ICHCA International Limited

INTERNATIONAL SAFETY PANEL
TECHNICAL/OPERATIONAL ADVICE
NO 1

VERTICAL TANDEM LIFTING OF FREIGHT CONTAINERS

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ICHCA International Limited

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ICHCA International Limited - INTERNATIONAL SAFETY PANEL

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VERTICAL TANDEM LIFTING OF FREIGHT CONTAINERS

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1 BACKGROUND AND INTRODUCTION

1.1 In the late 1980s the US Occupational Safety and Health Administration (OSHA) issued a letter to Matson Navigation Company authorising the lifting of two vertically coupled containers loaded with automobiles. In 1993 OSHA issued a letter to Sea-Land Service Inc. permitting the lifting of two empty freight containers vertically coupled by twistlocks, subject to some limitations.

1.2 In 1997, following the adoption of new Longshoring Rules, OSHA sought information about general vertical tandem lifting (VTL) operations from those concerned and in January 1998 held a public meeting in Washington, DC.

1.3 It became apparent that there was a need for international clarification by:

- The International Organization for Standardization (ISO) of the adequacy of the structural strength of containers.
- The International Labour Organization (ILO) of the use of equipment to couple containers together and to be part of the lifting operation.
- The International Maritime Organization (IMO) of the maintenance of the integrity of containers.

1.4 In 1998 a meeting between OSHA and ILO was held in Geneva that clarified ILO's position with regard to the application of ILO Convention 152 (Safety and Health in Dock Work) in relation to VTL.

1.5 Following a series of meetings of ISO Technical Committee 104 and its Sub Committees in Cape Town in 2000, ISO 3874 Series 1 Freight Containers – Handling and Securing has been amended. The amendment permits VTL operations subject to certain conditions.

1.6 At the same set of meetings it was recognised that there were potential hazards associated with VTL operations and therefore that there was a need for a single comprehensive document that would deal with all aspects of VTL operations. ICHCA's International Safety Panel was requested to develop such a paper.

1.7 This paper is the result of that request.

1.8 The paper has been developed by a working group of the Safety Panel with two rounds of formal consultation of relevant international and regional organisations. A list of consultees is included as Appendix 1.

1.9 The operational guidelines in section 8 are necessarily recommendations, therefore, they have been written in terms of 'should'. However, where a matter is a requirement of an ILO, IMO or ISO international instrument it has been written in terms of 'shall'.

2 SCOPE

2.1 The operational guidelines in section 8 are intended to cover operations in which ISO Series-1 freight containers, or containers of similar standard and capacity, in VTL units are loaded or discharged to or from the decks of ships, other than to or from deck cell guides, by shore gantry cranes and ancillary operations on the quay and terminal. The guidelines are not intended to apply to operations on hatchless container ships or to operations below deck.

2.2 However, it is recognised that the guidelines may also be applicable to similar operations elsewhere. Where this is so, the guidelines may be used as general advice on the safe handling systems and procedures to be followed.

3 OBJECTIVE

3.1 The operational guidelines in section 8 are intended to give authoritative safety and operational advice on VTL operations. The aim is to produce a common set of procedures and systems, based on international standards, which can be adopted by all parties involved with VTL operations in any part of the world. The objective is to enable VTL operations to be carried out safely in a way that is acceptable to all the parties concerned.

4 DEFINITIONS

4.1 **Approved continuous examination programme (ACEP).** An equipment examination programme, approved by a competent authority, which recognises that certain routine operational inspections can satisfy requirements for periodic equipment examinations. An example of a recognised ACEP programme is included in the International Convention for Safe Containers.

4.2 **Certificated.** The holding of a current, valid certificate, issued by a recognised body approved by a competent authority, that following satisfactory testing and thorough examination certifies the lifting capacity of the liftlock.

4.3 **Competent authority**. The appropriate national enforcement agency having jurisdiction over VTL operations in each port of call where such operations are proposed.

4.4 **Competent person**. A person possessing the knowledge and experience required for the performance of a specific duty or duties, authorised to act as such and acceptable as such to the competent authority. A competent person for the examination of liftlocks will be a person familiar with the proper maintenance and use of liftlocks by training, experience or both. Such a person will be able to detect defects or weaknesses and be able to assess the importance of them in relation to the safety and continued use of the liftlocks.

4.5 **Liftlock**. A twistlock, latchlock or other inter-box connector complying with Annex A or B of ISO 3874 and the operational guidelines in section 8 of this paper that may be used to couple two or three containers vertically together so that they may be lifted as one unit. (See Appendix 2 for a photograph and drawing of a typical VTL unit and liftlock).

4.6 **Ship.** Includes any waterborne craft capable of carrying containers.

4.7 **Thorough examination**. A detailed visual examination by a competent person, supplemented if necessary by other suitable means or measures in order to arrive at a reliable conclusion as to the safety of the appliance or item of loose gear examined.

4.8 **Vertical tandem lifting (VTL) operation**. The operation of lifting two or three containers that are coupled together vertically.

4.9 **Vertical tandem lift (VTL) unit**. Two or three containers, coupled together vertically by liftlocks, that are to be lifted as a single unit.

5 INTERNATIONAL REQUIREMENTS

5.1 International Organization for Standardization (ISO)

5.1.1 The ISO's Technical Committee on Freight Containers, Technical Committee 104 (ISO/TC104), has within its remit the development of international standards for the design and testing of freight containers and for container handling and securing. ISO/TC104 deals specifically with the structural issues that relate to the ability of a freight container to be handled and safely transported in intermodal (rail, road, sea and air) commerce.

5.1.2 ISO/TC104 concluded that the existing design and testing requirements contained in the TC104 family of standards cover VTL operations. TC104 determined that containers, their fittings and the twistlocks specified in the standards have sufficient structural strength to allow VTL operations to be safely carried out within the limits specified in the standards. The standards that are relevant to VTL operations are listed in Appendix 3.

Note: ISO/TC104 did not differentiate between different types of containers in their discussions on vertical tandem lifting as the design and structural test requirements set out in the ISO 1496 series of standards on the design and specification of series 1 freight containers (1496-1: General cargo containers, 1496-2: Thermal containers, 1496-3: Tank containers, 1496-4: Dry bulk containers and 1496-5: Platform containers) are identical for each type of container.

5.1.3 ISO/TC104's initial work on VTL operations confirmed that, if they were carried out with two empty containers, the forces to which the containers would be subjected would be within their design strength. After extensive structural testing of corner fittings, twistlocks and latchlocks by two independent national testing laboratories[1] and additional deliberations by TC104, it was determined that their design strengths were such that 2

[1] Swedish National Testing and Research Institute, Mechanics SP REPORT 1997:22, "Container Lashing", and US National Institute of Standards and Technology, NISTIR 6557, "Strength Evaluation of Connectors for Intermodal Containers, August 2000"

partially loaded containers (see 5.1.6) could also be safely handled as VTL units.

5.1.4 Tests conducted by the US National Institute of Standards and Technology (NIST) identified three key points relating to VTL operations and twistlocks, latchlocks and corner fittings that conform to the ISO standards:

- The safety critical components of a VTL unit that limit the total mass of the unit that may be lifted are the corner fittings of the container. ISO/TC104 confirmed that the horizontal faces of the top and bottom corner fittings are structurally identical. The Committee also concluded that the existing ISO structural tests adequately tested both the top and bottom corner fittings for VTL operations. Each corner fitting is designed to safely handle a tensile force of 150 kN (33,720 lb) over a minimum load carrying area of 800 mm^2 of the interior horizontal face surrounding the aperture. For VTL operations, TC104 incorporated an additional safety factor and limited this loading to 75 kN (16,860 lb) over an area of 800 mm^2. The standard specifically requires any twistlock or latchlock used for lifting to have an engagement area in the corner fitting of at least 800 mm^2.
- Existing twistlocks and some latchlocks typically exceed the structural requirements of ISO 3874.
- Single sided latchlocks do not meet the minimum engagement area requirement of ISO 3874 and should not be used for VTL operations.

5.1.5 In developing the amendment to ISO 3874, TC104 considered:

- The maximum wind loading that could be imparted to an interlocked VTL unit of containers by a 100 kph (28 m/s, 62 mph or 54 knot) wind.
- The mass (tare) of the empty containers that may be coupled together.
- Loadings that could result from cargo (payload) within the containers.

5.1.6 A structural safety factor of 5, based on the ultimate tensile strength of the components (twistlocks, corner fittings, corner posts, etc.) in a VTL operation, was used in the actual calculations carried out by ISO. This is also used in these guidelines. In addition, an extra safety factor was introduced by TC104 by using the most severe wind load as a constant in the calculations. These considerations led to the conclusion that a gross mass of up to 19,986 kg (20 tonnes) could be safely handled as a VTL unit. Appendix 4 is a technical and engineering analysis that has been carried out to confirm that the operational guidelines in section 8 incorporate the necessary safety factor. It identifies the types of containers that may be lifted in a VTL Unit.

5.1.7 Important limits placed on VTL operations by ISO/TC104 are:

- A maximum of three containers shall be vertically coupled together to form a VTL unit.
- Twistlocks and latchlocks used in VTL operations (liftlocks) shall comply with ISO 3874 and have a load carrying engagement area (contact area between the face of the twistlock head or latchlock latch and the corner fitting face surrounding the fitting's aperture) of at least 800 mm^2.

- The total mass of the VTL unit shall not exceed 20,000 kg.
- The twistlocks or latchlocks used in VTL operations shall be certificated for lifting with a Safe Working Load (SWL) of at least 10,000 kg.

Note 1: Safe Working Load is also used in the context of securing containers on board a ship. Twistlocks or latchlocks with an approved SWL of 25,000 kg for lashing and securing containers to the deck of a containership will not necessarily be certificated for lifting nor will they automatically have a SWL of 10,000 kg for lifting. This distinction should be kept in mind.

Note 2: It would be possible for a twin lift spreader to be able to lift two VTL units at the same time.

5.2 International Labour Organization (ILO)

5.2.1 The ILO is the United Nations Agency that deals with employment matters on shore. One of its Conventions (Convention 152) deals with safety and health in dock work. ILO Recommendation 160, a Code of Practice and a Guide support it.

5.2.2 VTL operations are not specifically mentioned in ILO Convention 152 as the Convention was adopted in 1979. However, discussions with ILO have indicated that the Convention relates to VTL Operations as set out in 5.2.4 and 5.2.5.

5.2.3 Articles of the Convention that are relevant to VTL operations are articles 21 to 27. These deal with design and construction, safe use, testing, thorough examination, inspection, recording and marking of lifting equipment.

5.2.4 In a VTL unit, each container is deemed to be part of a load, providing that the top container, or containers, is not always the same container or containers. This means that for purposes of the Convention, containers in a VTL unit are treated the same as a container that is lifted by itself and the rules as to whether they can be safely lifted are found in the relevant ISO Standards (see section 5.1). However, the Convention says that each container shall be:

- Of good design and construction, of adequate strength and maintained in good repair and working order.
- Used in a safe and proper manner.

5.2.5 Liftlocks used to connect containers in a VTL unit are considered to be "loose gear" for the purposes of ILO Convention 152. This means that each liftlock shall be:

- Of good design and construction, of adequate strength and maintained in good repair.
- Used in a safe and proper manner.
- Tested and thoroughly examined by a competent person in accordance with national laws or regulations applicable where the VTL operation takes place before being put into use for the first time and after any substantial alteration or repair.

- Periodically thoroughly examined by a competent person. Such examinations shall take place at least once in every 12 months.
- Inspected regularly before use.
- Clearly marked with its SWL for lifting by stamping or by other suitable means.

In addition, records shall be kept of tests and thorough examinations (see section 8.1.3).

5.2.6 ILO Convention 152 represents the international requirements for dock operations and its provisions are widely implemented by port states around the world. Article 2.2 permits national competent authorities to vary particular requirements of the Convention's technical measures provided that they are satisfied that the variations provide corresponding advantages and that the over-all protection afforded is not inferior to that which would result from the full application of the Convention's requirements. It is understood that some countries may impose a higher standard. Where the local national laws require an alternative or a higher standard, that standard will have to be taken into account by those intending to start a VTL operation in that country.

5.2.7 Section 8 sets out how these international requirements for safe use of liftlocks should be complied with and what criteria should be used for thorough examinations.

5.3 International Maritime Organization (IMO)

5.3.1 The IMO is the United Nations Agency that deals with maritime affairs.

5.3.2 One of IMO's instruments is the International Convention for Safe Containers (CSC), adopted in 1972. It was amended in 1981, 1983 and 1991. All these amendments are now fully in force. Further amendments were adopted in 1993 but they will not come into force until they have been accepted by two thirds of the contracting states to the Convention. The 1993 amendments are minor and include the substitution of units of mass for units of weight. The Convention does not specifically refer to VTL operations.

5.3.3 The two main objectives of the Convention are:

- To maintain a high level of safety of human life in the transport and handling of containers by providing generally acceptable test procedures and related strength requirements that have proved to be adequate over the years.
- To facilitate the international transport of containers by providing uniform international safety regulations.

5.3.4 The current, 1996, edition of the CSC is published by IMO as IMO-282E. This includes:

- The Convention, as amended.
- Regulations for the testing, inspection, approval and maintenance of containers.
- Structural safety requirements and tests.

- Recommendation on harmonised interpretation of the Convention, as amended.
- The 1993 amendments.

5.3.5 The CSC applies to all containers, whether built prior to or since 1977 (when the CSC came into force), that are used in international transport, other than those that are specifically designed for transport by air. The CSC definition of 'container' includes all ISO freight containers.

5.3.6 The CSC does not apply to offshore containers that are handled in open seas. However, guidelines for the approval of such containers were approved by the Maritime Safety Committee of IMO in 1998 and published as MSC/Circ.860.

5.3.7 The CSC requires that all containers shall be approved by the government of a contracting state to the Convention or by an organisation that has been approved for the purpose by such a government. In order to be approved, all new containers need to comply with the structural safety requirements and tests annexed to the Convention. Containers may be approved individually or on the basis of design type testing.

5.3.8 The structural safety requirements and tests were drawn up on the basis that the design strength of a container will be greater than the forces that act on it in any phase of its operation. Such forces may result from its motion or location on a ship or vehicle, stacking, its loaded mass and any external forces. The structural requirements are set out in general terms. Detailed requirements are set out in the complementary ISO standards (see Appendix 3).

5.3.9 Test loadings and associated externally applied forces and test procedures are set out for:

- Lifting.
- Stacking.
- Concentrated loads.
- Transverse racking.
- Longitudinal restraint (static test).
- End-walls.
- Sidewalls.

5.3.10 Lifting tests include lifting from top and bottom corner fittings (often referred to as corner castings) from above, from forklift pockets, grappler arm positions and by any other method. For lifting from above, the conventional test procedure uses a single container with the interior loaded so that the gross mass of the container is twice its maximum gross rating. However, the CSC also permits containers to be tested using externally applied forces. This could be by means of a container, or other mass, suspended from the bottom corner fittings. In such cases, the internal loads and externally applied forces are required to be representative of the acceleration conditions appropriate to that method. Whether interior and/or external loading is applied in the test, a container that satisfactorily passes the test is considered to be strong enough to be handled in service in a single lift with no external load applied to the bottom corner fittings.

5.3.11 Test procedures in Annex II of the CSC do not specifically cover the use of the underside apertures of bottom corner fittings for lifting purposes. However, the dimensions of bottom corner fittings and the apertures in their horizontal faces are the same as those of top corner fittings and the attachment characteristics between corner posts and both top and bottom corner fittings are also the same. For these reasons, the conventional CSC lifting test covers both the lifting of fully loaded containers in a single lift and the lifting of empty or partially loaded containers suspended from the bottom of a container in a VTL unit. This will be true providing that the total gross mass of containers, including any payload within those containers, below a container in a VTL unit does not exceed its maximum permitted payload. Furthermore, the ISO bottom-lifting test applies 300 kN tension to the bottom corner fitting at an angle of 30º to the horizontal. This is equivalent to a 150 kN tension force applied vertically to the bottom fittings, the same that applies to the top corner fittings.

5.3.12 The CSC requires that all containers shall be maintained in a safe condition. This is the responsibility of the owner of the container, or the lessee or bailee of the container if there is an agreement between the relevant parties. The methods by which owners ensure the continuing safety of their containers are not specified. However, the owner is required to have all containers examined in accordance with an approved examination scheme at intervals. This may be under a periodic or a continuous examination scheme. Examinations under a periodic examination scheme (PES) are required to be carried out within five years of the date of manufacture of the container and at intervals of not more than 30 months thereafter. The date of the next examination is shown on the CSC plate on the container. Examinations under an approved continuous examination programme (ACEP) are required to be carried out in connection with major repair, refurbishment, or on-hire / off-hire interchange at intervals of not more than 30 months. In this case the CSC plate or supplementary decal will bear the initials “ACEP” instead of the next examination date.

5.3.13 Container examinations should be carried out by persons with sufficient knowledge and experience of containers to enable them to determine whether a container has any defect that could place any person in danger. The examination should include a detailed visual inspection for defects or other safety-related deficiencies or damage that will render a container unsafe. The examination should include ‘the underside of a container’ and should specifically cover the corner fittings. The recommendation on interpretation suggests that this may be done with the container supported on a skeletal chassis, or, if the examiner considers it necessary, after the container has been lifted onto other supports.

5.3.14 Records of thorough examinations should be kept. The records may be kept electronically

5.3.15 Any examination will only reveal the condition of a container at the time of the examination. Further damage or deterioration of the container may take place subsequently.

5.3.16 Owners, lessees and bailees have no means of knowing whether or not their containers are likely to be lifted in a VTL unit. Therefore, it is considered that all thorough examinations of containers carried out in accordance with the CSC need to include examination of the lower apertures and undersides of bottom corner fittings.

6 SUMMARY

6.1 It is clear from tests and the engineering analysis at Appendix 4 that ISO freight containers are structurally sufficiently strong to permit their use in some limited VTL operations.

6.2 It is also clear that all the twistlocks and some latchlocks tested had sufficient tensile strength and load bearing area to be used as liftlocks.

6.3 ISO Standard 3874 has been amended to permit VTL operations subject to certain conditions.

6.4 ILO Convention 152 does not specifically refer to VTL operations as it was adopted in 1979 before the concept was developed.

6.5 However, ILO has indicated how it believes the Convention applies to VTL operations.

6.6 IMO's Container Safety Convention was adopted in 1972 (with a series of amendments made since). The Convention does not specifically refer to VTL Operations.

6.7 It is considered that the CSC's provisions requiring the regular examination of the underneath of containers, and all the corner fittings, addresses their fitness for VTL operations.

6.8 In view of the potential hazards of VTL operations, safe operational procedures, including appropriate precautions, need to be drawn up, agreed and published in order to ensure that VTL operations are carried out in a safe and proper manner.

6.9 Providing that the operational procedures are implemented, VTL operations may be safely undertaken.

7 RECOMMENDATIONS

7.1 Before any VTL operation is undertaken, the rules to be applied should be developed in consultation with the terminal operator, shipping company, workers representatives and competent authority.

7.2 The rules should be based upon the operational guidelines in section 8 or achieve an equivalent standard of safety.

7.3 The provisions of the instruments summarised in section 5 should not be varied, as they are international requirements.

7.4 If any of the provisions of the operational guidelines in section 8 are varied, all parties, including relevant competent authorities, need to agree to the variations.

7.5 The agreed rules for VTL operations should be published.

7.6 All persons expected to be involved in VTL operations should be suitably trained.

7.7 All parties carrying out VTL operations should implement the agreed rules and comply with them at all times.

8 OPERATIONAL GUIDELINES

8.1 Introduction

8.1.1 General

8.1.1.1 The potential hazards of VTL operations require close co-operation between all parties involved in the operations, including terminal operators, shipping companies, workers' representatives, and competent authorities, in order to develop safe operational procedures to enable the operations to be carried out both safely and efficiently. Such co-operation is necessary not only within container terminals but also between ships and their originating and destination terminals.

8.1.1.2 Operational procedures in this section of the paper are necessarily recommendations. Therefore, they have been written in terms of 'should'. However, where a matter is a requirement of an international instrument of the International Labour Organization (ILO), the International Maritime Organization (IMO) or the International Organization for Standardization (ISO) they have been written in terms of 'shall'.

8.1.1.3 VTL operations should only be carried out if the domestic legislation of the country in which they are to be carried out permits such operations under appropriate conditions.

8.1.1.4 Responsibility for ensuring the safety of VTL operations is shared by all who have control of relevant matters in accordance with national legislation.

8.1.1.5 It is recognised that it will not always be practicable to satisfy the relevant competent authority that all operational guidelines in this section can be fully implemented. It is likely that the following situations may arise:

- Appropriate controls exist in both originating and destination container terminals to enable the guidelines to be fully implemented so that VTL operations may be permitted.
- Appropriate controls do not exist to enable the guidelines to be implemented, possibly in common user terminals, so that VTL operations cannot be permitted.
- Appropriate controls to enable the guidelines to be fully implemented in a terminal exist for exports but not for imports so that VTL operations may only be permitted for export units.
- It would be possible to fully implement the guidelines for export or import units, or both, but the resources necessary to do so lead to a commercial decision not to carry out VTL operations.

8.1.1.6 All VTL operations should be planned, organised and carried out in accordance with operational procedures developed in accordance with these guidelines.

8.1.1.7 The operational procedures should be developed in consultation with all parties involved, including the port authority, the terminal operator, shipping company, workers representatives and relevant competent authorities.

8.1.1.8 All VTL operations should be carried out under the supervision of a person with appropriate training and experience.

8.1.1.9 Ship operators shall, when requested, provide evidence to those carrying out VTL operations that each liftlock complies with the relevant requirements of ILO Convention 152.

8.1.1.10 Adequate information on the existing or intended stowage plan should be made available sufficiently in advance to allow VTL unit preparation and loading and unloading operations to be properly and safely resourced and carried out.

8.1.1.11 No manual twistlock or latch lock should be used as a liftlock.

8.1.2 **Containers**

8.1.2.1 Only ISO freight containers should be lifted in VTL units.

8.1.2.2 No VTL unit with a total gross mass that exceeds the SWL of the crane or other lifting device shall be lifted in a VTL operation.

8.1.2.3 No VTL unit with a total gross mass of more than 20,000 kg shall be lifted in a VTL operation.

8.1.2.4 No VTL unit with a total gross mass of more than 18,800 kg that includes a thermal or refrigerated container shall be lifted in a VTL operation.

8.1.2.5 No folding end platform based container with its end frames erect should be lifted as part of a VTL unit. Folding end platform based containers with their end frames folded may be lifted in a VTL unit or, if they are designed to be so lifted, interlocked and lifted in a unit in accordance with ISO 3874, paragraph 6.4.4.

8.1.2.6 No tank container or other type of container carrying a flexible tank inside it that is fully or partially loaded with a fluid cargo shall be lifted as part of a VTL unit. Empty containers may be so lifted subject to the limitations in 8.1.2.1to 8.1.2.5.

8.1.2.7 No container that is fully or partially loaded with solid bulk cargoes shall be lifted as part of a VTL unit. Empty containers may be so lifted subject to the limitations above.

8.1.2.8 No container that is fully or partially loaded with dangerous packaged goods within the scope of the International Maritime Dangerous Goods (IMDG) Code should be lifted as part of a VTL unit.

8.1.3 **Liftlocks**

8.1.3.1 **Testing and thorough examination of new liftlocks**

8.1.3.1.1 Each liftlock made after [31 December 2002] shall be tested and thoroughly examined by a competent person before it is put into use for the first time. Each new liftlock shall either be individually proof loaded or be subject to a batch-testing regime, approved by a competent authority, before being thoroughly examined. Batch testing should only be accepted where the manufacturing process is subject to adequate quality control. If batch testing is to be carried out, one liftlock in every batch of 50 new liftlocks should be tested to destruction under the direction of a competent person or organisation recognised by the competent authority for such testing before the batch is put into use.

8.1.3.1.2 No liftlock made after [31 December 2002] shall be used for lifting unless it has been certificated with a SWL for lifting (SWLL - see Note 1 under 5.1.7) of at least 10,000 kg on the basis of a safety factor of not less than 5.

8.1.3.1.3 Every liftlock made after [31 December 2002] shall be clearly and durably marked with its SWL for lifting (SWLL) and an identifying number or mark that will enable it to be associated with its test certificate.

8.1.3.1.4 Persons or organisations owning liftlocks shall maintain records of tests and thorough examinations carried out in accordance with 8.1.3.1.1. These records may be kept electronically and should be kept for the life of the liftlock. The records should be made available to any competent authority on request.

8.1.3.2 Testing and thorough examination of existing liftlocks

8.1.3.2.1 All liftlocks made before [1 January 2003] shall be thoroughly examined and certificated for lifting. The certificates should be based on a proper and verifiable system for determining and checking the lifting capability of the liftlocks. Every existing liftlock shall be certificated with a SWL for lifting (SWLL) of at least 10,000 kg on the basis of a safety factor of not less than 5. In addition each liftlock should be clearly and durably marked with an identifying number or mark relating to its test certificate as soon as is practicable.

8.1.3.2.2 After any substantial alteration or repair to any part of a liftlock that is liable to affect its safety, the liftlock shall be tested and thoroughly examined before it is returned to service.

8.1.3.2.3 Persons or organisations owning liftlocks should maintain records of tests and thorough examinations carried out in accordance with 8.1.3.2.1 and 8.1.3.2.2. These records should be kept for the life of the liftlock. The records should be made available to any competent authority on request.

8.1.3.3 On-going maintenance, thorough examination and inspection of liftlocks

8.1.3.3.1 A liftlock examination and inspection programme should be approved by a competent authority.

8.1.3.3.2 Each liftlock shall be maintained in good repair and working order.

8.1.3.3.3 Each liftlock shall be subjected to a thorough examination by a competent person at least once in every 12 months to verify its safe condition.

8.1.3.3.4 Thorough examinations may be carried out in the traditional manner as separate examinations when liftlocks are not in service or as continuous examinations when liftlocks are in service as part of an approved continuous examination programme.

8.1.3.3.5 Each liftlock shall be regularly examined, including visual inspection before use.

8.1.3.3.6 Maintenance and examination procedures should ensure, as a minimum, that each liftlock is:

- Visually examined during operations for obvious structural defects.
- Physically operated to determine that the lock is fully functional with adequate spring tension on each head or latch.
- Checked for excessive corrosion and deterioration.
- Immediately removed from service when found, either on examination or inspection, to be defective.

8.1.3.3.7 In service examination and inspection procedures may form part of an operational process or part of an approved continuous examination programme of liftlocks.

8.1.3.3.8 Each liftlock shall be visually inspected before each use.

8.1.3.3.9 Each defective liftlock shall be repaired as required and restored to safe operating condition before it is returned to service, or disposed of in a manner that prevents its further use.

8.1.3.3.10 Suitable proof of regular thorough examinations should be available to any competent authority in the form of adequate records or an approved continuous examination programme that is being followed.

8.1.4 Training

8.1.4.1 All persons connected with VTL operations, including planning, examining, inspecting, stacking, transporting, hoisting, landing, securing and dividing containers handled in VTL units, should be appropriately trained. The extent and content of such training should be guided by the physical characteristics of the terminal and the containers to be handled, the container movement flow, the equipment to be used for lifting and transporting the containers and the experience of the personnel involved.

8.1.4.2 An operational training matrix that may be used as basic guidance for training purposes is at Appendix 5.

8.1.5 Operational limits

8.1.5.1 The increased sail area of a VTL unit will increase the stresses on the unit and affect the handling characteristics of the container crane during high wind conditions. Therefore, a maximum wind speed above which VTL loading or discharge operations will not take place should be established. This should not be more than 15 m/s (55 kph, 34 mph or 30 knots).

8.2 Operational procedures

8.2.1 Ship

8.2.1.1 Where VTL loading or discharge operations are to be carried out on a ship, it should be ensured that:

- The stacks are fitted solely with liftlocks and the ship's personnel can demonstrate that this is so.
- All liftlocks are tested and subject to thorough examination before they are used for the first time.
- All liftlocks that may be used for VTL operations are certificated by a competent person from a national or international organisation recognised by the relevant competent authority
- All liftlocks are regularly maintained and subjected to a thorough examination at least once in every 12 months to ensure their continued safe operation. It is the ship's master's responsibility to ensure that the maintenance programme exists and is carried out efficiently and on time.
- All liftlocks are visually inspected and functionally checked (see 8.2.2.3.5) by the person who is inserting them before they are incorporated into VTL units being made up on shore.
- The liftlocks used to make up a VTL unit are of uniform design and are locked and released in an identical manner. They should have a "telltale" incorporated in the design that indicates whether the liftlock is locked or unlocked in the corner fittings. This "telltale" should be visible from deck level.

8.2.1.2 The stowage plan should clearly indicate the gross mass of each VTL unit and its position so that both can be verified before the start of unloading operations.

8.2.1.3 If bad weather conditions or other incidents during a voyage may have caused damage to any VTL unit, liftlock or container corner fitting, it should be reported to the stevedores before the start of unloading operations.

8.2.1.4 If there are any circumstances that make VTL operations unsafe, the containers in a VTL unit should be lifted individually.

8.2.1.5 Ships should supply liftlocks in suitable bins so that they can be passed from the ship to the terminal and back.

8.2.1.6 A procedure should be agreed between the ship and terminal to ensure that defective liftlocks are returned to the ship separated from sound liftlocks. Separate, clearly marked bins should be provided for this purpose.

8.2.2 **Shore**

8.2.2.1 **General**

8.2.2.1.1 Cranes handling VTL units should be fitted with a properly calibrated load-indicating device.

8.2.2.1.2 Before VTL operations start, adequate consideration of the 'air draft' of the ship and the relationship between this and the container crane boom height should be made. This should include consideration of visibility and the location of VTL operations on the ship and shore.

8.2.2.1.3 A discharge plan that will ensure safe working should be agreed between the ship and the shore.

8.2.2.1.4 The procedures should include the notification to the container crane driver of the location and characteristics of all VTL units for loading or discharge.

8.2.2.1.5 Where the mass of a VTL unit notified to the crane driver or indicated by the load-indicating device is more than 20,000 kg, the unit should be broken down into smaller units of less than 20,000 kg before being lifted.

8.2.2.1.6 The top container of a VTL unit should be lifted from all four top corner fitting directly by a spreader.

8.2.2.1.7 When a VTL unit is lifted, a pause should be made when the initial strain has been taken and the lifting frame wires tensioned in order to check that all liftlocks are properly engaged.

8.2.2.1.8 A unit of platform based or folding end platform based containers should only be lifted in a VTL unit as the bottom component of a VTL unit

8.2.2.1.9 VTL units to be lifted by a twin lift spreader should both be of the same height and within 5% of each other in total mass.

8.2.2.2 **Imports**

8.2.2.2.1 Stowage plans should show the mass of individual containers and, consequently, the gross mass of each VTL unit and the location of the heaviest container in the unit will be known before discharge commences.

8.2.2.2.2 A suitably experienced shore-side person should identify the containers that are to be discharged as VTL units and ensure that the relevant lashings are removed before discharge.

8.2.2.2.3 The stevedores should assess the possible consequences of any damage observed or that has been reported to them in accordance with 8.2.1.3 and act accordingly.

8.2.2.2.4 Procedures and locations for breaking down VTL units will vary depending on the layout of the terminal and the type of equipment available. In all cases adequate procedures should be in place to ensure the safety of the people on the ground that break down the units. In particular, procedures should prevent injury to them by mechanical handling equipment or other vehicles.

8.2.2.2.5 Once removed from VTL units, all liftlocks should be returned to the appropriate ship. Any liftlocks that are seen to be below the required standard should be segregated and returned to a representative of the shipping line for repair, refurbishment or disposal. The ship operator should provide separate, clearly marked, bins for this purpose.

8.2.2.3 **Exports**

8.2.2.3.1 The gross mass of any container declared as partially loaded should be determined before it is made up into a VTL unit. This may be by means of a weigh-scale fitted to a lifting device, a weighbridge or any other equally effective means. The total mass of any VTL unit shall not exceed 20,000 kg. No more than three containers shall be lifted as one VTL unit.

8.2.2.3.2 Procedures and locations for making up VTL units will vary depending on the layout of the terminal and the type of equipment available. In all cases adequate procedures should be in place to ensure the safety of the people on the ground that make up the units. In particular, procedures should prevent injury to them by mechanical handling equipment or other vehicles.

8.2.2.3.3 Arrangements should be made between the terminal and the ship owners or operators for a supply of certificated liftlocks to be made available. This may be a specific type allocated to an individual ship, in which case the liftlocks should be returned to the ship before it sails. The liftlocks may be returned as component parts of export VTL units. If any liftlocks are left behind at a terminal, they should be quarantined and returned to the ship's representative or to the ship on its next call. Alternatively, fleet operators may leave a sufficient number of serviceable liftlocks at each port of call. This will enable VTL units to be made up before the arrival of the next ship of the fleet. If this system is used it should ensure that:

- All liftlocks are of a uniform design that lock and release in an identical manner throughout the whole fleet.
- The shipping line maintains a central register of test certificates and records of thorough examinations. These should, preferably, be kept electronically.
- The records are available to terminal operators and competent authorities.
- Documented evidence that the liftlocks are in compliance is available to terminal operators before the start of VTL operations.
- New ships introduced into a fleet have compatible liftlocks.

8.2.2.3.4 Liftlocks used to make up a VTL unit should be of uniform design that lock and release in an identical manner. They should have a "telltale" incorporated in the design that indicates whether the liftlock is locked or unlocked in the corner fitting. This “telltale” should be visible from deck level.

8.2.2.3.5 Before being inserted, all liftlocks should be visually inspected and functionally checked to ensure that they are all of the same design, function properly and have noticeable spring tension on rotation of each lock head. Such visual inspections and functional checks may form part of an approved continuous examination programme. Any liftlocks that are not up to the required standard should be segregated and returned to the ship or the owner for repair or disposal. The ship operator should provide separate, clearly marked, bins for these purposes.

8.2.2.3.6 The lift should be under the supervision of a person appropriately trained and experienced in the lifting and checking procedures required for a safe VTL operation. All liftlocks should also be checked for correct orientation. Any container that, in the opinion of the person supervising the lift, has defects that will affect the safety of the lift should be lifted individually and not in a VTL unit.

8.2.2.3.7 The method of transporting VTL units to the quayside for loading onto a ship will differ according to the type of transport equipment available and the layout of the terminal. A detailed assessment of this operation should take place. This should include:

- Ensuring the equipment for transporting VTL units is adequate and suitable for the task and maintained to preserve that suitability.
- Training of drivers of vehicles etc. used to transport VTL units. This training should be based on the organisation’s safe operating procedures. These should place particular emphasis on the speeds at which the vehicles enter turns, in order to avoid overturns and other accidents.
- Assessing the effect of wind speed on equipment stability and imposing a maximum wind speed above which the movement of VTL units will not take place. This speed should not be more than 15 m/s (55 kph, 34 mph or 30 knots).
- Conducting stability calculations applicable to a range of travelling speeds and turning radii. The calculations should include both the maximum speed and the minimum turning radius. The IMO/ILO/UN ECE Container Packing Guidelines permit up to 60% by weight of the load to be in one half of the length of the container. Any stability calculation should assume this. The vertical centre of gravity can be assumed to be at 50% of the total height of the container. The effect of surface gradient, potholes, rail tracks and crane tracks on stability should be included in the calculations. The surface of any area where a vehicle carrying a VTL unit is expected to make a turn should not have a gradient of more than 1°. Other factors affecting stability will vary according to equipment type, design and construction. Reference should be made to ISO 14829 for straddle carrier stability calculations. Appendix 6 is an example of stability calculations for a chassis/trailer based VTL operation.

- Ensuring that the heaviest container is in the lowest position in the VTL unit, the lightest on the top. This is necessary to maximise the stability of the unit during any movement on shore to or from the quayside.

8.2.2.3.8 Terminal operators should ensure that all VTL units are declared to the ship and clearly identified on the bay plan.

8.2.2.4 **Transhipment**

8.2.2.4.1 Transhipment VTL movements should fully comply with these guidelines.

9 STATUS

9.1 This paper has been developed by the International Safety Panel of ICHCA International Ltd after extensive consultation [and approved by the Board of ICHCA International Ltd]. It is published to assist all who may be concerned with VTL operations.

9.2 The paper has been developed with the knowledge and involvement of a number of international groups and national competent authorities.

9.3 The operational guidelines are believed to represent comprehensive advice that complements ISO Standard 3874, ILO Convention 152 and the IMO Container Safety Convention.

It is possible that experience may show the need for further amplification of the guidelines. Therefore, the Panel intends to review the guidelines in 2003, twelve months after their publication.

Appendix 1

List of consultees

The following regional or international organisations were consulted during the development of this paper:

Chamber of Shipping of America
Carriers Container Council
Hutchison Port Holdings
International Association of Classification Societies
International Association of Ports and Harbors
International Chamber of Shipping/International Shipping Federation
International Cargo Gear Bureau, Inc
International Labour Organization
International Maritime Organization
International Transport Workers Federation
National Maritime Safety Association
P&O Ports International
TT Club
United States Maritime Alliance Ltd
World Shipping Council

In addition to the ICHCA International Safety Panel, the following were consulted –

Container Handling Work Group of Ports' Safety Organisation/Ports Skills and Safety Ltd

Director of Operations, Medcenter Container Terminal

Appendix 2

VTL photographs and drawings

Figure 1: A VTL lift

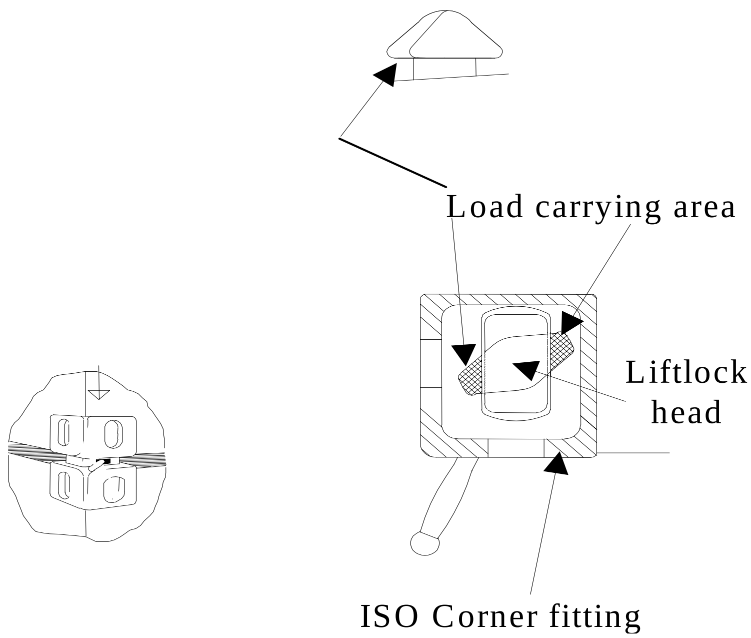

Figure 2: A liftlock in a corner fitting

Appendix 3

Relevant ISO standards

ISO 668:1995	Series 1 freight containers – Classification, dimensions and ratings
ISO 1161:1984	Series 1 freight containers – Corner fittings – Specification
ISO 1161:1984/Cor. 1:1990	Technical corrigendum 1:1990 to ISO 1161:1984
ISO 1496-1:1990	Series 1 freight containers – Specification and testing – Part 1: General cargo containers for general-purposes
ISO 1496-1:1990/Amd. 1:1993	Amendment 1:1993 to ISO 1496-1:1990, 1 AAA and 1 BBB containers
ISO 1496-1:1990/Amd. 2:1998	Amendment 2:1998 to ISO 1496-1:1990
ISO 3874:1997	Series 1 freight containers – Handling and securing
ISO 3874:1997/Amd. 1:2000	Amendment 1:2000 to ISO 3874:1997, Twistlocks, latchlocks, stacking fittings and lashing rod systems for securing of containers
ISO 3874:1997/Amd. 2:2002	Amendment 2:2002 to ISO 3874:1997, Vertical tandem lifting
ISO/TR 15069:1997	Series-1 freight containers – Handling and securing – Rationale for ISO 3874 Annex A
ISO/TR 15070:1996	Series-1 freight containers – Rationale for structural test criteria
DIS/ISO 14829:	Freight containers – Straddle carriers for freight container handling – Calculation of stability.

Appendix 4

Technical and engineering analysis

Executive summary

The practice of coupling a number of containers together vertically into a single unit and then lifting the unit is known as vertical tandem lifting (VTL). While this practice has taken place in the United States for several years, a formal engineering analysis has been needed to verify the number of containers that may be lifted in a VTL unit and the amount of payload, if any, that the containers may carry in VTL operations.

An analysis was carried out on the assumption that no more than three containers would be handled in a single VTL unit. The principal forces considered were tensile forces on the top corner fittings of the uppermost container. These forces were found to consist of wind force on the unit and the weight of the containers and their payloads. Compression, racking and shear forces were determined to be negligible, as stacked containers are subjected to much higher values of these forces when loaded and carried aboard a ship at sea. In order to provide maximum safety, the tensile force allowed on a corner fitting during a VTL operation was reduced to 50% of the ISO test limit. In addition, other simplifying assumptions for calculations were made that created additional safety factors. These safety factors, taken together, exceed the value of 4 or 5 that commonly applies in container handling situations.

The amount of payload allowable in a VTL unit was determined to be a function of the maximum wind speed under which VTL operations would be conducted. When a maximum allowable wind speed was set at 75 kph (21 m/s, 46 mph or 40 knots), a figure at which even single container lifting is usually stopped at terminals, it was found that all the types of containers considered maintained their structural integrity when lifted in VTL units, even in partially loaded three-high units. (Loaded tank containers, which are subject to especially critical conditions, were not considered for VTL units.)

The analysis also considered the most severe cases, including handling of 20 and 40-foot high-cube general-purpose containers, 40-foot high-cube refrigerated containers, platform and tank containers in high wind conditions. Other than loaded tank containers, all of these types of containers (as well as those that were less stressed such as normal height general cargo containers) were found to maintain their structural integrity when handled in two-high VTL units at a wind speed of as much as 100 kph (28 m/s, 62 mph or 54 knots).

Because of the great effect that wind speed has on the capability of empty and partially loaded containers to be handled in VTL operations, setting the appropriate maximum wind speed for VTL operations should be a priority. Based on structural engineering considerations, the maximum recommended wind speed for VTL operations of 55 kph (15 m/s, 34 mph or 30 knots) is more than 25% less than the wind speed of 75 kph under which three-high VTL operations may be carried out for virtually all types of containers.

1 INTRODUCTION

1.1 Containers handled in vertical tandem lift (VTL) units are in units of two or more containers high and secured vertically by liftlocks from the lower corner fittings of the upper container(s) to the top corner fittings of the lower container(s). Typically, double-cone semi-automatic liftlocks are used to secure one container to the container above, as they provide the necessary bearing surface on the container corner fittings distributed evenly on both sides of the lock shaft. The top container is lifted using a conventional spreader.

1.2 In all cases, all four top corner fittings of each container in a VTL unit are engaged with liftlocks, as are the four bottom corner fittings of all but the lowest container in the unit. In past practice, containers below the top container in the unit have been empty or lightly loaded to the extent that the forces acting on the corner posts, corner fittings and liftlocks did not exceed operational safe working loads.

1.3 Different types of containers may need to be subject to different limits in order to be handled safely in a VTL unit. This paper analyses various cases to determine the appropriate number of various container types that may be handled in a VTL unit, including whether or not the containers may be partially loaded. In this analysis, the most structurally critical cases - high-cube general-purpose and refrigerated containers and platform-based (flatrack) containers - will be considered. However, no more than three containers in a VTL unit will be considered. If the most critical cases are structurally sound in a VTL operation, it may be concluded that less critical cases, such as standard-height general-purpose containers, may also be handled in VTL units.

1.4 ISO/TC104, the main international standards committee dealing with freight containers, has incorporated VTL operations into its container handling standard, ISO 3874. In connection with its work on developing this standard, ISO asked ICHCA and its International Safety Panel to develop operating guidelines for VTL operations. This analysis was requested by the Panel to provide technical support for its proposed guidelines.

2 STANDARDS REQUIREMENTS

2.1 According to ISO 3874: 1997 Amendment 1, twistlocks that are used for lifting, i.e., liftlocks, shall be able to withstand a tensile force of 178 kilo-Newtons (kN) (40,000 lb). In fact, according to Report 1997:22 of the Swedish National Testing and Research Institute (SP)[1], all major ship classification societies already routinely test liftlocks to a tensile-force testing limit of 200 kN (45,000 lb). In ISO 1161, the standard governing container corner fittings, both top and bottom corner fittings are required to be tested to a tensile limit of 150 kN (33,750 lb). Thus, the liftlock/corner fitting interfaces in both the top and bottom frames of the containers are tested to withstand a combined minimum tensile force of 600 kN (135,000 lb). This is also confirmed in the ISO 1496 lifting test,

[1] Lars Andersson, “Container Lashing”, Mechanics SP REPORT 1997:22, Swedish National Testing and Research Institute, 1997.

which requires testing of containers to a load of 2R, which is also approximately 600 kN for 40-foot containers. Each of the four corner fittings thus need to withstand a minimum force of 150 kN. For a 20-foot container, where the ISO R-value is 24,000 kg instead of 30,480 kg for larger containers, each corner of the container is only required to handle 24 ÷ 30.48 x 150, or 118 kN. ("R" is defined as the gravitational force exerted on the maximum gross mass of the container at sea level.)

3 ENGINEERING CONSIDERATIONS

3.1 It is important to understand that the corner fitting itself is required to withstand a minimum tensile force of 150 kN. The container as a whole is tested to withstand a total tensile force at each corner of 150 kN for all containers other than 20-footers (118 kN for 20-footers). Because the liftlock is tested to a minimum of 178 kN per ISO 3874 requirements, and 200 kN per classification society practice, and the corner fitting only to 150 kN, the container corner fitting, not the liftlock, is the limiting component. Nevertheless, in order to account for unanticipated forces that may act in a vertical tandem lift, the analysis in this paper will reduce the allowable maximum load to half of these values - 75 kN (16,875 lb) for 40-foot and 59 kN (13,275 lb) for 20-foot containers.

3.2 Other forces that act on the container corner fittings include compression, racking and shear forces. Because containers are designed to be stacked and connected together on deck in the fully loaded condition, the corner fittings are designed to withstand vastly more of these forces than could ever be present in even exaggerated VTL operations. Thus, compression, racking and shear forces experienced in VTL operations are negligible in this analysis. The analysis, therefore, will be limited to consideration of tensile forces to which containers could be subjected during VTL operations.

3.3 Tensile forces on the container corner fittings during VTL operations are of two general origins: wind force and container weight. The latter is composed of tare weight and payload, or contents of the container. For closed containers with walls, wind force is strictly a function of container size and unrelated to container type or the type and amount of payload. In this analysis, wind force will be calculated using the American Bureau of Shipping (ABS) formula. This can be simplified numerically to:

Wind force = 0.6203 x container height x container length

where the wind force is in kilo-Newtons, and container height and length are in metres. This formula assumes a wind speed of approximately 100 kph. It should be noted that this speed is far in excess of the practical limit of approximately 55 kph at which VTL operations would be suspended under actual field conditions. It should also be noted that force varies as the square of wind speed. Therefore, a reduction of 50% in wind speed from the original speed would reduce wind force to 25% of the force at the original speed. This would be important in allowing handling of containers in VTL units in real-world conditions with greater loads or in higher units than would be permitted under the ABS formula at a wind speed of 100 kph.

4 SAFETY FACTORS FOR LIFTLOCKS

4.1 In cargo handling and securing, safety factors of 4 to 5 are typically used. For a liftlock, the factor is defined as the ratio between the tested breaking (ultimate) strength and the safe working load (SWL) of the liftlock. Both the Swedish SP Report 1997:22 and a similar study[2] conducted by the U.S. government tested tensile strength of liftlocks alone and in combination with corner fittings. The weakest tested specimen broke at 382 kN, with most specimens breaking in the 474-800 kN range. Even the weakest specimen had a safety factor greater than 5, as the SWL of both the liftlock and the corner fitting separately and together is assumed to be 75 kN in this analysis.

5 CASES TO BE EXAMINED

5.1 Summary

5.1.1 In general, most containers that are likely to be handled in VTL units will be normal general-purpose closed containers in 20-foot and 40-foot sizes. However, the height of the containers may vary up to 9 foot 6 inches for high-cube containers. In addition, it may be likely that specialised containers may be handled in VTL units, most likely refrigerated containers and possibly platform or platform-based (flatrack) containers. Containers carrying liquid tanks raise special concerns.

5.1.2 Therefore, the following cases will be considered in this analysis:

I. 40-foot high-cube closed general-purpose containers
II. 40-foot high-cube refrigerated containers
III. 20-foot high-cube closed general-purpose containers
IV. Flatracks and other platform-based containers
V. Tank containers and closed general-purpose containers carrying flexible tanks

5.1.3 Each of these cases will be considered under two different wind speed conditions:

A. at the 100 kph (28 m/s, 62 mph or 54 knots) wind speed assumed under the American Bureau of Shipping (ABS) formula for wind force, and

B. at a 75 kph (21 m/s, 46 mph or 40 knots) wind speed which is rounded up from the proposed practical limit of 55 kph (15 m/s, 34 mph or 30 knots) for real world container handling operations

5.2 Cases I.A, II.A, III.A, IV.A and V.A: Wind speed assumed to be 100 kph

The ability of containers to be handled in VTL units is examined below by combining the container type (in Roman numerals) with a wind speed assumption (either A or B, above). For example, case I.A considers 40-foot high-cube general-purpose closed containers at a wind speed of 100 kph.

[2] H.S. Lew, et. al., “Strength Evaluation of Connectors for Intermodal Containers,” Report No. NISTIR 6557, U.S. National Institute of Standards and Technology, August 2000.

5.2.1 Case I.A: 40-foot high-cube closed general-purpose containers

5.2.1.1 The total wind force per container, using the ABS formula and assumptions, is:

$$0.6203 \times 2.896 \times 12.192 = 21.9 \text{ kN}$$

5.2.1.2 The maximum wind force will occur when the wind is blowing perpendicular to the side of the container. The two corner fittings on the windward side will experience tension due to wind force, and the two fittings on the leeward side will be in compression due to wind force. For further conservatism and safety, the tension force due to wind will be calculated in each of the two windward fittings, and that force will be assumed to apply to all four top corner fittings of the uppermost container. As mentioned earlier, the compression forces are negligible when compared to the ability of the container to withstand them.

5.2.1.3 Moments are taken about the upper corner fittings on the leeward side, yielding the following wind force in each windward fitting. The container width is assumed to be the ISO standard 2.44 m. The moment arm represents the distance from the uppermost corner fitting to the vertical midpoint of the container, as wind force calculations are a function of container geometry and not a function of container loading.

5.2.1.4 Top container: The moment arm is 1.45 m, yielding the following contribution of wind tensile force on each of the two top corner fittings in tension from this container:

$$21.9 \times 1.45 \div 2.44 \div 2 \text{ windward corner fittings} = 6.5 \text{ kN}$$

5.2.1.5 Second container: The next lower container from the top one has a moment arm of 4.35 m, yielding the following contribution of wind tensile force on each of the two top corner fittings in tension from this container:

$$21.9 \times 4.35 \div 2.44 \div 2 \text{ windward corner fittings} = 19.5 \text{ kN}$$

5.2.1.6 Third container: If a third container is suspended below two others, its moment arm is 7.25m, yielding the following contribution of wind tensile force on each of the two top corner fittings in tension from this container:

$$21.9 \times 7.25 \div 2.44 \div 2 \text{ windward corner fittings} = 32.5 \text{ kN}$$

5.2.1.7 The conservative assumption mentioned above that the leeward fittings will also be in tension, which is not in fact the case, will be made. If two containers are in the unit, the wind force on each top corner fitting will be 6.5 + 19.5 or 26.0 kN. If three containers are in the unit, the wind force on each top corner fitting will be 6.5 + 19.5 + 32.5 or 58.5 kN.

5.2.1.8 The tare weight contributes (generously) about 4.5 tonnes (approximately 10,000 lb) per container, or 11 kN per top corner fitting per container in the unit.

5.2.1.9 Therefore by combining wind force and tare weight, two empty stacked containers apply a tensile force of 26 + (2 x 11) or 48 kN per top corner fitting. Three empty stacked containers apply 58.5 + (3 x 11) or 91.5 kN tensile force per top corner fitting.

5.2.1.10 If the limit of tensile force is 75 kN per top corner fitting and the maximum allowable wind speed is 100 kph, the following inferences may be drawn:

- Three 40-foot high-cube containers may not be lifted in a VTL unit.
- Two such containers may be lifted in a VTL unit and the unit could be loaded with some cargo as well.

5.2.1.11 The amount of payload that may be carried in both containers combined may not apply a tensile force greater than 27kN (75 - 48) per top corner fitting. The calculation of the total combined payload for the VTL unit would be 27 kN ÷ (9.8 kN/tonne) x 4 top corner fittings, resulting in a payload of 11 tonnes.

5.2.1.12 The maximum gross weight of two 40-foot high-cube containers that may be handled in a VTL unit would be (2 x 4.5) tonnes tare + 11 tonnes payload, or a total of 20 tonnes. This is less than the gross weight of a single loaded 40-foot container, so lifting VTL units would not overstress devices capable of lifting loaded 40-foot containers.

5.2.2 **Case II.A: 40-foot high-cube refrigerated containers**

5.2.2.1 The wind forces on a 40-foot high-cube refrigerated container are the same as for the normal closed general-purpose containers in Case I. The tare weight component is somewhat different, not only because refrigerated containers are heavier than normal closed general-purpose containers, but also because the machinery weight is concentrated in the front end. The tensile force on the front corner fittings is greater than that on the rear fittings, and will be assumed to be the limiting factor. Assuming the tare weight of a 40-foot steel high-cube refrigerated container is 4,740 kg (10,500 lb), this may be divided into a 4,200 kg (9,300 lb) insulated container with its centre of gravity at the centre of the container and a 540 kg (1,200 lb) refrigeration machine with its centre of gravity midway between the front corner posts, each of the front corner fittings of the container will be subjected to a tare force of 1,320 kg (2,910 lb), or 13 kN.

5.2.2.2 In a two-high unit of refrigerated containers, the combined wind force and tare weight would be 6.5 + 19.5 + (2 x 13) or 52 kN tensile force on each of the front corner fittings. For additional safety and conservatism, it will be assumed that each of the four top corner fittings (not just the two front fittings) could have to bear a 52 kN tensile force. The maximum allowable force due to payload becomes 23 kN (75 - 52) per corner fitting.

5.2.2.3 The following inferences may be drawn:

- A two-high unit of refrigerated containers may be lifted in a VTL unit with an allowable total payload of 9.4 tonnes in the unit. This is also equivalent to an allowable maximum gross weight of 18.9 tonnes for the two-high unit, which is slightly less than the 20 tonnes permissible for normal closed general-purpose containers.
- This is a more severe case than case I.A. A three-high unit of high-cube refrigerated containers may not be lifted in a VTL unit at the

wind speed of 100 kph, as the total tensile force per corner fitting is 97.5 kN.

5.2.3 **Case III.A: 20-foot high-cube closed general-purpose containers**

5.2.3.1 This case will be examined with exceptionally conservative assumptions compared to real world conditions: that 20-foot containers would be built to 9 foot 6 inch high-cube heights while at the same time conforming to a design of reduced strength compared to 40-foot equipment (24,000 kg maximum gross ISO limit rather than the 30,480 kg design limit now commonly used). There are few, if any, containers meeting both of these requirements in actual service. Because of the latter assumption, the total allowable tensile force on each top corner fitting is reduced from 75 to 59 kN.

5.2.3.2 Wind force per container, according to the ABS formula, is:

0.6203 x 2.896 x 6.058 = 10.9 kN

5.2.3.3 Assuming a three-high unit and taking moments around the uppermost leeward corner fitting, the wind force is:

Top container:	10.9kN x 1.45m (height) ÷ 2.44m (width) ÷ 2 fittings = 3.24 kN
Second container:	10.9 kN x 4.35 m (height) ÷ 2.44 m (width) ÷ 2 fittings = 9.72 kN
Third container:	10.9 kN x 7.25 m (height) ÷ 2.44 m (width) ÷ 2 fittings = 16.19 kN

5.2.3.4 Total wind tension force for a two-high unit would be 3.24 + 9.72 or approximately 13 kN and 29 kN for a three-high unit.

5.2.3.5 The tare weight of 20-foot high-cubes has to be assumed, since few, if any, of these containers exist. A tare of 2,450 kg (24 kN or approximately 5,500 lb) is assumed for each such container. This yields a tare tensile force of 6 kN per corner fitting per container in the unit. The total tensile force would be: for a two-high unit, 13 + (2 x 6) or 25 kN per corner, and for three-high unit, 29 + (3 x 6) or 47 kN per corner.

5.2.3.6 If the allowable maximum tensile force is 59 kN per corner fitting, the following inferences may be drawn:

- A two-high VTL unit of 20-foot closed containers may be lifted, including a total payload of up to 13.9 tonnes.
- A three-high VTL unit of 20-foot closed containers may also be lifted, including a total payload of up to 4.9 tonnes.

5.2.3.7 Both of these conditions would result in a crane load of less than 20 tonnes, which may easily be accommodated.

5.2.4 **Case IV.A: Flatracks and other platform-based containers**

5.2.4.1 The lifting of a VTL unit should not be confused with the lifting of a pile of interlocked empty flatracks or platform-based containers with the end structures folded down. The latter operation is already permitted by ISO

3874, providing that the unit height is not greater than 2,591 mm (8 foot 6 inches).

5.2.4.2 Two other conditions are possible for flatracks:

- A loaded flatrack with no ends, or a platform-based container with ends folded down: In this case, it would be impossible to calculate the wind resistance, as the surface profile presented to the wind would vary according to the shape of cargo carried on the flatrack. The consequences of poor cargo restraint on cargo integrity are greater for flatracks than for closed containers, because there are no walls to restrain loose cargo, and cargo could fall out more easily than it could for a closed container. However, cargo on flatracks is more carefully secured than is the case in closed containers, and, as the container is open to view; securement integrity can easily be determined during operations. The geometry of the loaded flatrack (or platform-based container without ends erected) would require that the container would have to be the top container in a VTL unit. On balance, it would seem reasonable that the partially loaded flatrack, or platform-based container with ends folded down, could be lifted in a VTL unit with a 20-tonne maximum load under the spreader for the entire unit.
- A platform-based container with ends erected: There would be spring tension created during lifting with the ends erected. The combination of those forces with the possibility of multiple load shifts among the containers in the VTL unit due to swaying when lifting would be unpredictable. While there appears to be no structural problem with lifting a VTL unit that includes a platform-based container with ends erected and cargo properly secured, there may be operational difficulties and uncertainties when handling such containers in a VTL operation.

5.2.4.3 The following inferences may be drawn:

- A flatrack, or a platform-based container with the ends not erected, may be lifted in a VTL unit under the same constraints that apply to general-purpose containers, whether empty or partially loaded. However, if such a container were loaded, it would have to be the top container in a VTL unit.
- While structurally permissible in theory, it may not be operationally feasible to lift a platform-based container with ends erected in a VTL unit.

5.2.5 Case V.A: Tank Containers and closed general-purpose containers carrying flexible tanks

5.2.5.1 Containers carrying liquid loads, including tank containers and general-purpose containers containing flexible tanks, require special considerations. When empty, such containers do not behave differently from other types of containers and need not be excluded from VTL units for engineering reasons. However, the danger of combined surging forces that could result from simultaneous movement of the liquid cargo of several containers could be hazardous. Moreover, in practice, the payload limits for containers lifted in VTL units that apply to closed general-purpose containers as shown in case I may violate tank ullage requirements and create even stronger surges than if the containers were completely full.

5.2.5.2 For these reasons the following inference may be drawn:

- It is **not** practical to lift tank containers and closed general-purpose containers carrying flexible tanks in VTL units unless the containers are empty.

5.3 Cases I.B, II.B and III.B: Wind speed assumed to be 75 kph

The inferences that were drawn above are based on an assumption of a possible maximum wind speed of 100 kph during which VTL operations might take place. However, as the maximum allowable wind speed is reduced, the potential for VTL operation increases. As will be demonstrated, a wind speed of 75 kph would allow VTL operations to take place in all the cases considered. (Higher wind speeds, of course, could be allowed by engineering considerations during VTL operations in less stressed cases, e.g. when using standard-height containers rather than high-cubes.)

Since wind force varies as the square of speed, a reduction in maximum wind speed to 75 kph would reduce wind force to 56.25% of the forces calculated in the above cases. Using a speed of 75 kph and recalculating total tensile force on the top corner fittings in the cases above for which original calculations were made, yield the results below.

5.3.1 Case I.B: 40-foot high-cube closed general-purpose containers

5.3.1.1 The tensile force per top corner fitting in a VTL unit will be:

- Two-high unit: Wind force = 0.5625 x 26 = 15 kN
  Tare force (unchanged) = 22 kN
  Total tensile force = 37 kN instead of 48 kN.

- Three-high unit: Wind force = 0.5625 x 58.5 = 33 kN
  Tare force (unchanged) = 33 kN
  Total tensile force = 66 kN instead of 91.5 kN.

5.3.1.2 Since both the two-high and three-high units create a maximum force of less than 75 kN, both two-high and three-high units may be lifted in a VTL unit at wind speeds of up to 75 kph. In addition, a total payload of 15 tonnes (two-tier unit) or 3.7 tonnes (three-tier unit) distributed within the unit could also be carried in a VTL unit in a wind speed 75 kph. Since the tare is approximately 9 tonnes (two-high unit) or 13.5 tonnes (three-high unit), the gross weight transmitted to the spreader would be 15 + 9 or 24 tonnes for a two-high unit or 3.7 + 13.5 or 17.2 tonnes for a three-high unit. Since both of these gross weights are less than 30 tonnes, the ISO rating for a loaded 40-foot container, the spreader capacity will not be exceeded.

5.3.2 Case II.B: 40-foot high-cube refrigerated containers

5.3.2.1 The tensile force per top corner fitting in a VTL unit will be:

- Two-high unit: Wind force = 0.5625 x 26 = 15 kN
  Tare force (unchanged) = 26 kN
  Total tensile force = 41 kN instead of 52 kN.

- Three-high unit: Wind force = 0.5625 x 58.5 = 33 kN
  Tare force (unchanged) = 39 kN
  Total tensile force = 72 kN instead of 97.5 kN.

5.3.2.2 Since both the two-high and three-high units create a maximum force of less than 75 kN for refrigerated containers as well as for normal closed general-purpose containers, both two-tier and three-tier units of 40-foot high-cube reefers may be lifted in a VTL unit at wind speeds of up to 75 kph. In addition, a total payload of 14 tonnes (two-high unit) or 1.2 tonnes (three-high unit) distributed within the unit could also be carried in a VTL unit. Since the tare is approximately 9.5 tonnes (two-high unit) or 14.25 tonnes (three-high unit), the gross weight transmitted to the spreader would be 14 + 9.5 or 23.5 tonnes for a two-high unit or 1.2 + 14.25 or 15.45 tonnes for a three-high unit. Since both of these gross weights are less than 30 tonnes, the ISO rating for a loaded 40-foot container, the spreader capacity will not be exceeded.

5.3.3 **Case III.B: 20-foot high-cube closed general-purpose containers**

5.3.3.1 The tensile force per top corner fitting in a VTL unit will be:

- Two-high unit: Wind force = 0.5625 x 13 = 7.3 kN
  Tare force (unchanged) = 12 kN
  Total tensile force = 19.3 kN instead of 25 kN.

- Three-high unit: Wind force = 0.5625 x 29 = 16.3 kN
  Tare force (unchanged) = 18 kN
  Total tensile force = 34.3 kN instead of 47 kN.

5.3.3.2 As in the case of maximum wind speed of 100 kph, both two and three-high units of 20-foot containers may be lifted in a VTL unit. Because of the change in wind speed, the total distributed payload would rise to 16.2 tonnes (from 13.9) for a two-high unit or 10 tonnes (from 4.9) for a three-high unit. Since the tare is approximately 5 tonnes (two-high unit) or 7.5 tonnes (three-high unit), the gross weight transmitted to the spreader would be 16.2 + 5 or 21.2 tonnes for a two-high unit or 10 + 7.5 or 17.5 tonnes for a three-high unit. Since both of these gross weights are less than 24 tonnes, the ISO rating for a loaded 20-foot container, the spreader capacity will not be exceeded.

5.3.4 **Case IV.B: Flatracks and other platform-based containers and Case V.B: Tank containers and closed general-purpose containers carrying flexible tanks**

5.3.4.1 The effect of a reduced wind speed of 75 kph would be the same as that indicated for the higher wind speed of 100 kph. Flatracks or platform-based containers with ends folded may be lifted in a VTL unit under the same constraints as normal closed general-purpose containers (for the same wind speed) and empty tanks may be lifted in a VTL unit in the same manner. Even at 75 kph, it is still not practical to lift loaded tanks or closed general-purpose containers carrying flexible tanks in a VTL unit.

6 CONCLUSIONS

6.1 It is concluded that:

- The effect of wind speed is significant on the ability of containers to be lifted in a VTL unit.
- At the ABS maximum wind speed of 100 kph (28 m/s, 62 mph or 54 knots), a speed greater than the maximum recommended for actual lifting operations, two-high units of all types of containers other than platform-based containers with ends raised, loaded tank containers and loaded closed general-purpose containers carrying flexible tanks may be lifted safely according to engineering calculations that take known boundary conditions into account. Three-high units of 20-foot containers may also be safely lifted.
- At a wind speed of 75 kph (21 m/s, 46 mph or 40 knots), which is still greater than the reasonable maximum for real-world operation, three-high units of all container types other than platform-based containers with ends raised, loaded tank containers and loaded closed containers carrying flexible tanks, but including 40-foot containers, may be safely lifted.
- A safety factor of 5 for existing liftlocks has been established by physical testing of liftlocks that would typically be used in VTL operations. This testing was performed by governmental agencies in Sweden and the USA.
- In order to have a safety factor of 5 all liftlocks need to have an ultimate tensile strength of not less than 375 kN.
- At a wind speed of 55 kph (15 m/s, 34 mph or 30 knots), which is proposed by the ICHCA Safety Panel as a reasonable maximum limit for VTL operations, an additional safety factor for handling three-high VTL units is included.
- The amount of allowable distributed total payload in the containers in a VTL unit depends on the maximum wind speed at which VTL operations are permitted.

6.2 Vertical tandem lifting of a wide variety of container equipment is definitely feasible from a structural standpoint. Calculations justifying lifting VTL units have been made based on chains of very conservative assumptions that would be unlikely to occur simultaneously in real world operations.

Appendix 5

VTL operations training matrix

Who is concerned with what?

Necessary areas for training	Foremen/ gang carriers/ headers	Marine/ yard Super-intendents	Crane Operators	Yard tractor operators	Other PIT* operators	Deckmen / holdmen	Lashers	Ground men	Planners
Whether and how to perform VTL operations									X
Ground movement considerations	X	X		X	X			X	
Correct gear to hoist (inspections)	X	X						X	
Verify working/locking condition of liftlocks	X	X				X	X	X	
Pre-lift check (test lift)	X	X	X		X	X		X	
Integrity of container components	X	X				X	X	X	
Actual lifting	X	X	X			X		X	
Landing the load	X	X	X			X		X	
VTL unit make-up/division	X	X			X			X	X
Container/VTL unit weight limitations	X	X	X						
Conformity to stowage plan	X	X	X						
Information transfer (origin/discharge ports)									X

NOTE: "**X**" denotes that training in this area is appropriate for the persons indicated.

* = Powered industrial truck

Appendix 6

Sample chassis stability calculations

The calculations below are examples of methods to calculate the capsizing or overturning speed of a tractor and trailer combination carrying two or three empty 40-foot containers. The results of calculations for other sizes of containers and the effect of a load are at the end of this appendix.

Assembly component	Weight (pounds)	Height of centre of gravity (inches)	Force (inch-pounds)
TRACTOR			
Engine and exhaust system	900	44	39600
Steering axle and tyres	300	24	7200
Drive shaft, tandem axles and transmission	2000	24	48000
Cab	1000	60	60000
Frame	2000	38	76000
Fifth wheel assembly	1000	40	40000
Battery and electrics	200	24	4800
Brake system	400	24	9600
Fuel system and tank	300	24	7200
Bumper	300	24	7200
Tractor total	**8400**	-	**299600**
TRACTOR CG CALCULATED		299600 ÷ 8400 = **35.7 inches**	
TRAILER			
Main rails and cross-members	1500	34	51000
Front bolster and horn	300	38	11400
Kingpin and upper coupler	500	48	24000
Tandem axles and tyres	2800	26	72800
Rear bolster	400	44	17600
Brake system	200	36	7200
Bumper	300	36	10800
Trailer total	**6000**	-	**194800**
CHASSIS CG CALCULATED		194800 ÷ 6000 = **32.5 inches**	
EMPTY CONTAINER (40’ x 8’ x 8’6”) **Tare Weight – 8223 pounds**			
Side rails, cross-members and flooring	3633	7	25431
Rear end structure, doors and hardware	900	54	48600
Front end structure	600	54	32400
Roof	1000	101.4	101400
Side walls	2090	54	112860
Container total	**8223**	-	**320691**
CONTAINER CG CALCULATED		320691 ÷ 8223 = **39.0 inches**	
LIFTLOCKS	64	1	64
LIFTLOCKS CG CALCULATED		64 ÷ 64 = **1.0 inch**	

DETERMINING THE CENTER OF GRAVITY OF A VTL ASSEMBLY COMPRISING TWO EMPTY 40' x 8' x 8'6" CONTAINERS, A TRAILER AND A TRACTOR

Component	**Height of CG above pavement (inches)**	**Force due to component (weight x height)**
Tractor	35.7	299600
Trailer	32.5	195000
Lower container	48.0 + 39.0 = 87.0	715401
Liftlocks	150.0 + 1.0 = 151.0	9664
Upper container	152.0 + 39.0 = 191.0	1570593
Total of assembly		**2790258 inch-pounds**

Conversion from inch-pounds to foot-pounds: 2790258 ÷ 12 = **232521.5 foot-pounds**

Weight of the VTL unit and vehicle assembly using 40' x 8' x 8'6" containers:

Tractor	**8400 lb**
Trailer	**6000 lb**
Lower container	**8223 lb**
Liftlocks	**64 lb**
Upper container	**8223 lb**
Total weight of assembly	**30910 pounds**

The centre of gravity of all of the components taken as a single composite solid body is therefore:

Height of CG of VTL unit assembly is 232521.5 ÷ 30910 = 7.52 feet

Capsizing force

W = Weight of the whole assembly
d = Distance from vertical centreline of trailer to outer tyre pivot point
h = Height of CG of the assembly
F = Force required to capsize assembly

$$W \times d = F \times h$$

$$30910 \times 37/12 = F \times 7.52$$

$$\mathbf{F = 12673.65\ ft\text{-}lb}$$

Velocity (speed) at which capsizing occurs

v = Velocity at which capsizing occurs
F = Force required to capsize assembly
W = Weight of whole assembly
g = Acceleration due to gravity
LTR = Radius of turn to the LEFT = 25 ft.
RTR = Radius of turn to the RIGHT = 12.5 ft.

LEFT TURN capsizing speed

$$W \times v^2 = F \times g \times LTR$$

$$30910 \times v^2 = 12673.6 \times 32.2 \times 25$$
$$v^2 = 330.06$$
$$v = 18.17 \text{ ft/s}$$

v = 18.17 feet per second or 12.39 miles per hour for a LEFT turn

RIGHT TURN capsizing speed

$$W \times v^2 = F \times g \times RTR$$

$$30910 \times v^2 = 12673.6 \times 32.2 \times 12.5$$

$$v^2 = 165.03$$
$$v = 12.85 \text{ ft/s}$$

v = 12.85 feet per second or 8.76 miles per hour for a RIGHT turn

DETERMINING THE CENTER OF GRAVITY OF A VTL ASSEMBLY COMPRISING THREE EMPTY 40' X 8' X 8'6" CONTAINERS, A TRAILER AND A TRACTOR

Component	Height of CG above pavement (inches)	Force due to component (weight x height)
Tractor	35.7	299600
Trailer	32.5	195000
Lower container	48.0 + 39.0 = 87.0	715401
Liftlocks	150.0 + 1.0 = 151.0	9664
Middle container	152.0 + 39.0 = 191.0	1570593
Liftlocks	254.0 + 1.0 = 255.0	16320
Upper container	256.0 + 39.0 = 295.0	2425785
Total of assembly		**5232366 inch-pounds**

Conversion from inch pounds to foot pounds: 5232366 ÷ 12 = **436030.5 foot-pounds**

Weight of the VTL unit and vehicle assembly using 40' x 8' x 8'6" containers:

Tractor	8400 lb
Trailer	6000 lb
Lower container	8223 lb
Liftlocks	64 lb
Middle container	8223 lb
Liftlocks	64 lb
Upper container	8223 lb
Total weight of assembly	**39197 pounds**

The centre of gravity of all of the components taken as a single composite solid body is therefore:

Height of CG of VTL unit assembly is 436030.5 ÷ 39197 = 11.12 feet

Capsizing force

W = Weight of the whole assembly
d = Distance from vertical centreline of trailer to outer tyre pivot point
h = Height of CG of the assembly
F = Force required to capsize assembly

$$W \times d = F \times h$$

$$39197 \times 37/12 = F \times 11.12$$

$$\mathbf{F = 10868.47\ ft\text{-}lb}$$

Velocity (speed) at which capsizing occurs

v = Velocity at which capsizing occurs
F = Force required to capsize assembly
W = Weight of whole assembly
g = Acceleration due to gravity
LTR = Radius of turn to the LEFT = 25 ft.
RTR = Radius of turn to the RIGHT = 12.5 ft.

LEFT TURN capsizing speed

$$W \times v^2 = F \times g \times LTR$$

$$39197 \times v^2 = 10868.47 \times 32.2 \times 25$$
$$v^2 = 223.21$$
$$v = 14.94 \text{ ft/s}$$

v = 14.94 feet per second or 10.19 miles per hour for a LEFT turn

RIGHT TURN capsizing speed

$$W \times v^2 = F \times g \times RTR$$

$$39197 \times v^2 = 10864 \times 32.2 \times 12.5$$

$$v^2 = 111.56$$
$$v = 10.56 \text{ ft/s}$$

v = 10.56 feet per second or 7.20 miles per hour for a RIGHT turn

Note:

The sample calculations above are based on empty 40’ x 8’ x 8’6” containers. However, using the same calculation method, the capsizing speeds have also been determined for three other popular container sizes in two and three high VTL configurations. These include the nominal sizes: 20’ x 8’ x 8’6”, 40’ x 8’ x 9’6” and 45’ x 8’ x 9’6”. The results of all of the calculations are shown in tabular form below. In all cases, the tare weights reflect typical containers owned by both marine carriers and container leasing companies. The calculations can be varied to reflect other tare weights.

Additional weight, such as a load, in the lower container will improve stability while additional weight in the upper container will lessen stability.

The different radii for left and right hand turns illustrate the different radii when turning around between adjacent near side and off side lanes in a country that drives on the right.

The results of the calculations are capsizing speeds in the particular circumstances. To ensure stability it is necessary to apply an appropriate safety factor to such speeds.

Two high VTL configuration

Container size (nominal)	Tare weight of container (pounds)	Vertical centre of gravity (inches)	Capsizing force of assembly (foot-pounds)	Left turn capsize speed (mph)	Right turn capsize speed (mph)
20 x 8 x 8’6”	5000	42.36	11481.10	13.25	9.37
40 x 8 x 8’6”	8223	39.00	12673.65	12.39	8.76
40 x 8 x 9’6”	8560	44.80	11957.40	11.90	8.42
45 x 8 x 9’6”	9900	44.50	12458.41	11.66	8.25

Three high VTL configuration

Container size (nominal)	Tare weight of container (pounds)	Vertical centre of gravity (inches)	Capsizing force of assembly (foot-pounds)	Left turn capsize speed (mph)	Right turn capsize speed (mph)
20 x 8 x 8’6”	5000	42.36	9386.05	10.91	7.71
40 x 8 x 8’6”	8223	39.00	10868.47	10.19	7.20
40 x 8 x 9’6”	8560	44.80	10164.61	9.73	6.88
45 x 8 x 9’6”	9900	44.50	11180.87	9.73	6.88