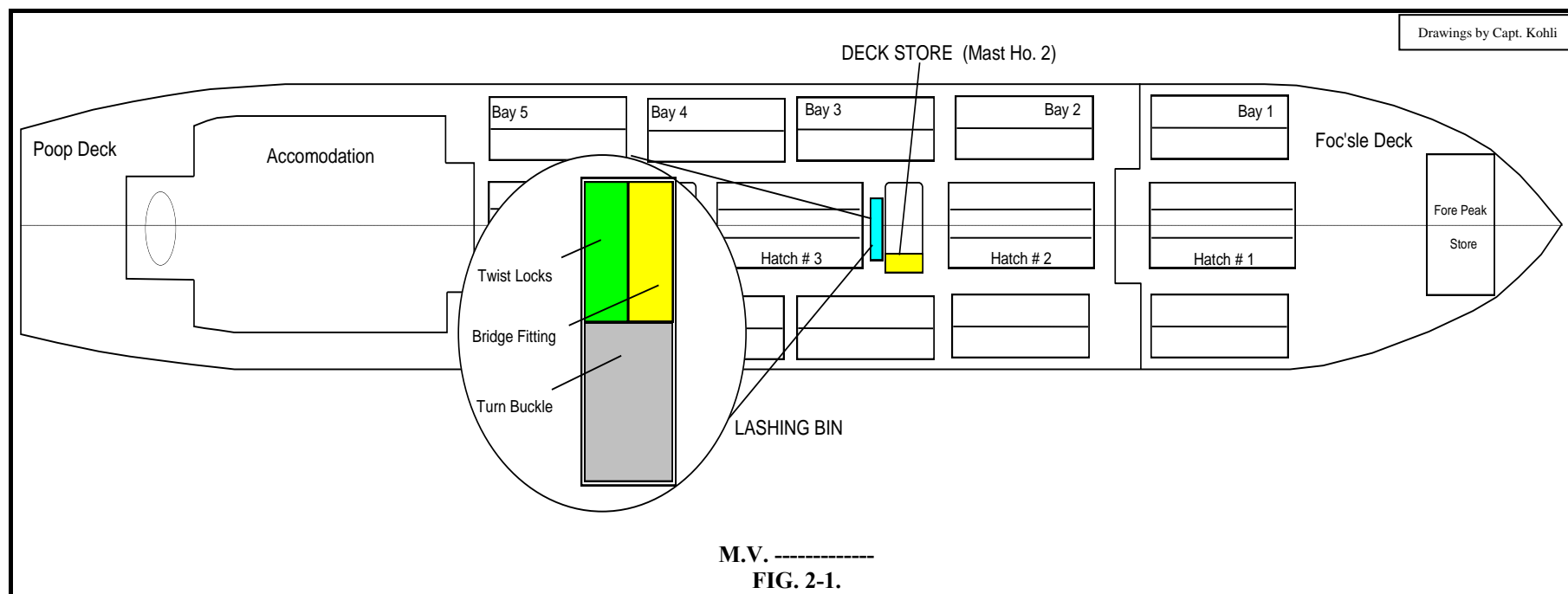


Fig. 4 shows the fixed securing arrangements for 20' containers in Hold 3. Here, 20' containers are stowed athwart ship (3 rows) and can go upto 4 tiers. The diagram shows the apertures/raised pots (4 x 3 available) for the bottom locks (twist locks) and the fixed foundations for the Thrust Pad (TP) Elements. See Fig. 3-7. for details of TP Elements.

CHAPTER 2: Location and stowage of portable securing gear.



Portable securing gear is located in the Deck store and in a Lashing Bin the locations of which are indicated on the diagram above.

The Deck Store (Stbd side aft of Hatch 2) is used to stow the Lashing rods when they are not in use.

The Lashing Bin is used to stow the Bridge Locks, Twist Locks & Base Locks and the Turnbuckles. The Lashing Bin is designed into three sections, segregating its contents as shown in the diagram above.

Spare Lashing equipment is stowed in the Forepeak Store.

CHAPTER 3: Details of portable securing gear & Inventory of items.

This Chapter describes the functions and design characteristics of the portable lashing gear carried on the vessel. An Inventory of items and their location on board is also indicated.

1. Turn Buckle

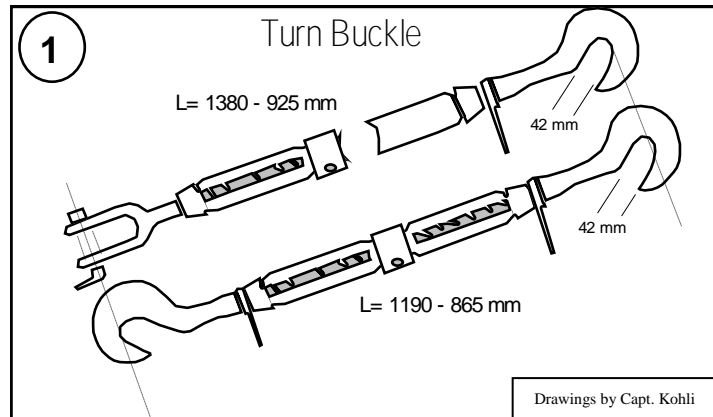


Fig. 3-1

Features:	Pipe Body with two Swivel Hook Bolts OR one Hook bolt and one Jaw Bolt.
Size:	As per Sketch
Finish:	Galvanized.
Location:	Lashing Bin
Inventory:	44 pcs.
Maintenance:	Regular greasing and inspection.
SWL:	

Locking nuts are provided to prevent inadvertent opening of the turn buckles. In any case they are to be checked for tightness frequently during a sea voyage.

2. Bottom Cone Lock (Base Lock or Dovetail twist lock)

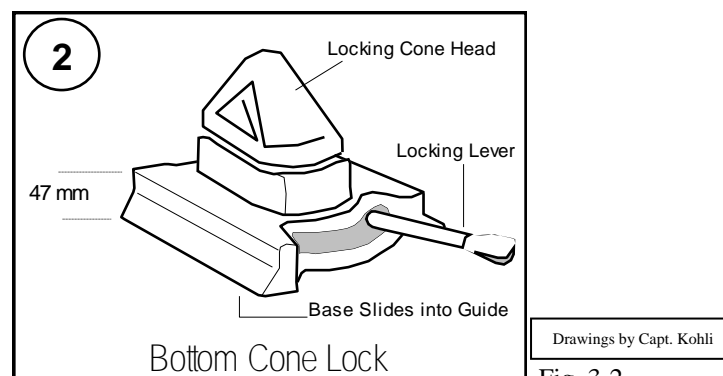


Fig. 3-2

Features:	Base plate slides into Guide on Deck.
Flange Thickness:	47 mm
Finish:	Galvanized.
Location:	Lashing Bin
Inventory:	144 pcs.
Maintenance:	Inspection and Oiling.
SWL:	

3. Twist Lock

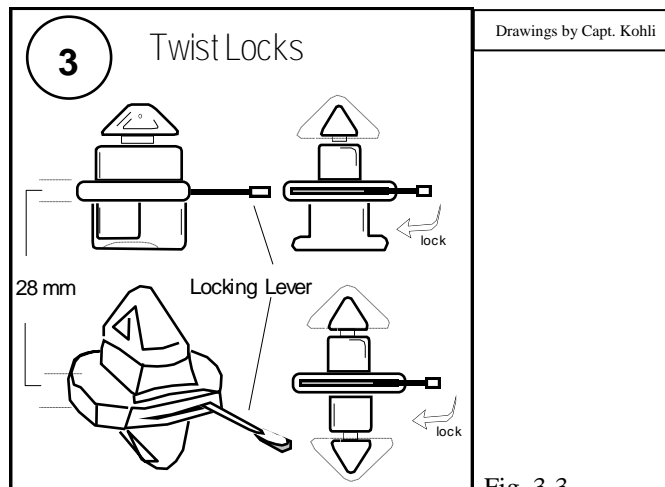


Fig. 3-3

Features:	Left hand locking or Right Hand Locking
Flange Thickness:	28 mm
Finish:	Galvanized.
Location:	Lashing Bin
Inventory:	206 pcs. (LH 99 pcs, RH 107 pcs)
Maintenance:	Inspection and Oiling.
SWL:	

These twist Locks are used to interlock container tiers. They are available on board as right hand or left hand locking. (Painted to indicate locking side).

4. Lashing Rod

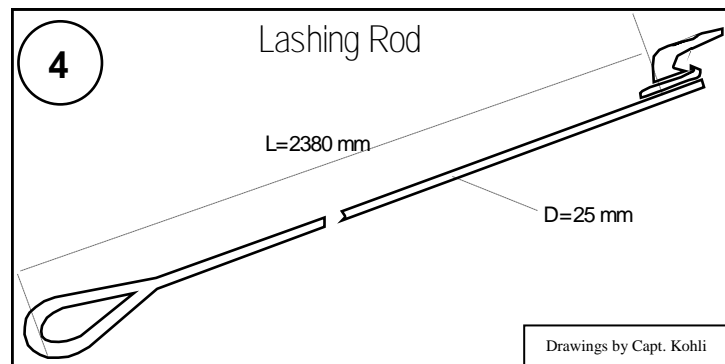


Fig. 3-4

Features:	Eye on one end and slip hook on other end. No Corner Hooks needed.
Diameter:	25 mm.
Finish:	Galvanized.
Location:	Deck Store (Mast Ho. 2)
Inventory:	64 pcs
Min BL:	36 tons.

These Lashing Bars are used to secure containers on upper deck stow positions when carried in two tiers or more. When, in the case of carrying High Cube containers, these rods are too short, extension rods are appended to it. Lashing rods and turnbuckles can turn slack during the course of a voyage and need to be checked frequently.

5. Bridge Lock

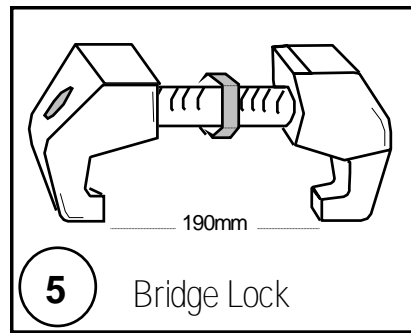


Fig. 3-5

Features:	Max Opening 190 mm.
Finish:	Galvanized.
Location:	Lashing Bin
Inventory:	48 pcs.
Maintenance:	Inspection and Greasing to keep free.
Min BL:	

Bridge Locks are used across the top of adjoining containers and are optional when securing single tier containers. Care has to be taken that these are checked and re-tightened in the duration of the voyage.

6. Lashing Rod Extension

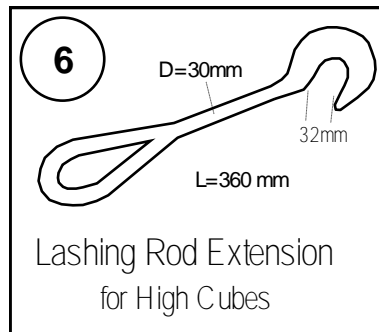


Fig. 3-6

Features:	Used to extend Lashing Bar when loading High Cubes.
Length:	360 mm
Finish:	Galvanized.
Location:	Deck Store
Inventory:	48 pcs
Min BL:	42 tons

All Drawings by Capt. Kohli

These are used to extend the length of the cross lashing rods as and where required. The hook end is attached to the lashing rod and the eye attached to the turn buckle.

7. T.P. Element (Buttresses)

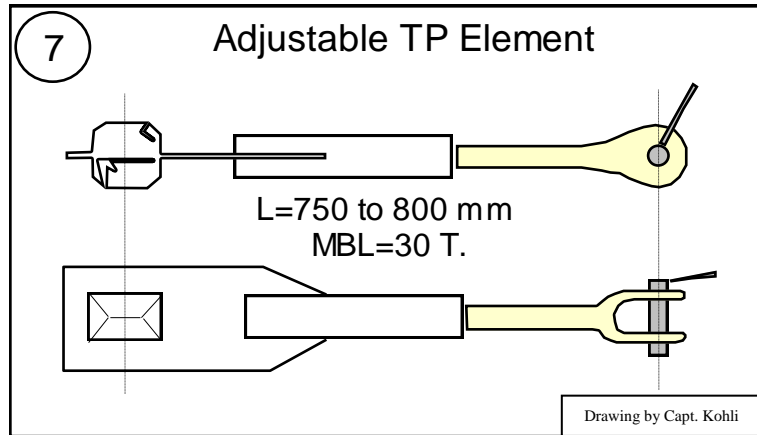


Fig. 3-7

Features:	Adjustable Length.
Finish:	Galvanized.
Location:	Deck Store
Inventory:	6 pcs.
Maintenance:	Inspection and Greasing. To be kept free.
Min BL:	30 tons
Manufacturer:	

8. Inflatable Dunnage Bags: Two types available on board-

Maker:	Type 1 Air Pac	Type 2 Cargo Pack
Max Gap:	400 mm	450 mm
Max Pressure:	1.5 KPa/2.0 PSI	1.5 KPa/2.0 PSI
Size:	2000 x 850 mm	1000 x 1850 mm.

Inventory of items:

Lashing Gear	Quantity on Board	Location
BASE CONES	144	Lashing Bin
TWIST LOCKS	206	Lashing Bin
BRIDGE LOCKS	48	Lashing Bin
ROD EXTENSIONS	48	Deck Store
LASHING RODS	64	Deck Store
TP ELEMENTS	6	Deck Store
TURN BUCKLES	44	Lashing Bin
INFLATABLE DUNNAGE BAGS	700	For'd Store

CHAPTER 4: Correct application of portable securing gear.

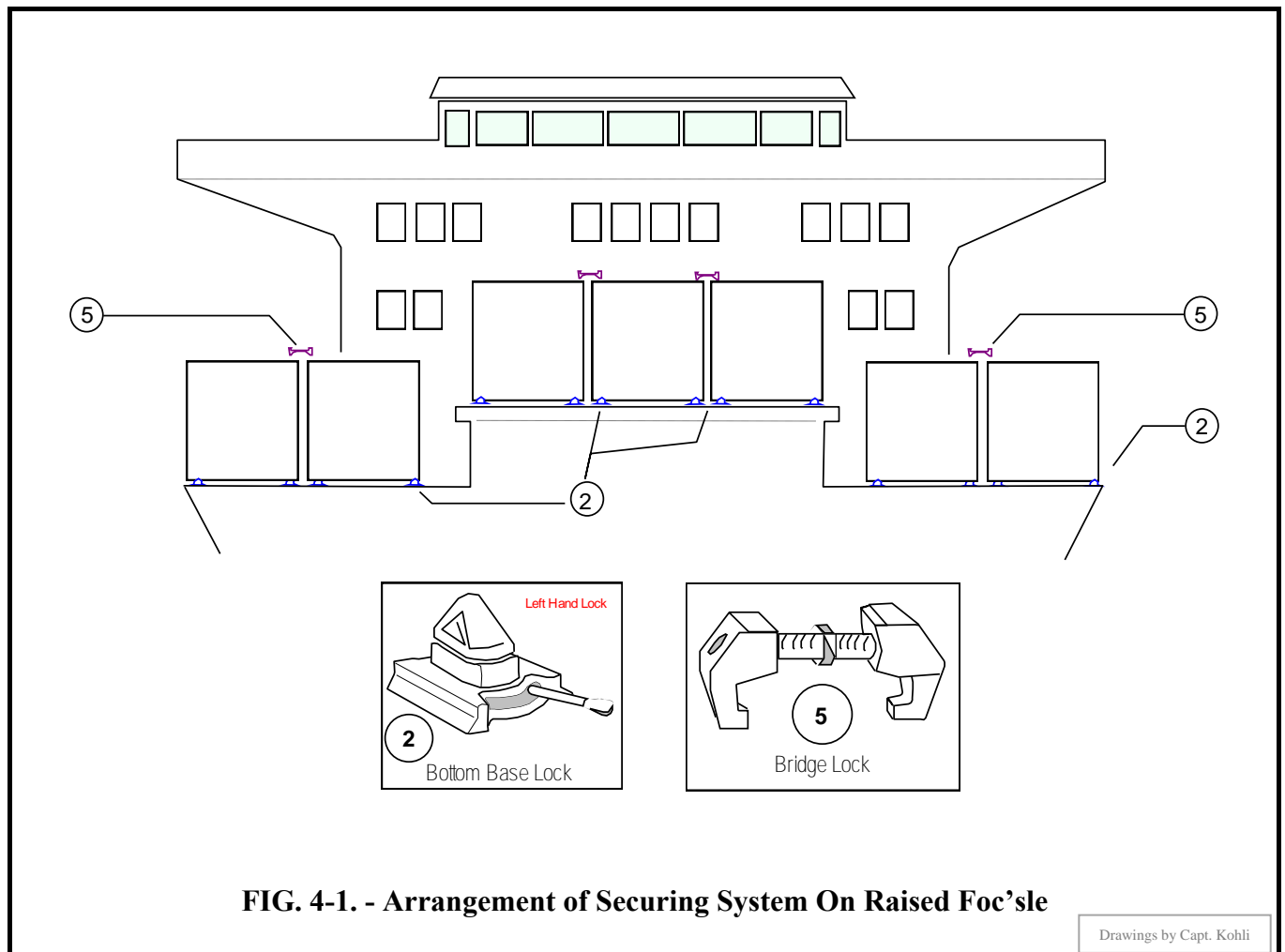
The Provisions for securing cargo, contained in this chapter, should be interpreted as minimum requirements. Additional Lashing should be taken to that prescribed here if so considered by the Master. The Master should in applying portable securing gear, take into account the following factors:

1. duration and geographical area of voyage
2. sea conditions which may be expected
3. vessel's design and characteristics
4. dynamic forces under expected weather conditions
5. type and weight of cargo carried and their intended stowage pattern

◆ Container Cargo:-

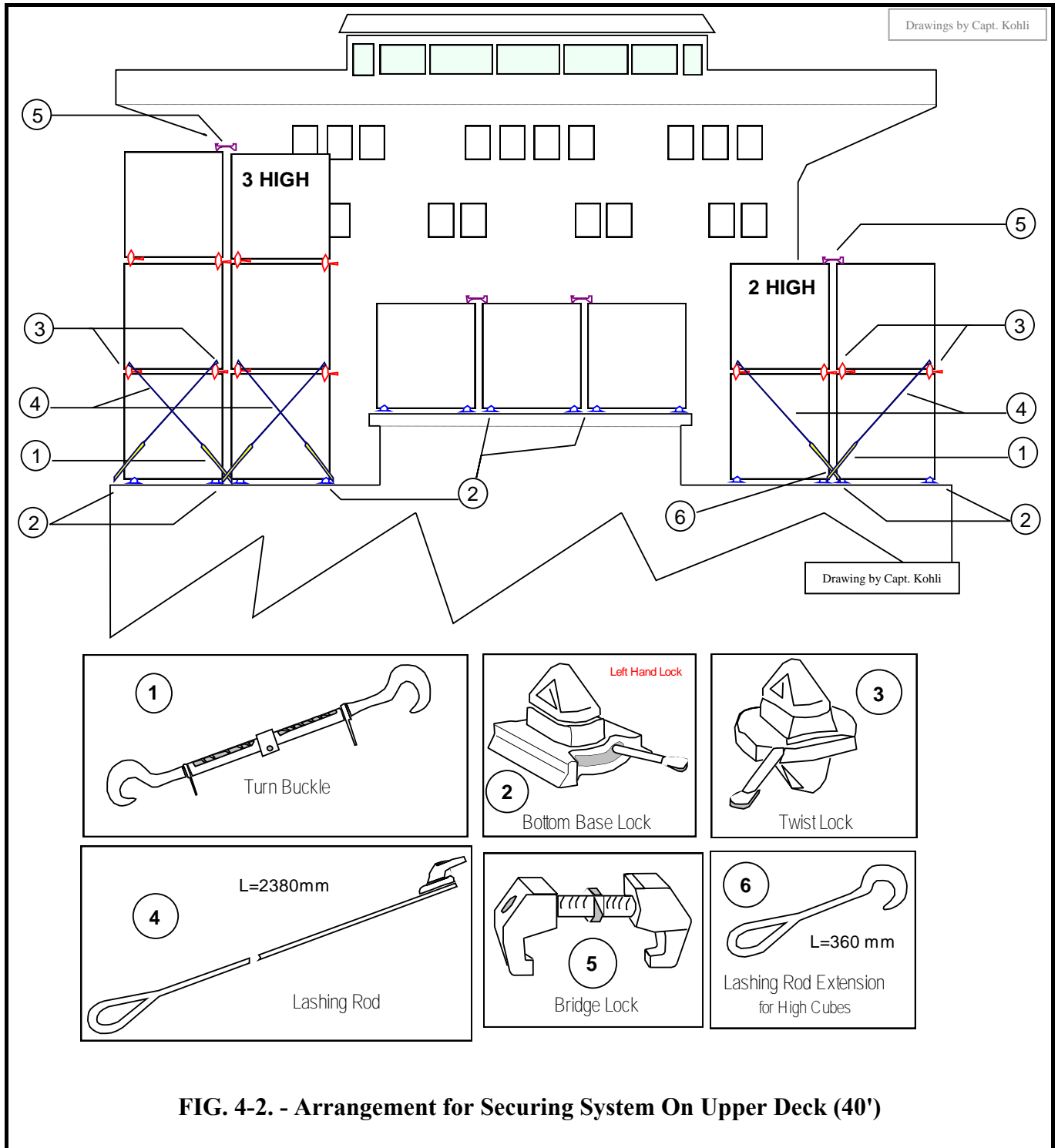
Containers on Foc'sle Deck:

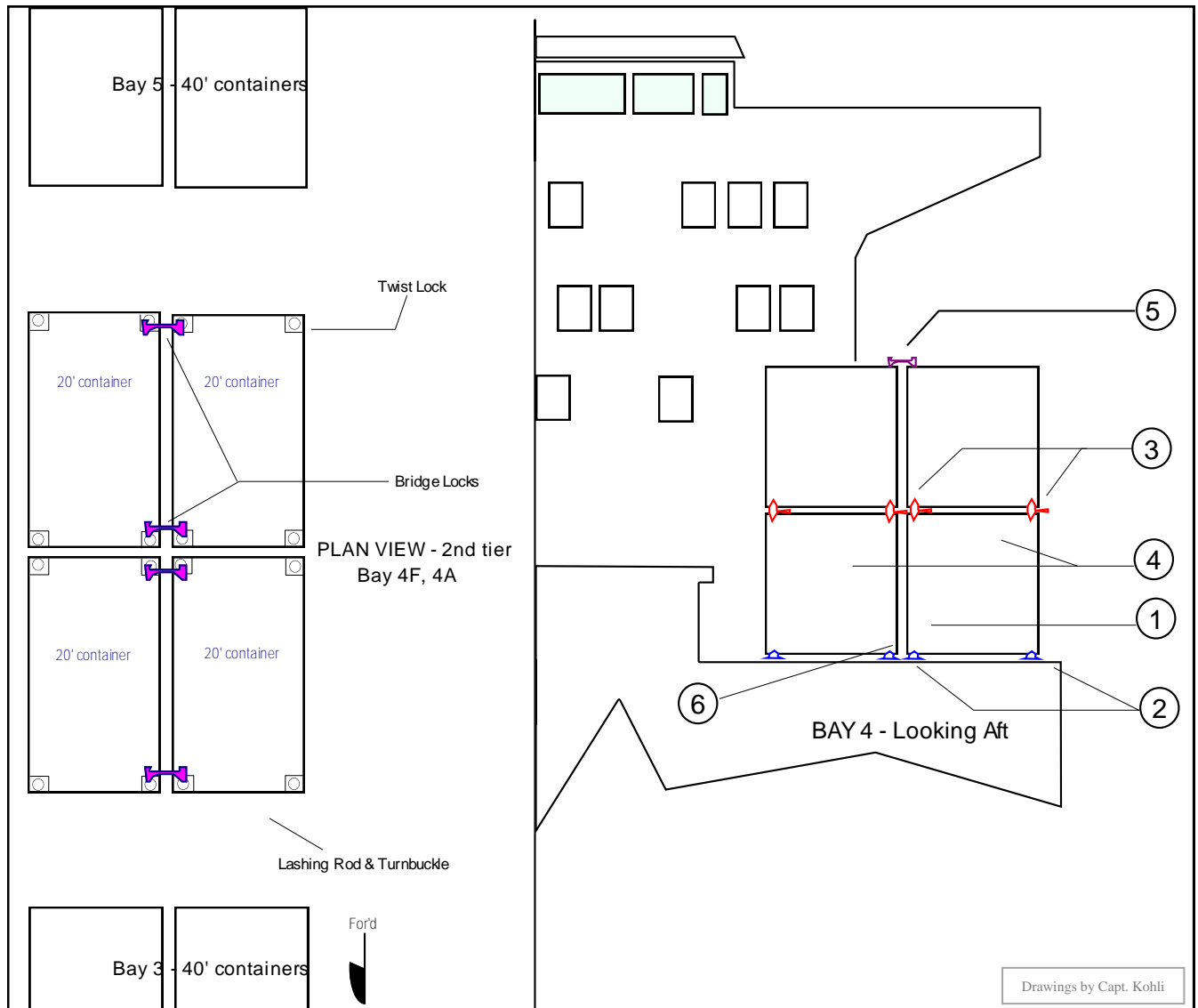
The following diagram shows the general lashing arrangement when carrying containers on the foc'sle deck, i.e. on Bay 1 and Hatch top 1. This arrangement also applies to single tier stow on all other positions.



Containers on Upper Deck:

The following diagram shows the general lashing arrangement when carrying containers on the upper decks, i.e. on Bays 2 to 5 and Hatch tops 2 to 4. The vessel normally carries a maximum of two tiers and cross lashing bars from the outside of each stack suffice. When carrying 3 tiers (usually empty container on the third tier) criss-cross lashing arrangement is suggested. SEE DIAGRAM BELOW.

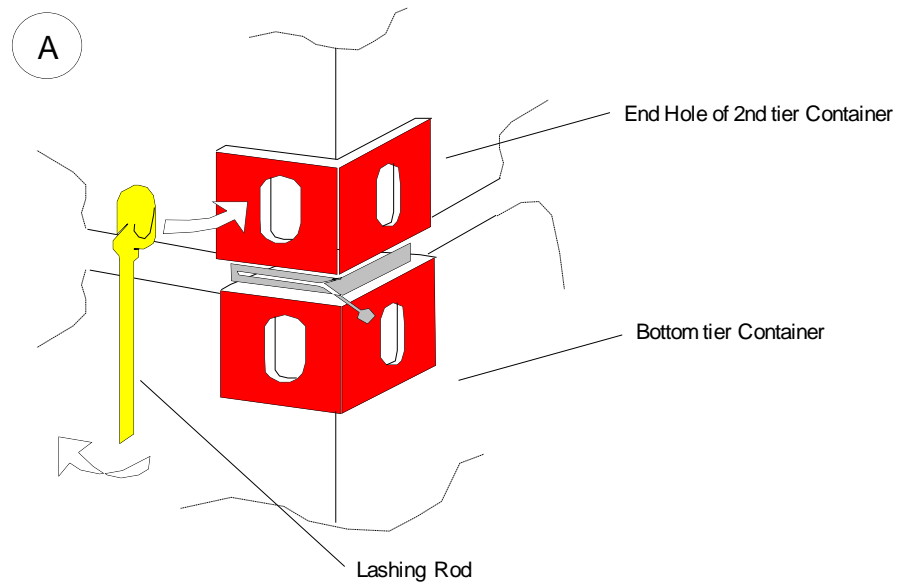


20' Containers on Bay 4 :**FIG. 4-3. - Securing Arrangement for 20' containers on Deck.**

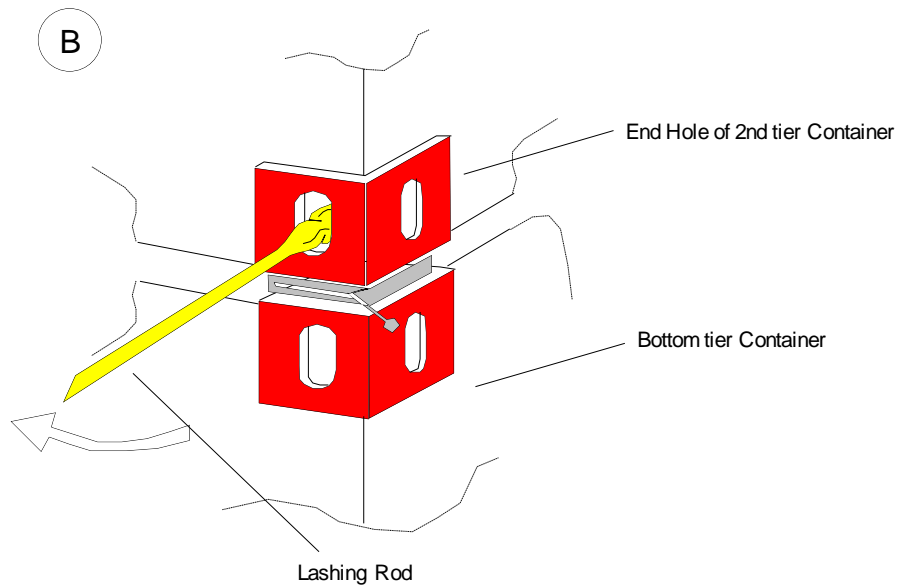
When Stowing 20' containers in Bay 4, each 40' stow position is effectively divided into two - for'd and after.

To secure two high 20' containers in Bay 4, bridge locks are used to secure each stack with the adjoining one. Lashing rod system need not be used. It is not possible to secure lashing bars between two fore/aft containers within Bay 4.

Base locks are used at the Bottom tier and Twist Locks are used between each tier.

Handling Method of Lashing Rod :

- A.** Insert Hook of lashing rod into lower end hole of the second tier container - raise the rod, line up the hook with the end hole, insert.



- B.** Swing the other end to cross lash and attach to the turnbuckle. Tighten the turnbuckle to secure the lash.

Bowed / slacked or overfastened lashing is not desirable. Hand adjust to proper tension with the turn buckle.

20' Containers in Hold :

The following diagram shows stowage pattern and lashing arrangement in Hold.

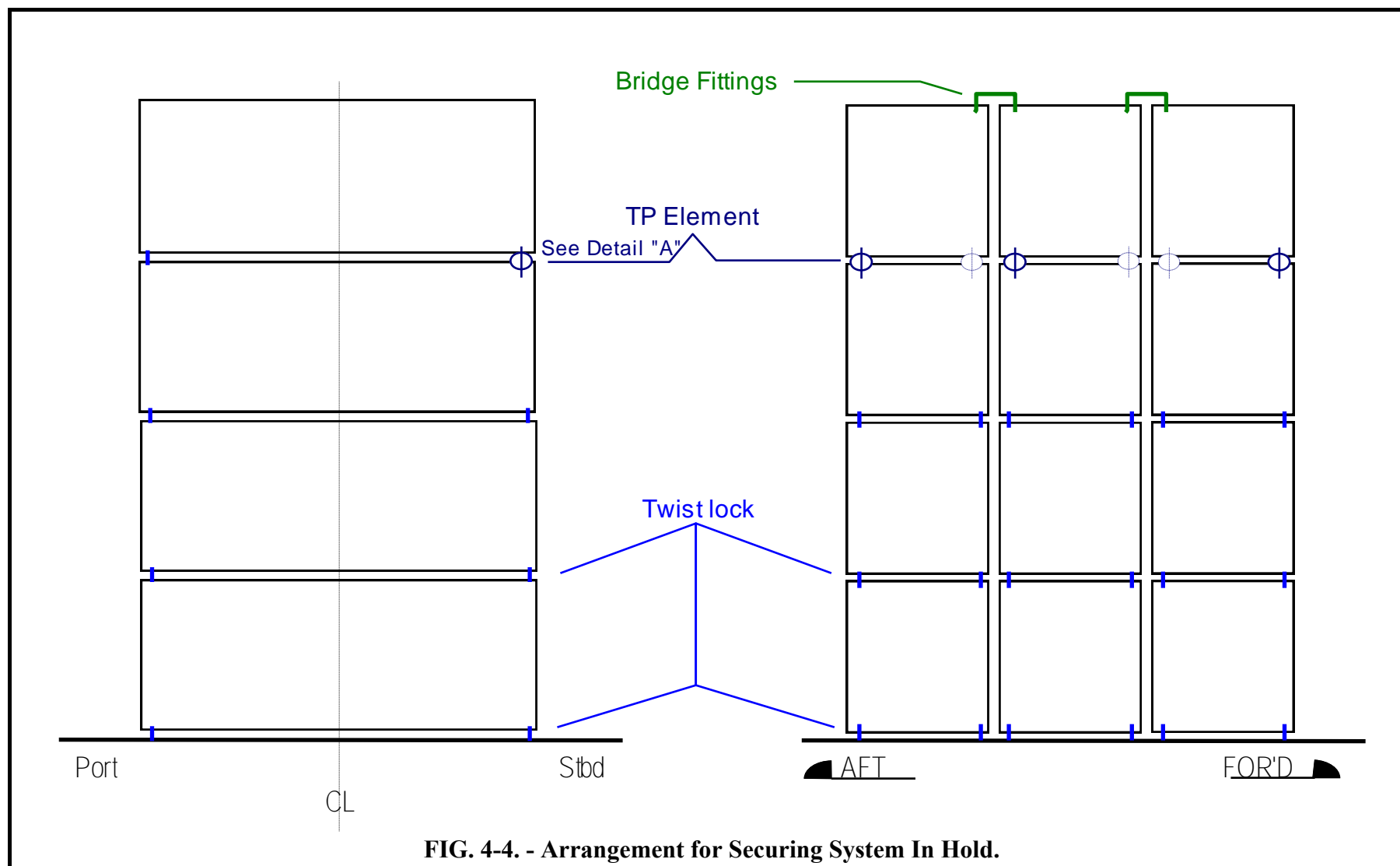
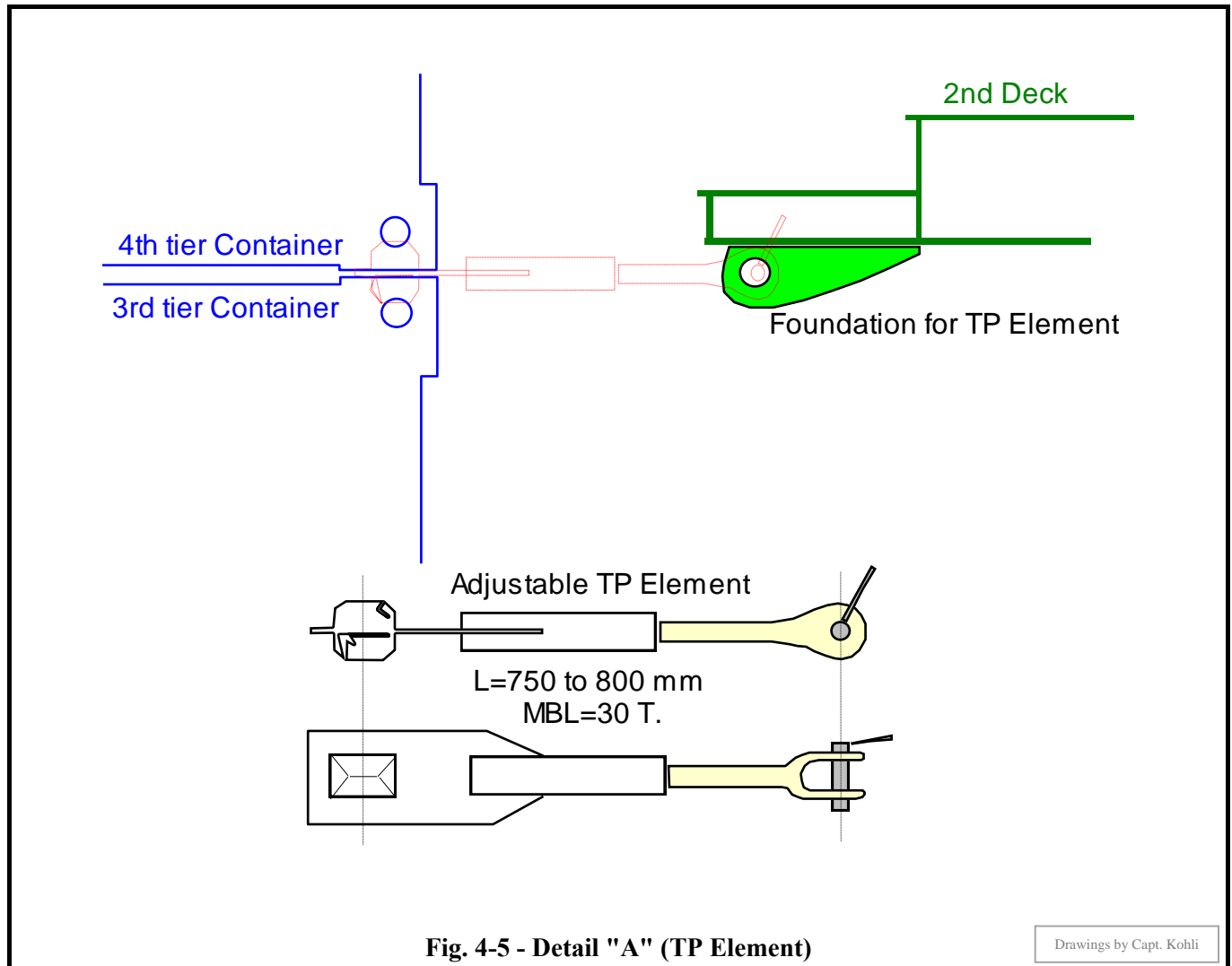


FIG. 4-4. - Arrangement for Securing System In Hold.

TP Elements (Buttresses) :

The following diagram "Detail `A`" shows securing arrangement for TP Element when loading 4 high 20' containers in Hold 3.



The TP Elements (Buttresses) are fastened on one end to the foundation on the 2nd Deck (A deck) of Hold 3. The other end, shaped like a double cone fits into the upper and lower corner pockets of the 3rd and 4th tier containers. The TP Element is then screwed tight. This then acts as a thrust pad and prevents athwartship racking movement of the containers in Hold 3.

◆ Palletized Reefer Cargo:-

When carrying palletized reefer cargo, the side boards on the hatch sides are erected to present a vertical side to the end pallets. This enables a secure tight stow. Additionally, portable Inflatable Dunnage Bags are used as required to ensure a tight stow. When the hold is partly full, wooden shoring is applied, observing prudent seamanship, to prevent shifting of cargo.

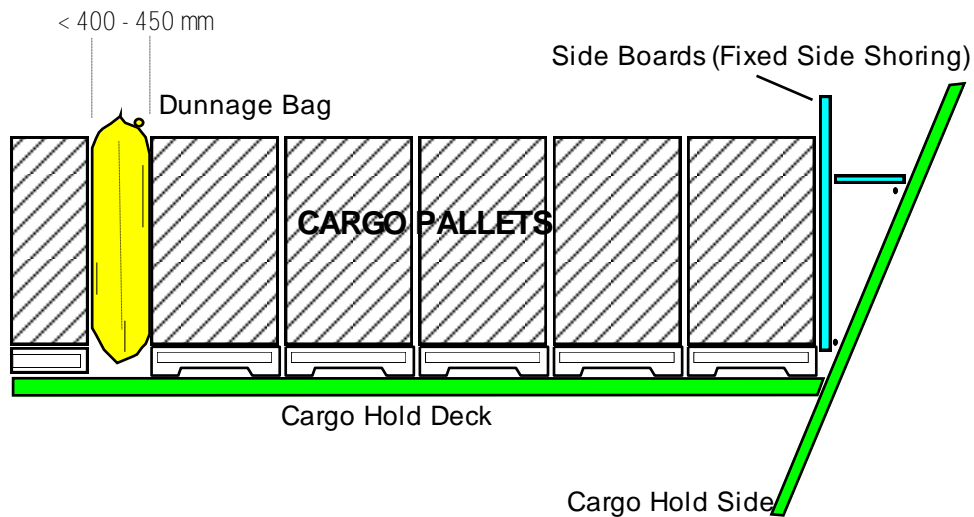


Fig. 4-6. -Pallet stow/securing arrangement in Reefer Holds

◆ Carrying cars Under deck:-

To secure cars under deck, the air circulation holes on the deck gratings are used as lashing holes for the car lashing hooks. As vessel does not usually carry such cargo, the portable lashing is obtained when necessary. No stock on board.

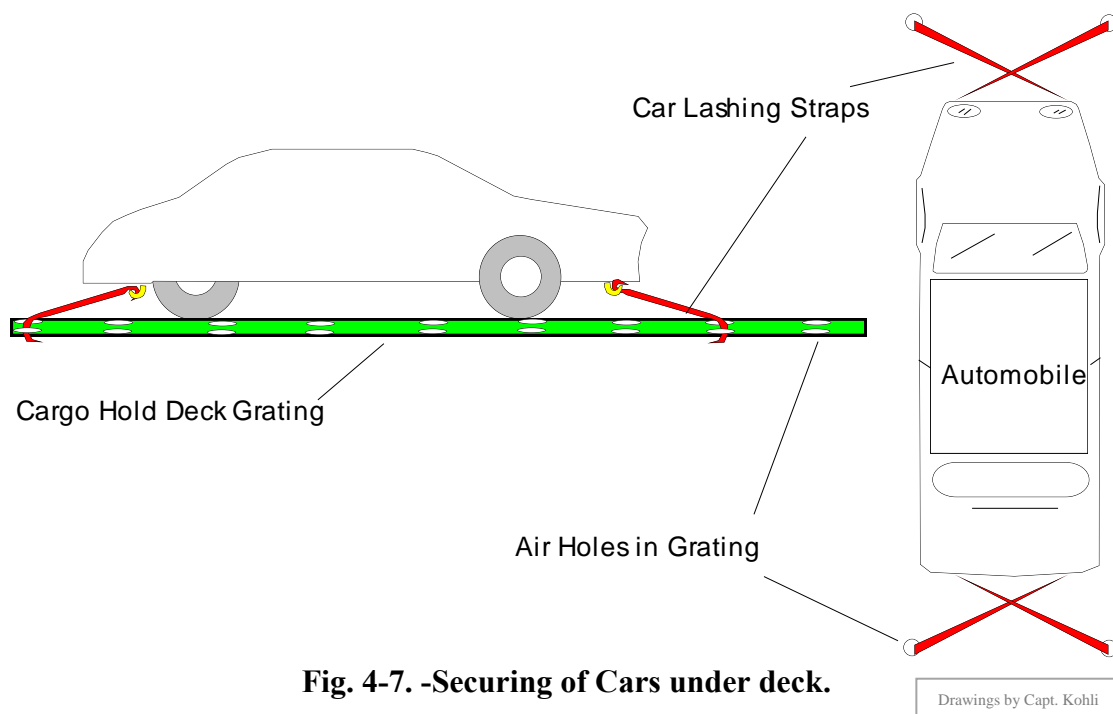


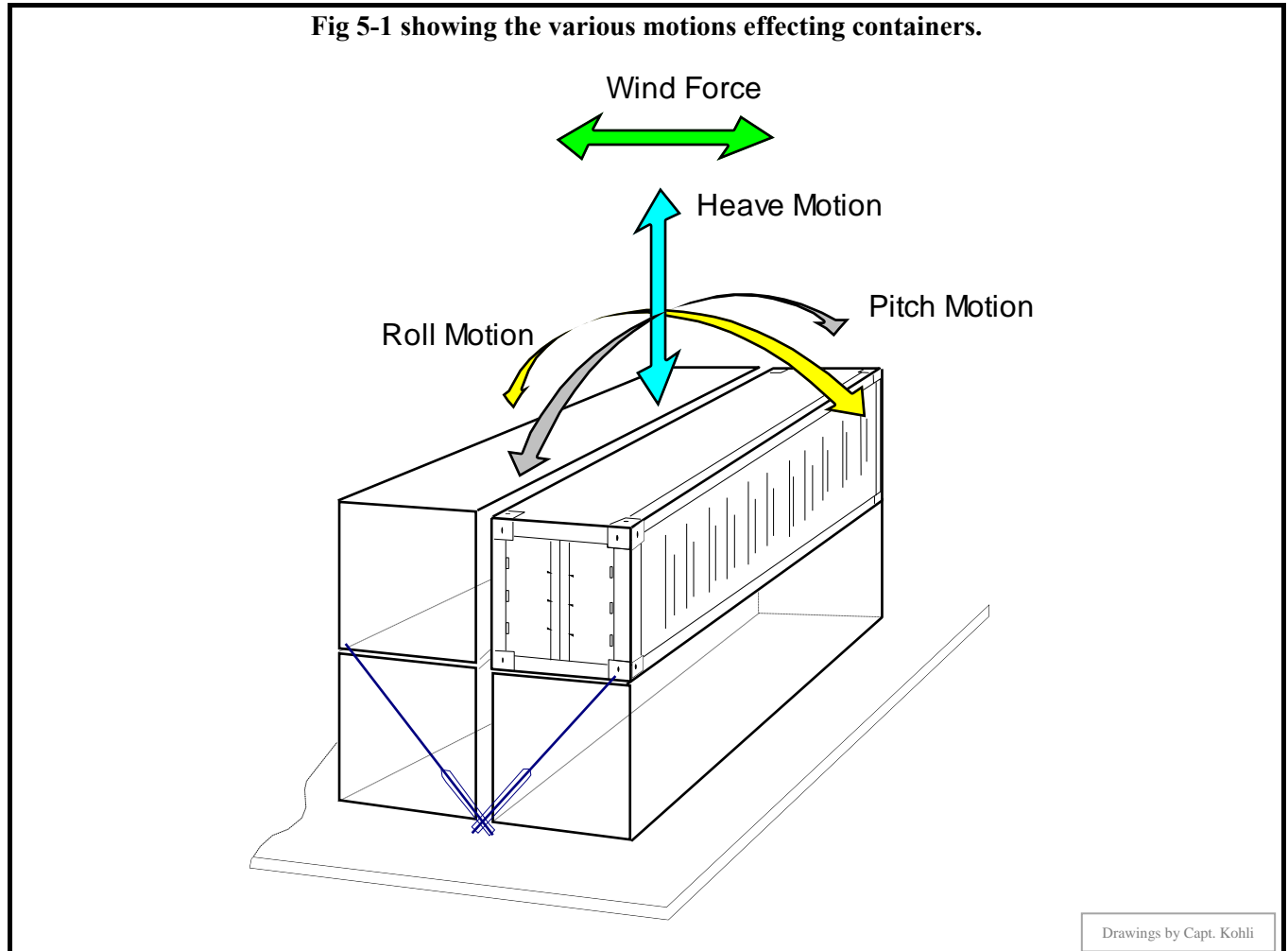
Fig. 4-7. -Securing of Cars under deck.

NOTE: Effective new IMO regulations, Cars must be certified free of fuel before they can be carried under deck or where the cargo space is not certified suitable for dangerous goods. Enhanced ventilation systems need to be provided for car carriage.

CHAPTER 5 : An Indication of Forces Acting on Cargo Units.

A cargo unit stowed on board will be subjected to the same movements the vessel experiences at sea. The most important, for securing purposes, are:

1. Rolling.
2. Pitching.
3. Heaving.
4. Wind Force.



Of the above mentioned motions, the time period involved and the amplitude of motion are significant.

- The time period of roll motion is obtained from the formula " $T_r = 0.7B \div \sqrt{GM_T}$ ". In general a value of GM is selected so that the period of roll is around 12 to 16 seconds (a convenient relationship- $GM_T = 0.06B$). This leads us to " $T_r = 2.86 \sqrt{B}$ ". A maximum roll amplitude of 30 degrees is specified.
- Pitch time period is " $T_p = 0.5 \div L_{pp}$ ". A maximum pitch amplitude of 8 degrees is used.
- Heave period is " $T_h = 0.5 \div L_{pp}$ ". The Heave amplitude is $L_{pp} \div 80$ m.
- Wind force is considered to act constantly, athwart ship only and at the maximum of 40 m/s. The magnitude of wind force is 1.8 tonnes on the sides of a 20' container and 3.6 tonnes on a 40' container.

The centre of motion (though constantly changing the affect of such changes is small), is considered to be:

1. on the centreline of the vessel.
2. at the long. centre of floatation.
3. at the waterline or at one half of the moulded depth, whichever is greater.

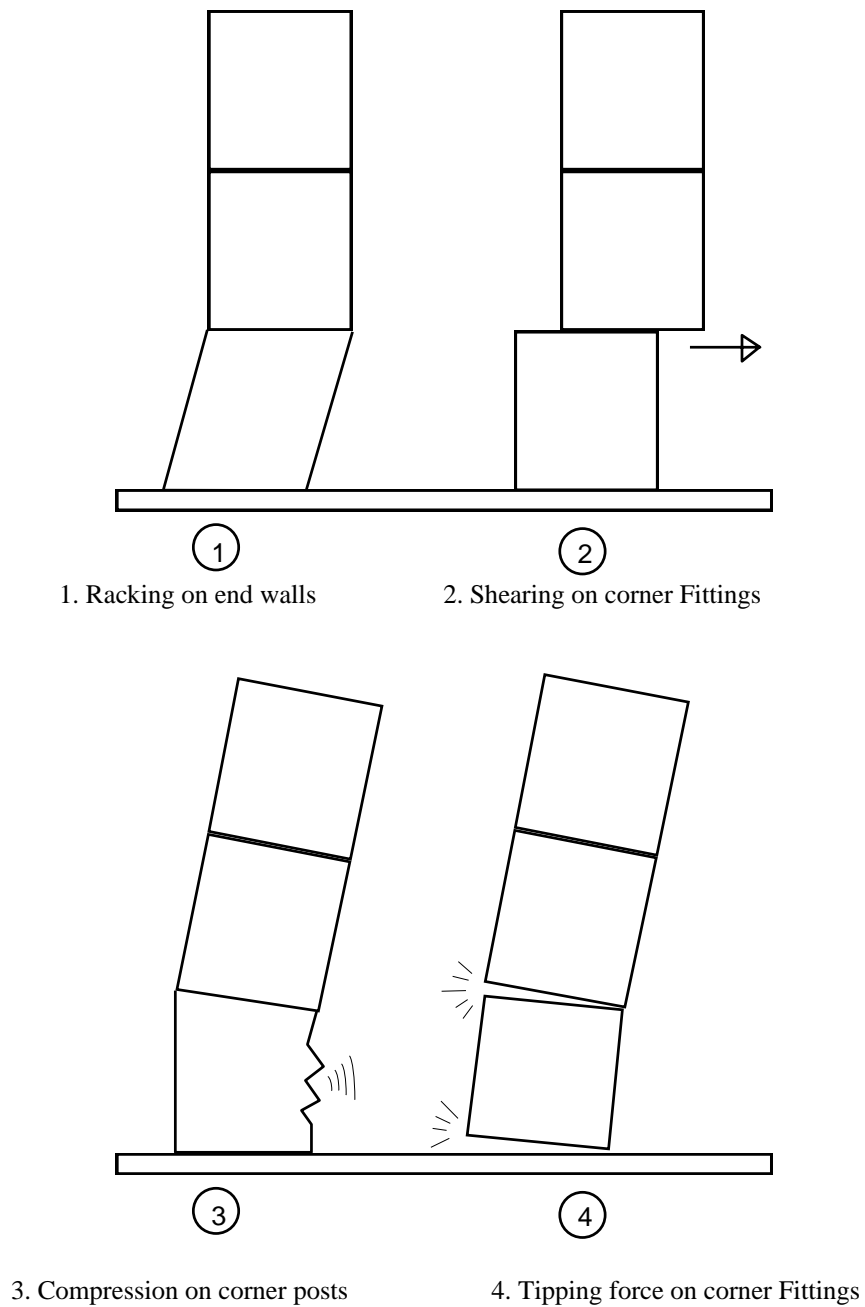
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- **Possible Modes of Failure:**

Subject to the Forces acting on a container stack, the following modes of failure are possible:

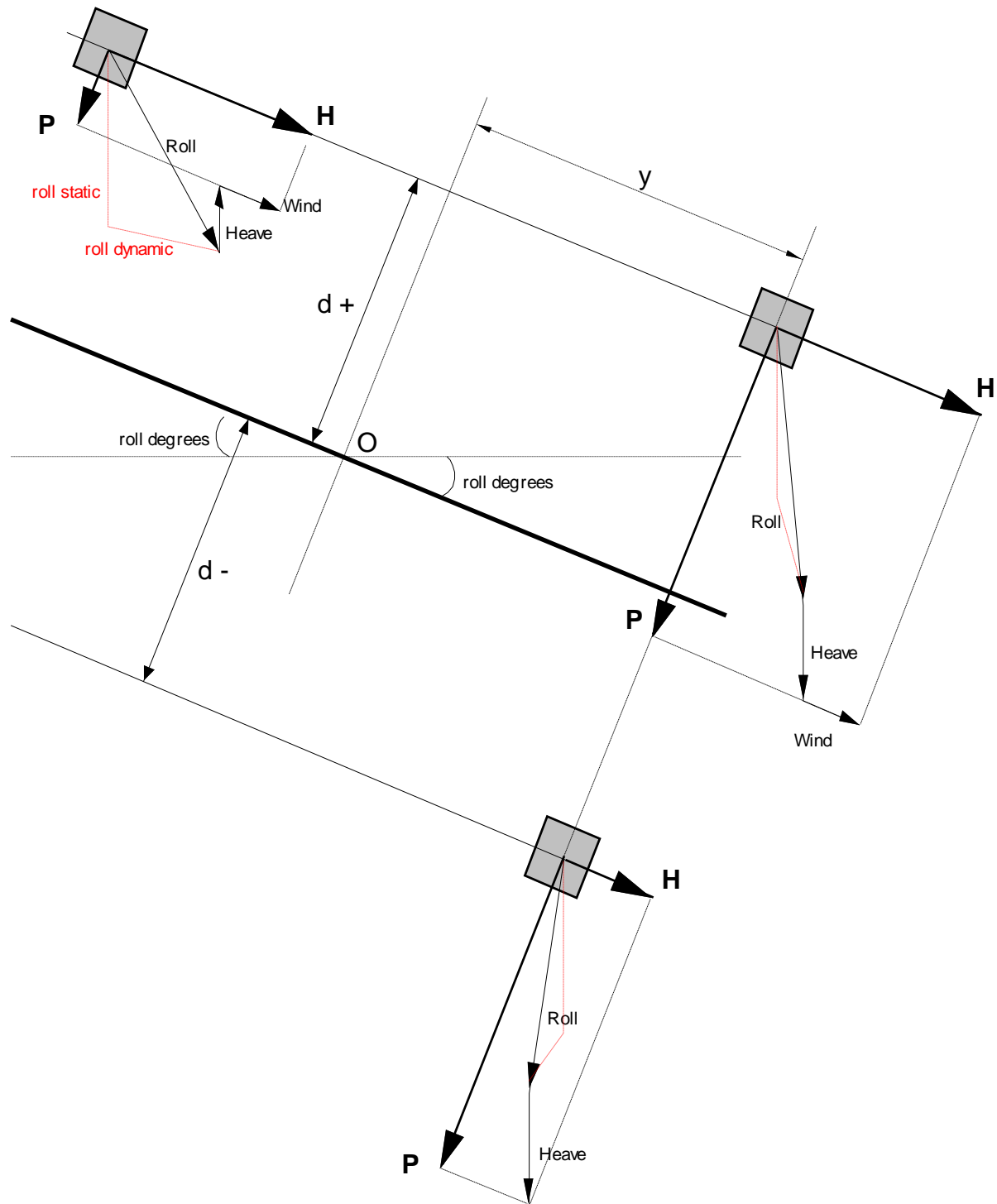
- i) Racking on containers' structure
- ii) Shearing of fittings between containers
- iii) Compression on containers' corner posts
- iv) Tipping (pull out) on container corners

Fig 5-2 : Modes of Failure of a Container Stack



Drawings by Capt. Kohli

The Forces acting on a container stack can be resolved into vertical and transverse directions.



In the figure above, O is the motion centre, $d+$ & $d-$ are the vertical distances (positive or negative) from this centre. The transverse distance from O is shown as y . The force P is the pressure acting normal to deck and H is the sliding force normal to deck. Both have been resolved from the forces that arose due to:

- i) Rolling (dynamic and static)
- ii) Heave, and
- iii) Wind (acts on above deck boxes).

• Formulae Used:

TABLE 5.1 - Ship's Motions

Motion	Maximum Amplitude	Period in Seconds	for -----
Roll	$\emptyset = 30$ degrees	$T_r = 2.86 \sqrt{B}$	30^0 in 13.27 secs.
Pitch	$\beta = 8$ degrees	$T_p = 0.5 \sqrt{L_{pp}}$	08^0 in 5.90 secs.
Heave	$L_{pp} \div 80$ m.	$T_h = 2.86 \sqrt{B}$	1.74 m in 5.90 secs.

TABLE 5-2:
Components of
Force-

Source	Component of force, in tonnes		
	Pressure (normal to Deck) "P"	Sliding (parallel to Deck)	
		transverse "H"	longitudinal "J"
STATIC			
Roll	$W \cos \emptyset$	$W \sin \emptyset$	
Pitch	$W \cos \beta$		$W \sin \beta$
Combined	$W \cos 0.71 \emptyset \cos 0.71 \beta$	$W \sin 0.71 \emptyset$	
DYNAMIC			
Roll	$0.07024W \frac{\emptyset}{T_r^2} y$	$0.07024W \frac{\emptyset}{T_r^2} d_r$	
Pitch	$0.07024W \frac{\beta}{T_p^2} z$		$0.07024W \frac{\beta}{T_p^2} d_p$
Heave:			
Roll	$0.05W \frac{L_{pp}}{T_h^2} \cos \emptyset$	$0.05W \frac{L_{pp}}{T_h^2} \sin \emptyset$	
Pitch	$0.05W \frac{L_{pp}}{T_h^2} \cos \beta$		$0.05W \frac{L_{pp}}{T_h^2} \sin \beta$
Wind		$8.25 AV^2 \cos \emptyset \times 10^{-5}$	

Where :-

\emptyset = roll in degrees

W = weight of container in tonnes

T_r = Roll period

β = pitch in degrees

L_{pp} = Length 'tween perpendicular

T_p = Pitch period

T_h = Heave period

A = surface Area

V = wind velocity

y = transverse distance from centre of motion

z = longitudinal distance from centre of motion

d = vertical distance from centre of motion

Reference: IMO Publications

• **FORCES ON A CONTAINER IN THE STACK:**

The components of force on each container are summed up for each set of motions.

In Rolling Condition:

$$P_{\max} = W[(1 + 0.05L_{pp} \div T_h^2) \cos \theta + 0.07024 \theta y \div T_r^2]$$

$$H_{\max} = W[(1 + 0.05L_{pp} \div T_h^2) \sin \theta + 0.07024 \theta d \div T_r^2]$$

In Pitching Condition:

$$P_{\max} = W[(1 + 0.05L_{pp} \div T_h^2) \cos \beta + 0.07024 \beta z \div T_p^2]$$

$$J_{\max} = W[(1 + 0.05L_{pp} \div T_h^2) \sin \beta + 0.07024 \theta d \div T_p^2]$$

In the combined condition (roll & pitch) the ax calculated angles are assumed at a factor of 0.71.

When calculating the forces on a supported (lashed) container stack, the flexibility of container walls (mm/t), flexibility of lashing (mm/t), effective modulus of elasticity (t/mm²), tension in each support, etc. are to be taken into account.

In a container stack the vertical force P, is divided equally between the four corner posts, that is P/4 per corner. The sliding force H is divided between the ends (sides) of the container, that H/6 at the top and H/3 at the bottom. The wind force is taken half to the top frame and half to the bottom (further divided for end walls).

Considering a 2 tier container stack on the -----, using the following symbols,

h = container height metres

b = container breadth metres

Q = Wind force in tonnes

H₁, H₂ = Transverse (sliding) force tonnes (per tier)

P₁, P₂ = Vertical force (per box) tonnes

The forces in a stack are given by:

a) Racking per end wall:

$$\text{Tier 2 racking} = \frac{H_2}{6} + \frac{Q}{4}$$

$$\text{Tier 1} = \frac{1}{2} (H_2 + H_1/3) + 3Q/4$$

b) Shear force per bottom corner:

$$\text{Tier 2} = 1.1 (H_2/4 + Q/4)$$

$$\text{Tier 1} = 1.1 (H_2/4 + H_1/4 + Q/2)$$

factor 1.1 is used to relate the shear to the connecting fitting between containers.

c) Downward Pressure force, per corner:

$$\text{Tier 2/1} = \frac{P_2}{4} \pm \frac{h}{b} (H_2/6 + Q/4)$$

$$\text{Tier 1/base} = \frac{P_2 + P_1}{4} \pm \frac{h}{b} (2H_2/3 + H_1/6 + Q)$$

• **ISO STANDARDS FOR CONTAINERS:**

Racking Force: the allowable limit is 15 tonnes in the end walls and 7.5 tonnes in the side walls.

Corner post compression: a limit is placed by the capability of the container below to withstand compression in its corner posts. The limit is 2.25 x the rated weight of the container, i.e. 45 tonnes for a 20' box and 67.5 tonnes for a 40' box. (not a significant factor unless 5 or more tiers are stowed).

Vertical tension (tipping force): the allowable pull out force on the corner castings is 20 tonnes at the bottom and 15 tonnes at the top. The safe working load of the twist locks must be greater than this.

Shear: the top and bottom of the corner casting is of substantial thickness and the limiting factor for shear is the strength of the twist lock. A minimum allowable shear strength of 15 tonnes is recommended.

• **CALCULATIONS SPECIFIC TO M.V. -----:**

Two situations are considered. A two high stack of 40' containers (25 tonnes each) and a two high stack of 20' containers (37.5 tonnes total). In each case the stacks are considered to be unsupported (NO LASHING) - for the purpose of calculating the forces on an unsupported stack.

Bay 5 position is assumed as that is the furthest from the LCF (centre of motion) for 40' two high containers. Bay 4 aft is assumed for the same reason for 20' boxes. In both cases the outboard stack is assumed, also to get a maximum (transverse) separation from the centre of motion. Centre of motion is taken at waterline at draft 7.30m (max. Banana draft); LCF at draft 7.30m is -2.726m.

1. BAY 5 outboard - 40' containers, 2 tiers of 25 t each. Stack weight = 50 tonnes, $y = 11.97\text{m}$, $d = 6.966$ & 9.56 m

Components of forces acting:-

In Rolling Condition:

P (pressure force normal to deck) = 29.56 t. (P_1 & P_2)

H (transverse sliding force parallel to deck) = 17.08 (H_1) and 17.86 (H_2) t.

In Pitching Condition:

$P = 37.88$ t (P_1 & P_2)

J (longitudinal sliding force parallel to deck) = 6.99 (J_1) and 8.03 (J_2)

In Combined (roll and pitch) Condition:

P_1 & $P_2 = 31.53$ t.

$H_1 = 10.56$ t $H_2 = 11.11$ t

$J_1 = 1.995$ t. $J_2 = 5.21$ t

Calculating the forces in the stack:-

	Racking Force per Wall (t)		Shear force per bottom corner (t)	Downward pressure per corner (t)
	Side wall	End Wall		
In Rolling condition:				
Tier 2	-	3.87	5.9	11.51
Tier 1	-	14.47	11.59	34.28
In Pitching condition:				
Tier 2	1.54	-	3.20	11.85
Tier 1	5.80	-	6.11	29.69
In Combined condition:				
Tier 2	1.07	2.75	4.04	10.81
Tier 1	3.55	10.02	7.94	29.33

Wind speed of 40 m/s has been applied on the sides. When calculating racking (longitudinal) of side walls, wind has been considered to act on the ends. All other cases wind force is acting on the sides (larger area) at a force of 3.6 tonnes per container.

It is seen that racking force in end wall of the bottom tier approaches the ISO limit of 15 tonnes in the rolling condition (3% less than limit).

In the above mentioned example, twist locks, bridge locks and "V" lashing rods from outer containers is suggested.

2. BAY 4 aft, outboard - 20' containers, 2 tiers, bottom of 20 t and upper tier of 17.5 t. Stack weight = 37.5 t

Components of forces acting:-

In Rolling Condition:

$$P_1 = 23.6 \text{ t.} \quad P_2 = 20.7 \text{ t.}$$

$$H_1 = 13.67 \text{ t.} \quad H_2 = 12.5 \text{ t.}$$

In Pitching Condition:

$$P_1 = 26.6 \text{ t.} \quad P_2 = 23.3 \text{ t.}$$

$$J_1 = 5.59 \text{ t.} \quad J_2 = 4.89 \text{ t.}$$

In Combined (roll and pitch) Condition:

$$P_1 = 22.62 \text{ t.} \quad P_2 = 19.7 \text{ t.}$$

$$H_1 = 8.45 \text{ t.} \quad H_2 = 7.78 \text{ t.}$$

$$J_1 = 1.60 \text{ t.} \quad J_2 = 3.65 \text{ t.}$$

Calculating the forces in the stack:-

	Racking Force per Wall (t)		Shear force per bottom corner (t)	Downward pressure per corner (t)
	Side wall	End Wall		
In Rolling condition:				
Tier 2	-	2.53	3.93	7.86
Tier 1	-	11.05	8.19	24.27
In Pitching condition:				
Tier 2	1.04	-	1.84	7.17
Tier 1	4.00	-	3.87	18.84
In Combined condition:				
Tier 2	0.74	1.75	2.63	6.78
Tier 1	2.70	6.65	5.45	19.50

Wind speed of 40 m/s has been applied on the sides. When calculating racking (longitudinal) of side walls, wind has been considered to act on the ends. All other cases wind force is acting on the sides (larger area) at a force of 1.8 tonnes per container.

It is seen that the ISO limits are not exceeded. The closest is the racking in end walls in rolling condition, where it is 22% less than the 15 tonnes limit. Twist locks and bridge locks suffice in this situation. In any case, no lashing rods can be used between Bay 4 for'd and Bay 4 aft - any lashing rods taken on one end would not be considered to affect the unlash end. The stack would in effect be considered to be unlash, supported by twist locks and bridge locks only.

Summary:

Calculations show that on -----, single tier containers need only be supported with twist locks. With two high containers, in the case of 20' boxes, twist locks and bridge locks will suffice. In the case of two high 40' boxes, though no force limits are exceeded, the additional support of lashing rods ("V" lashing) is preferred.

These are of course the minimum requirements. In actual practice, the vessel has sufficient stock of gear to secure lashing rods, twist locks and bridge locks on all containers. It is always advisable to err on the safe side.