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Safety of workers when accessing the top of tank containers

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EXECUTIVE SUMMARY

OBJECTIVES

- Identify the occasions when access to the top of tank containers is necessary, the personnel and activities that are carried out when on top of the tankers, and any equipment or tools that are used.
- Review current working methods for access to the top of tank containers and identify the range of access arrangements provided on the tank container and/or otherwise provided at site to assist with access, such as gantries.
- Conduct a search for literature relevant to access methods and the design of access and fall prevention systems relating to tank containers.
- Take measurements and video recordings of access arrangements and operations; and from this identify opportunities for falls to occur and highlight other ergonomics issues associated with access generally.

MAIN FINDINGS

The operation of climbing on and off the top of a tank container or Swap-tank is performed routinely by workers worldwide in many different environments without any fall protection. Considering the range of ladder and walkway configurations seen, and the possible range of environmental conditions in which these activities can be performed, the activity of accessing the top of a tank container, using only the facilities provided on the tank itself, presents a high risk of serious injury.

Avoiding all tank top access is not a widely applicable option. At present no (permanently) tank-based systems have been identified within the UK that could effectively prevent or protect a worker from the consequences of a fall while on the ladder or tank top.

There are a number of ergonomics and safety improvements that can be made to the access system features presently provided on tank containers. These could be used in standardising the access system features.

When considering the requirement for the safety of the load for road (and rail) travel to be established, it is not clear that tank top access by personnel is necessary. A detailed examination of these possibilities, as well as the legislative requirements is required in order to establish exactly what is expected of haulage drivers, and others, when dealing with tank containers.

RECOMMENDATIONS

In order for the risk of falls from tank containers to be effectively controlled, fall prevention/protection systems are required. Given the practical difficulties associated with basing such systems on the tanks, the conclusion has to be that fall prevention/protection systems external to the tank container are needed at the locations where tank top access is required.

Detailed recommendations are provided for the design features of tank based access arrangements.

This report and the work it describes were commissioned by the Health and Safety Executive. The contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

1 INTRODUCTION

A tank container is a vessel for bulk transport of liquid and powder that fits within the corner dimensions of the familiar box-like international shipping container. In terms of its lifting, stacking, and transport it is intended to be handling in exactly the same way as a regular shipping container, using the corner castings of the container. As there are hatches and valves located on the top of the tank for filling, discharge and cleaning purposes, people are required to gain access to the top of tank containers in various locations wherever they are used worldwide. The height of a shipping container and therefore a tank container is typically around 2.6metres, and often access is made to the top of the tank when it is located on top of a road trailer or other means of transporting it. The working height in such situations can easily be 4m above ground. The potential for serious injury or fatality in falling from this height is well known. In some situations where people are required to go on top of a tank, this risk is controlled through the use of physical arrangements to prevent a fall. These are typically in the form of a stairway and gantry providing a means of getting to the level of the tank top, with either a fall arrest system (such as harness and inertia line), or a means of providing access to the tank top with fall protection in the form of guard rails (such as a fold down stair/walkway to the tank with integral all round guardrail).

However, in practice, there are many situations where people do access the tank top, and there is no form of access structure or fall protection, and people will use the access arrangements provided on the tank itself to gain access. Typically this is a vertical ladder at one end of the tank, with a narrow walkway running the length of the tank, with or without a fold up handrail. This provision on the tank is obviously limited by the need to lift and stack the tank containers.

This report aims to outline those situations and critically look at the arrangements provided on the tank containers themselves for assisting with access to the tank top.

1.1 AIMS

Specifically, the aims of this project were to:

- Identify the occasions when access to the top of tank containers are necessary, the personnel and activities that are carried out when on top of the tankers, and any equipment or tools that are used;
- Review current working methods for access to the top of tank containers and identify the range of access arrangements provided on the tank containers and/or otherwise provided at site to assist with access, such as gantries.
- Conduct a search for literature relevant to access methods and the design of access and fall prevention systems relating to tank containers;
- Take measurements and video recordings of access arrangements and operations; and from this identify opportunities for falls to occur and highlight other ergonomics issues associated with access generally

One aim has not been achieved fully, and that is to observe and make video recordings of a representative number of top access operations. It has not been possible to observe routine access during any of the site visits, and only one ascent and descent has been recorded.

1.2 SITE VISITS

Information on the practicalities and realities of tank container top access has been gained through a series of 6 site visits. These have covered the following perspectives on top access: manufacturer, repairer, owner, leasor, operator, haulier, cleaning, and dock and freight mode transfer depots. Discussions have been held with staff representing the individual companies as well as representatives of the International Tank Container Organisation (ITCO), the trade association representing the international tank container industry. The assistance of all those who participated is gratefully acknowledged.

Visits have been made to the following sites during the course of this project:

- Isotank Services UK – Immingham. (John Wilson - Director)
- Stolt Neilsen – Skelmersdale. (Meeting with Colin Humphrey UTT, Jack Hopkins ITCO, Steve Woodward - Stolt Depot Manager)
- Tees & Hartlepool Port Authority. (Bill Beveridge – H&S Manager)
- Suttons - Widnes. Tank container owners, hauliers and managers (Alwyn Christmas – H&S Manager)
- Freightliner - Trafford Park (Paul Roper – H&S Manager)
- UBH – Burscough. Manufacturers (Alex McConnagle UBH Design Engineer, Martin Levitt UTT Engineering Manager)

The tank fleets for the operating companies visited are approximately as follows:
ISO Tank Services UK ~
UTT ~ 7000 (65% Owned)
Stolt Neilsen ~ 19000
Suttons ~ 500 leased, 1850 owned, 800 managed
Altogether, ITCO claim to represent approximately 85% of tank container operators, manufacturers and lessors.

1.3 THE TANK CONTAINER

The tank container is defined by the International Standard BS ISO 1496:1995 Series 1 freight containers – Specification and testing – Part 3: Tank containers for liquids, gases and pressurized dry bulk.

This standards sets out the basic specifications and testing requirements for ISO series 1 tank containers for the carriage of gases, liquids and dry goods which may be loaded or unloaded by gravity or pressure discharge for international freight movement by rail, road and water. The dimensional specifications relate to those established in ISO 668, the general international freight container standard, which defines the dimensions and locations of the corner fittings. BS ISO 1496-3 requires that no part of the tank container, its fittings or equipment shall project beyond the dimensions established in ISO 668, and gives requirements for performance and testing specific to tank containers.

Figure 1. A typical tank container of the original, or ‘frame-tank’ design on a trailer chassis.

There are special requirements for the transport of dangerous goods, as classified by the United Nations, the main one being that there can be no bottom discharge equipment. There are over 300 substances that require top only tanks.

In terms of detailed design specifications, the Standard does include a consideration of the closures and access arrangements. Closures “which if unsecured could lead to a dangerous situation’ need to be provided with a means of securing them, ‘having, so far as is reasonably practicable’ an external indication that the closure is effective and secure”. This is a particularly important element, as in principle it could mean that access to the top of the tank to make a physical check of security of closures is unnecessary; a visual inspection being sufficient.

1.4 THE NEED FOR TOP ACCESS

There are various reasons throughout the tank cycle of use where access to the top of the tank is required. One reason that is particularly contentious is the requirement to check on the safety of a load before and during transport.

An appraisal of the current legislation is beyond the scope of this report, but there appear to be several pieces of legislation specifying the requirement for a safety check:

The European framework directives concerning the International Carriage of Dangerous Goods by Road and Rail, ADR and RID respectively, and; our own regulations that implement these directives, the Carriage of Dangerous Goods by Road Regulations (1996), and Carriage of Dangerous Goods by Rail Regulations (1996). There are also regulations covering the movement of goods by inland waterway.

These do not appear to be particularly prescriptive in describing what constitutes a suitable check. For example, what should a road haulage driver do when dealing with a tank container ? The Carriage of Dangerous Goods Regulations 1996[1] states that the driver:

> *"..shall ensure so far as is reasonably practicable, that - (a) all openings in the tank; and (b) where any discharge or filling opening in the tank is fitted with one or more valves or is fitted with a cap, all such valves and that cap, are securely closed prior to the commencement of and throughout the journey."(p17 19-(10))*

Whereas, the most relevant text of the ADR states that the carrier shall in particular:

> *"ascertain visually that the vehicles and loads have no obvious defects, leakages or cracks, missing equipment etc.;*
> *Where appropriate this shall be done on the basis of the transport documents and accompanying documents, by visual inspection of the vehicle or the containers and, where appropriate, the load." (1.4.2.2.1)*

Neither of these therefore specify whether a person needs to necessarily go and make a physical check of the condition of the manway or any valves on the top of the tank by, for example applying force to them manually or with a tool, or whether a visual inspection from a gantry alongside the tank will be sufficient.

From discussion with industry representatives for the rail freight industry, it is apparent that a visual inspection is made of every tank container Tank container before it travels on the Network Rail infrastructure. This check is documented.

The requirements of other legislation, such as for sea transport, and the requirements of countries outside Europe have not been considered here.

1.5 TYPICAL TANK TOP ACCESS ARRANGEMENTS

Probably the most common top access arrangement is a ladder running up one end of the tank leading to a F-shaped walkway, with the longest section running longitudinally along the edge of the tank from the ladder to the tank framework at the opposite end. This will then have at least two lateral sections providing access to the man-way/hatch and any valves.

Concerning access requirements BS ISO 1496 specifies the following:

- Requirement for and the dimensions of manholes;
- Provision should be made for the sealing of the tank closures in accordance with international customs requirements;
- Where provided, walkways should have a minimum width of 400mm. They must also meet certain strength requirements (3kN force over an area of 600x300mm);
- Where provided, ladders should be capable of withstanding a load of 200kg on any rung. No dimensions are specified.

The Standard also mentions doubler plates, which are additional reinforcement at the top corner fittings – these are also known as mis-stacking plates. These are permitted to extend inwards longitudinally up to 750mm from the container ends, and across the whole width.

[1] To be replaced by the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 (S.I.2004/No.568)

It is not clear how much impact these may have on access, but it is considered that their presence may reduce the opportunity for handholds in the vicinity of the top of the ladder. In practice it seems that these plates are not usually very large, and some have handholds cut into them (see Figure 9).

1.6 TANK CONTAINER DESIGN VARIATIONS

Within the scope of BS ISO 1496 there are two main tank design types:

- The original type with the tank suspended within a frame providing the 8 corner fittings, referred to as a 'frame tank', and;
- A more modern variation, with the 8 corner fittings attached to the tank, where the tank is a structural element and is typically of larger capacity than the original type, referred to as a beam tank.

Both tank types have a maximum capacity in the region of 26000 litres.

1.6.1 Frame tanks / Beam tanks

Figure 2. Some variations on the 'beam tank' design.

There are apparently few differences between these two in terms of the ladder access arrangements. The beam tanks tend to fill the volume within the 8 corners somewhat more than frame tanks. As a consequence it is probably fair to say that beam tanks typically have less toe clearance than frame tanks. Toe clearance as low as 25mm has been seen during visits. This clearance behind the ladder rungs will often vary throughout the length of the ladder due to the domed shape of the tank ends.

For the walkway arrangement, there is also little difference, but on a beam tank the perimeter of the unit is not defined with an outer frame. This means that often the only structure joining the tops of the end frames is the walkway. While the walkway may be identical to that found on a frame tank, the lack of any structure at the sides makes the situation more precarious, and further limits the opportunities for recovering from a slip or fall on the walkway, as there is nothing to prevent a person sliding off the tank side, and nothing to grab hold of. This may also mean that providing a handrail alongside the walkway is more difficult, and/or not very effective, since there may be a space beneath the bottom of the handrail large enough to fall through.

Similarly, on a frame tank, where the walkway is not present, or only extends only partially along the length of the tank, the gap between the tank surface and the frame may be large enough for a person to fall through, and this would also apply to a beam tank with a temporary handrail fitted between the corner castings on one side.

There has been at least one accident where a worker has fallen through such a gap and been seriously injured (see Appendix)

Overall, the beam tank design presents fewer opportunities for recovery from / preventing a clear full height fall than the frame tank due to the lack of any structure to break the fall / provide something to grasp.

1.6.2 10 foot tanks

These are a smaller derivative of the 20ft unit, of around 5000 to 10000 litre capacity, transportable as a pair making up a 20 foot unit, and aimed primarily at offshore applications, but included here because one manufacturer (UBH), make these available with retractable handrails which are operated from ground level (See Figure 3).

Figure 3. 10 foot tank container unit with slide-up handrails

1.6.3 Swap-body tanks

This variation is referred to as a swap-body tank, or swap-tank. These tanks are not covered by BS ISO 1496-3, but have their own standards, BS EN 283:1991 and BS EN 1432:1997. These are therefore a European concept (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom are listed as involved in the standards drafting process). They are used for domestic and international multimodal freight movements by road, rail, short sea, inland waterway, including RoRo ferry transport. They are not intended for intercontinental deep-sea traffic. They have been seen used in RoRo operations where they remain on a road or shipping trailer. They can be stacked on dockside up to 3 high, and have been seen stacked 2 high on shipping trailers. These tanks can have a capacity of up to 35 000 litres.

In brief:

- The container and attachments etc. are permitted to extend (longitudinally) beyond the 8 corner fittings of ISO668.
- While there is a requirement for the tank openings to be fitted with adequate closures, there is no requirement for the closure to have an external indicator of state as BS ISO 1496.
- Closures are specified, similar to BS ISO 1496;
- Customs sealing requirements are also specified;
- Doubler plates as for BS ISO 1496
- Walkways and ladder strengths as per BS ISO 1496, but no dimensions are specified.

Figure 4. A swap-body or swap tank on a trailer ready for transport by road. Note the extension beyond the corner castings, and the design of the ladder. This one has a fold up handrail, which can be raised once at the top of the ladder.

Despite the apparent lack of detail within the Swap-tank Standard for access arrangements, they typically have a level of specification for the access arrangements noticeable higher than that seen on other tank container varieties.

This invariably consists of an access ladder and a fold up handrail alongside a walkway. The ladders typically have good toe clearance, and are often only vertical for around to 2/3 - 3/4 of the height of the tank, then angled for the remainder, as seen in Figure 4. This is likely to make the climbing operation somewhat easier when moving onto the horizontal walkway.

Overall, the access arrangements commonly seen in Swap-tanks have much in common with those now provided on road tankers, with the exception of the fold down bottom section of the ladder being interlinked with the handrail. On Swap-tanks the handrail must be erected when at the top of the ladder.

This level of specification for the access system exceeds that commonly seen on all other varieties of tank container. From discussions with industry representatives, it appears that Swap-tanks are increasingly being purchased by operators who are used to working with road tankers. A Swap-tank and road trailer chassis is a cheaper (and more flexible) alternative to a complete road tank trailer. These customers therefore have certain expectations about the access system, and are specifying one similar to a road tank trailer.

2 REQUIREMENTS FOR ACCESS TO THE TOP OF TANK CONTAINERS AND SWAP TANKS AND THE PERSONNEL INVOLVED

These activities were not studied in detail as part of this project, but access to the tank top is typically required for the following reasons:

- Fasten / unfasten hatches, weather covers, manways etc.
- Make / break hose and pipe connections.
- Operate valves
- Take samples
- Measuring levels (dip stick)
- Checking security of closures
- Inspection of customs seals

All of the above activities may require the application of some force, and possibly the use of tools on fastenings locate at or below walkway level. This will therefore mean that the workers are adopting a stooped, crouching or kneeling posture. The operation of hatches, manway lids, and valves etc., may therefore involve quite awkward postures. For sampling and level checking, the worker may need to take equipment with them.

For routine operational access onto the tank top, items that may be taken up include general hand tools such as mallets and C-spanners, spanners for use on flanges, and replacement drip caps for pressure relief valves.

The following list of occasions where personnel are required to access the top of tank containers and swap-tanks have been identified from discussion with industry representatives during the site visits.

1. At the tank filling point – this usually a large facility dealing with a significant number of daily tank movements - it is therefore practicable to have permanent access arrangements in the form of a gantry, with fall protection in the form of harness and line, or a fully protected perimeter. If access is allowed by the site, access will be made to the tank top by the driver and/or the dedicated filling site personnel.

2. The driver is required to ensure the security of load before travel. If the driver is not allowed to access the top of the tank at the filling (or collection) site using their access gantry, access may be made without a gantry either on or off the site, depending on whether this is permitted.

In practice the driver will want to physically check that the hatches and valves are shut and safe for transport. This may involve the application of force; the driver may use a tool such as a mallet or C spanner that will be carried up.

3. At discharge point –. For every supplier (filling location) there will be many more delivery locations (ITCO estimate up to 30). There are usually a lower frequency of tank movements at the delivery points, and the practicability of dedicated access arrangements such as gantries needs to be considered on a case by case basis as there are a number of factors that need to be included.

Access will be made either by the driver or by site personnel. Again, tools such as mallets, spanners, etc., may be used.

4. Access may be required to access the top of the tank before emptying for the purposes of sampling or level checking before discharge. This may be done by the driver or site personnel, or by sampling contractors.

5. Site personnel and/or driver may be required to connect or place various lines/hoses at the tank top for filling / discharge / venting / pressure relief / nitrogen, etc:

Filling

- Bottom filling may require the manhole or airline valve to be opened (and closed on completion)
- Goods may be carried under a Nitrogen blanket. If so, this would require connection to the top air line valve (and disconnection on completion).

Discharge

- Bottom discharge may require the manhole on the top to be opened (and then closed on completion).
- Pumped discharge requires the manhole or airline valve to be opened (and closed on completion).
- Pressure discharge requires hose connection to and opening of the top airline valve (and the reverse when completed).
- Nitrogen blankets require connection to the top air line valve (and disconnection on completion).

It is not clear to what extend that multiple trips to the tank top may be made, or made by different personnel, for any single filling or discharge operation.

6. Cleaning – this is usually performed by dedicated cleaning staff. Facilities at depots are practicable. Driver does not need to gain access during cleaning, but may be required to check tank before leaving the cleaning depot.

7. At tank container collection point, e.g. dock, railhead or storage. The driver collecting a load from one of these locations will be required to physically check the security of any hatches, valves, etc. as at 2 above. There may or may not be access gantries provided for this purpose. Tank top access without the use of a gantry is generally not permitted at these sites. In practice, drivers will therefore tend to pull up outside the premises, and then make their checks. NB: Such 'uncontrolled' practices present clear risks and need to be judged against legal duties to take measures to prevent falls and injury.

2.1.1 Vehicle factors

Since the majority of occasions where 'uncontrolled' access is made, the tank container is on a trailer chassis and not at ground level, i.e. after collection at dock, outside filling location etc., the provision on the trailer for getting to the level of the tank container should be an integral part of the overall access system. In practice the level of provision for the driver to climb up onto the trailer bed is variable (Figure 5).

Although the potential for serious injury or death from a fall at trailer bed height (around 1250mm) is not as serious as from the tank top at around 4 metres, the potential for serious injury is still present.

The bottom of the tank container ladder is located above exposed wheels.

Clearly some more thought has gone into the design of this trailer chassis in terms of providing a means for access to the top of the trailer.

Figure 5. Vehicle based access systems

2.1.2 Discussion

None of the operational sites visited reported allowing access to the tank top within the site without the use of a fall protection system such as a gantry. This included docks, rail freight terminal and storage / distribution. Routine access at Manufacturing/repair depots sites did use separate stairways and/or fall arrest system, and/or all round handrails. However, some of these sites did also appear to allow access without necessarily having a set of steps or fall arrest devices. Top access was avoided in many cases by rotating the tank to give access to the top surface from ground level.

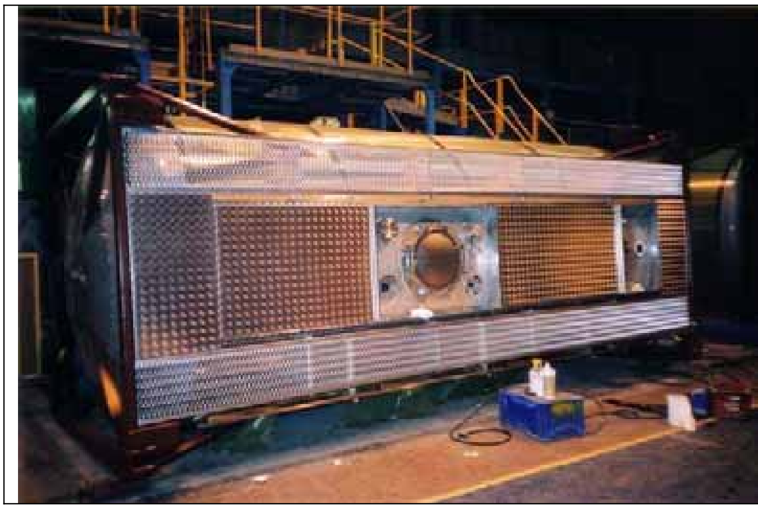

Figure 6. Tank rotated to give access to the top surface during manufacture.

Tank-top access arrangements during manufacture and repair have not been covered in detail because at these locations the issue of working at height is either avoided through turning the tanks on their sides (Figure 6), or are addressed through the use of purpose built gantries and fall arrest systems.

3 THE RANGE OF ACCESS SYSTEMS

3.1 PROPRIETARY ACCESS SYSTEMS

The following collection of images illustrates the proprietary access systems seen during the site visits.

 Access gantry provided for haulage drivers leaving a dock after collecting their load. It provided access to the height of the load and a fold down walkway across to the tank top with handrails, but no fall protection once on the tank top.	 Cleaning access gantry with fall arrest system for dedicated personnel.
 A maintenance depot mobile access ladder giving stepped access to the tank top. Transferring to and from the tank walkway may not be straightforward.	 This is a container that has been fitted with an all round safety rail, and stairs (far end). It is used for the fitting of temporary handrails, and not for access to the tank top.

 Another container modified to form a viewing platform for visual checks of the tank top at a rail freight terminal.	

Figure 7. The variety of access arrangements.

3.2 TANK BASED ACCESS ARRANGEMENTS

The following collection of images illustrates the variability of climbing provision on tank containers.

 Frame tank with a largely uninterrupted ladder. The structure of the end frame interferes with the ladder towards its centre rather than at the top or bottom. Toe clearance looks to be good throughout the length of the ladder. However the ladder has a stile on one side only. The right side is too large to be grasped	 A beam tank with a conventional ladder. However the structure of the end frame obstructs the ladder rungs at the top and bottom. There also appears to be restricted toe clearance. While there are stiles on both sides, the clearance around the left hand stile appears to be restricted, especially for a gloved hand.

<table>
<tr>
<td>
Another beam tank design. Here the ladder is partial. There appears to be a small additional step provided close to the top. Toe clearance appears to be reduced for the central portion of the climb. Stile on both sides, at least partially. High first rung. Offset top step.</td>
<td>
This is a frame-tank design with a full length ladder, but the toe clearance is severely restricted throughout the climb.
Stiles on both sides, but the lack of clearance behind may obstruct a gloved hand.
Solid design means that the position of the rungs cannot be seen through the walkway from above.</td>
</tr>
<tr>
<td>

This tank has a cut away design to the end of the tank insulation to ensure reasonable toe clearance.
Stiles continuous, but not enough clearance on right hand side to allow the stile to be grasped.</td>
<td>

Good toe clearance but obstructed/altered rungs at the middle of the ladder.
Rungs obstructed near the mid point of the ladder.
Right hand stile is the tank frame. Too large to grasp.</td>
</tr>
</table>

 No top and bottom rungs. Angled foothold / slip hazard in place of rungs! High bottom rung Partial right hand stile Left hand stile too thick to grasp.	 This illustrates the difference in the vertical spacing between the rungs provided, as there are 4 rungs. Rung spacing is consistent though. Angled structure is not in the place of a rung, and so less likely to present a hazard.
 A further design variation. The frame structure forms the top and bottom rung, but the toe clearance is very restricted. Hand holds are on the rungs only. Ladder cannot be seen from above.	 This design appears to enable a complete conventional ladder to be provided, with good toe and hand clearance throughout (6 rungs). Only criticism is that the position of rungs cannot be seen from above.
 This is an unusual design, but the ladder is largely unobstructed.	

 Swap-tanks have conventional ladder designs, with full length stiles (runners). About the top third of the ladder is sloping. High bottom step, but good handholds at bottom step.	 The fold up handrails are reached and operated when most of the way up the ladder.
 Very restricted toe clearance behind the rungs. Increased likelihood of a slip. Hand clearance is also severely restricted on some of the right hand stile.	 Showing the effect of cut-away section of the insulation behind the ladder rungs to give greater toe clearance

Figure 8. The variety of tank based access features

3.3 VARIATIONS IN WALKWAY DESIGN AND LAYOUT

The standard (BS ISO 1496) does state a minimum width for the walkway, but there are no further requirements in terms of its layout.

The amount of walkway provided obviously effects the construction cost for a tank, as well as its overall weight. The incentive is therefore to have the minimum possible.

Arguably the most common layout is an F-shaped walkway, with a longitudinal section running from the top of the ladder access to the far end of the frame. This will then have lateral sections providing access to the man-way/hatch and any valve gear.

The provision of walkway area should relate to the activity that is to be carried out on top of the tank. For some tank applications, there may be hardly any call for persons to go on top, for others access may be more frequent. Tanks can be constructed with a

particular application in mind, but typically the aim is for flexibility.
The hatches / man-ways that workers may be required to raise can be heavy, and require lifting forces over 25kg to be exerted at near foot level (or even below). The design of the hatch, in terms of the direction it operates in, how far it opens etc., should be considered in relation to the walkway provided. The typical F-shaped walkway giving access to two sides of the hatch on a 400mm wide surface is considered to be less than optimal for the tasks involved in terms of enabling the workers to adopt appropriate postures for exerting force, etc.

We have seen an example where the longitudinal walkway is located on the opposite side of the tank from the ladder; a lateral walkway providing access across to it.

Space to move from ladder to standing, and vice versa. The minimum 400mm walkway does not allow a great deal of space for manoeuvre, for example when turning to prepare for descent.

Mesh or perforated plate walkways can enable a view of the ladder steps/footholds during descent.
Cut out frame design – a manufacturer supplies a particular customer with tanks that have a small cut out in the frame of the tank at the top of the ladder (~30mm deep). This is not considered to represent a significant advantage.

3.4 HAND HOLDS

Hand-holds are sometimes provided in the walkway and the doubler/mis-stacking plates near to the top of the ladder.

Hand hold in doubler / mis-stacking plate. (Picture courtesy of UTT)

Handhold in end of walkway. (Picture courtesy of UTT)

Figure 9. Handholds at the tank top.

From discussions with industry representatives, it is apparent that tanks can be built and supplied (or leased) under a particular contract where the application is very specific and the requirements for access on top of the tank are limited. Under these circumstances the tanks have been specified with a commensurate degree of walkway provision. This saves money in the build and subsequent maintenance of the walkway, as well as reducing overall tank weight and maximizing payload. At the end of the contract, modifications can be made to up-rate the access arrangements, if required, for more general applications.

3.5 HANDRAILS/GUARDRAILS

Fold up handrails/guardrails both permanently attached and removable types, are being provided increasingly often. There are no design specifications in the tank container Standards relating to hand/guard rails, so the design appears to be largely up to the customer and/or manufacturer. A manufacturer will typically have these as standard design options that can be added to a build specification if required.

The typical design is one that folds up from a position laying flat beside the walkway, similar to those now provided on road tankers. The handrail must be secured in its down position to avoid inadvertent folding up (and latching) into the fully upright position. This can apparently happen on rail journeys, with serious consequences – and so is reportedly a requirement of Network Rail for use on UK infrastructure.

The function of what is referred to as a handrail may need to be clarified, and this has arisen in discussion with manufacturers. At present, the handrails are made as sturdily as possible within the constraints of weight and the ability to fold flat. There are currently no standards against which the performance of a handrail is tested or approved. Although these handrails are undoubtedly effective in providing an additional handhold, and will aid balance etc., there is some uncertainty whether these devices will be effective in restraining a person if they were to fall against them.

3.5.1 Practical issues for handrails

The current design of handrail found on tank containers is folded up by pulling on a handle attached to the first upright. This is typically some distance from the end of the tank frame and ladder. Figure 10 shows what is believed would be a fairly typical posture.

Figure 10. Typical posture when reaching to raise the handrail to the upright position.

The forces required to operate the handrail have not been measured, however, in the posture seen in Figure 10, even a small force is likely to present a risk of musculoskeletal injury (especially to the back and shoulders). Operating the raising mechanism in this way is therefore not ideal. Operating from a lower position on the ladder, perhaps with the mid chest area level with the tank top would be more suitable. Information on appropriate operating forces is contained within BS EN 1005-3:2002 - Safety of machinery - Human physical performance - Part 3: Recommended force limits for machinery operation.

The operation of applying a force from this position may also present a risk of falling if the grasp of the handle slips.

Some handrails are latched into the down position to prevent them from being jolted into the upright position during transport. It is important that the latching and raising mechanism can be operated with one hand.

Based upon body size data, and avoiding the forward trunk flexion seen in Figure 10, the reach distance from the end of the tank to the raising handle should be much less, more in the region of 500-650mm, bearing in mind the variation in body size between different populations worldwide (e.g. Japanese small female grip reach = 522mm).

3.5.2 Clearance for walking

The minimum width for a walkway of 400mm is stated in BS ISO 1496. The handrail is usually mounted along the edge of the walkway, and folds up to be in a position running parallel to and vertically above the outer edge of the walkway. Considering a person moving along the walkway, walking forward facing the direction of travel, and with one hand holding onto the handrail - Depending upon the size of the worker, this may be quite awkward on a 400mm walkway while keeping to its centre.

Assuming that the height of the handrail is appropriate, at between standing knuckle and elbow level. In any case the handrail needs to be around 1100 mm to be effective in preventing a fall over it. At this level the body is generally wider than the space occupied by the feet. The 400mm width may be linked with the 95th percentile male hip breadth of 403mm, plus clothing. The 95th percentile female Hip Breadth is 442mm + clothing, and Elbow to Elbow Breadth is 528mm + clothing).

To walk along a 400mm wide walkway with the hips brushing the handrail may be awkward, and even hazardous if clothing snags etc. An offset handrail on a 400mm walkway is likely to be beneficial to allowing a normal gait for most workers when wearing bulky clothing, etc. This should also minimize the likelihood of trips. An offset of 75mm to 100mm is suggested.

Certainly on a 300mm walkway (the absolute minimum allowing for foot fall), there will need to an offset of around 115mm on the handrail, to allow room for the width of the hips and to have the arm at the side, so that the worker can walk forward keeping to the centre.

3.5.3 Handrail coverage

The hand/guard rail will by necessity be shorter than the length of the side of the tank, because of the requirements to fold away. It can extend from close to the tank end at the ladder. However, any worker will invariably be accessing hatches and valves etc, at the centre of the tank and possibly some distance from the ladder and close to the opposite end of the tank. Assuming that the handrail does provide some fall protection, in this position there is an equal likelihood of a fall from the unprotected side of the tank or from the end. At best the handrail therefore only assists with movement to the place of work and protects against a fall for the extent of its length. The opposite side of the tank and both ends remain unprotected. It is therefore important to consider where workers will need to go when designing the walkway and handrail layout.

3.6 OTHER PRACTICAL CONSIDERATIONS

During discussions with industry representatives, the subject of maintaining the equipment fitted to tank containers was raised. During the journeys of tank containers there can be a considerable amount of damage and theft. Stainless steel fitting such as walkways and handrails are often a target for thieves due to its relatively high value in certain parts of the world. The costs of maintaining a tank container were reported to be significant. Therefore, as well as the impact on payload, it is desirable for operators to have as little ancillary equipment fitted to the tank as possible.

Footwear type is an important consideration. As well as having suitably non-slip soles, for secure footing on ladders footwear with a heel to locate onto ladder rungs is best.

Walkway surfaces need to be non-slip (see Section 8 for details), but consider whether the surface is to be grasped during ascent or descent, and whether the surface is suitable. Walkways are often constructed of perforated plate, which can have sharp edges. It is also worth considering how any contaminants and or water will be shed from the surface.

4 THE TANK CONTAINER LADDER CLIMBING OPERATION

The following sequential images are taken from video footage of a depot worker who was highly experienced in tank container ascending and descending. The climb and descent were performed at normal speed, and with a notably smooth series of movements, demonstrating habituation to the operation. While the technique demonstrated here may not represent how every worker might approach these operations, they are considered to be highly indicative for workers experienced in tank top access.

A less experienced worker is considered likely to complete the transfer onto the walkway on all fours, or in a crouch, and then move to an upright stance.

4.1.1 Observations

The corner casting is used as a handhold on both ascent and descent (as there are no alternative suitable handholds).
When ascending all the ladder rungs are used, right to the top.
When descending the top rung is missed out, the worker preferring to place their first foot lower down on the ladder, in this case the 2nd rung down from top.
For an experienced worker in favourable conditions, when ascending, once the first foot is placed on the walkway, it may be the only point of contact.

In the absence of purpose provided handholds, the corner casting and the edge of the walkway and the tank end frame will be used as handholds for climbing up and down. On some tanks seen, the walkway is so close to the frame structure that there is no clearance between them for a handhold.

The transfer between the ladder and the walkway, particularly in descent, is considered to be the most hazardous element of the whole access operation because of the following factors:

- Proximity to the tank edge spanning approximately 270 degrees during the transfer manoeuvre
- Awkward postures and movements required
- Likely high demands on strength to maintain stability
- Less than 3 contact points is normal
- A lack of purpose provided handholds
- Difficulty in seeing footholds during descent
- Lack of opportunity for recovery / Lack of protective measures - e.g. no handrail protection
- Typically small area on tank top for maneuvering into position

	A conventional vertical ladder climbing posture. One hand has moved to grasp into the corner casting.	 .	The other hand is moved from the ladder to grasp the tank frame		The worker uses the top rung of the ladder with one foot, while having a handhold either side of the body
 .	The first foot is moved up over the tank frame to be placed on the walkway		In a dynamic move, the weight is transferred to the foot on the walkway, the handholds are released as the worker drives forward and upward with one leg.		At this point the transfer from the ladder to the walkway is complete. The worker has only one point of contact with the tank.

Figure 11. The climbing sequence

The worker will typically move back to the ladder facing it, and turn on the narrow walkway.

They will need to turn and crouch so that the hands can grasp any handholds present – the corner casting and the walkway edge, on the same side of the walkway.

Whilst turning the worker will begin to drop a leg over the end of the tank

Typically they will not attempt to use the top rung of the ladder, but the 2nd rung down. The hands are both grasping the same side of the walkway, and the worker twists as the leg is lowered. They are relatively unstable.

The first foot engages in the ladder rung. There has been a change of grip with the hands, to a handhold either side of the walkway, and the worker is again stable.

The second foot is then moved over the edge

The second foot can either join the first on the rung down, or move straight for the next rung.

Here the worker is now in a stable ladder climbing posture, but still using handholds on the top of the tank.

Figure 12. The descent sequence.

4.1.2 Effect of ladder obstructions

As seen in this climb sequence the top rung of the ladder is used. Any obstruction to the ladder rung, or inconsistency of its spacing, width, depth etc. will have greatest impact in this region. Unfortunately it is in the upper (and lower) sections of the ladder that it is most often affected by the presence of the tank frame etc. However the effect of obstructions appears to be less critical during descent, since the top rung(s) of the ladder are not used.

5 LITERATURE/GUIDELINES ON ACCESS SYSTEMS IN SIMILAR SITUATIONS

There are a number of relevant Standards dealing with the design of access systems. These appear to represent the current best knowledge in terms of design criteria, many of which are considered to be directly applicable to the tank container/swap-tank situation. For ease of reference these are collated and presented in Appendix 2.

6 ALTERNATIVE ACCESS AND PROTECTION APPROACHES

Gantry access systems with harnesses and lines, or fold down stairs with surrounding guard rails are reasonably well established as a fall protection options for site where access is required on a routine basis.

Presented here are options that might be applicable to those sites where a means of fall protection has hitherto been considered to be not reasonably practicable.

6.1 MOBILE ACCESS LADDERS AND FALL PROTECTION CAGES.

These devices are considered to be suitable for sites accepting deliveries by tank container on a periodic basis. The cost of these devices is in the region of £5000. The devices can be moved manually or alternatively with a lift truck. They can be adjusted to suite the height of the particular tank container load. The fall protection is in the form of guardrails, providing a reasonably sized working area. However, it may be that the worker may require access to a larger area of the top of the tank than these proprietary systems allow. It may be possible for these systems to be modified to provide a larger access area.

Figure 13. Example of a mobile height adjustable ladder and fall protection guard, and a fall arrest post (Source: UCL Safety Systems, Unique Concepts Limited 1500 King Edward Street, Winnipeg, Manitoba, Canada, http://www.uclsafetysystems.com).

6.2 CONTAINER MOUNTED FALL ARREST SYSTEMS

This (UCL Safety Systems, Canada) Container Mount Fall-Arrest Post is a portable fall protection device for workers performing various tasks near edges of stacked shipping containers. It is designed to quickly engage and disengage all I.S.O. type container corner castings without tools. Whether or not it can be fixed in place without accessing the top of the tank container is not known, but it would seem reasonable to expect that it could be from a platform or gantry of less than 2m high. It weighs 11kg.

Figure 14. The corner casting mounted fall arrest post (Source: UCL Safety Systems, Unique Concepts Limited 1500 King Edward Street, Winnipeg, Manitoba, Canada, http://www.uclsafetysystems.com)

6.3 TANK TOP PROTECTION SYSTEMS

This device, from Australia (Standfast Enterprises, Queensland), is called The TRAM (Total Restraint Access Module). It is reported to be a cost effective means of providing fall protection during access to the top of road tankers and tank containers. The cost of fitting the TRAM to a road tanker is reported to be lower than that for fitting handrails. When not in use, the device folds flat and adds approximately 50kg to the weight of the tanker. The device provides fall protection from a point partially up the ladder, through the transition to the walkway and along the full length of the walkway. The ascending worker has to wear a waist belt harness that is donned before climbing the ladder. The harness is attached to the device as the worker climbs the ladder. The company promotional material includes some video of the device in use, and it appears to be a practical and workable option. Of particular benefit is the fact that the device provides fall protection where it is arguably needed most; at the transition between ladder and walkway, both during ascent and descent.


The user wears a purpose-designed restraint belt attached by two lanyards

The user attaches the lanyards to the TRAM hand-hold when on the ladder.

The hand-hold moves from a horizontal position (when the driver is on the ladder) to its vertical position (when the driver is standing on top of the tanker).


The horizontal movement of the TRAM along the fixed rail ensures that the operator can move safely along the top of the tanker.

Whilst standing and walking the anchor points are at waist level. Horizontal travel is controlled by a brake.


If the driver is required to kneel, squat or sit to work, then the hand-hold and anchor points can be lowered to accommodate this change in posture.

Figure 15. The TRAM working sequence (Source: Standfast Enterprises, 4/7 Camford Street, Milton, Queensland 4064, Australia. www.standfastenterprises.com.au).

Standfast Enterprises report that they have successfully fitted the TRAM to tank containers for specific applications where stacking is not required (unfortunately no images were available at the time of writing). Although the stacking issue would need to be overcome before this kind of device could be routinely provided on a tank containers, this does highlight the possibilities for tank mounted fall protection as the TRAM can be configured to allow the necessary degree of mobility on top of the tank container while still affording protection. The use of the device with a vertical ladder was not reported to be problematic. This kind of device may be most immediately applicable to Swap-tanks.

6.4 HANDRAILS

ITCO have presented financial estimates for modifying a fleet of tank containers to have a permanently fitted fold up handrail. These are based on a cost of £400 materials and £100 labour per tank. For a medium sized company operating 4000 tanks would be liable for costs in access of £2,000,000 for installation. The larger operators and leasing companies with over 15000 tanks could have costs of up to £7,500,000. ITCO also estimate that the maintenance costs associated with the handrail can be as high as £100 over a 2.5 year operation cycle, as theft and damage are common problems.

The ITCO favoured alternative, is for delivery sites to have some from of fall protection. The cost per site for this is estimated to start from around £2500-£5000.

A number of tank container operators have adopted the approach of fitting temporary fold up handrails to tanks where there is a requirement to do so. These fix into the tank container corner castings. It is not clear to what extent the decision to use one is always based upon a risk assessment, or a customer requirement (although the latter may itself be based upon a risk assessment). These devices appear to offer essentially the same degree of protection as a permanently fitted handrail, but some offer less protection (see the accident example in the Appendix). There were reported to be considerable logistical problems associated with having a limited number of temporary handrails and providing them on the right tank in the right place, and getting them back to the depot again. The handrails generally require the use of a gantry or other high level platform for fitting and removal (see Figure 7).

7 SUMMARY / CONCLUSIONS

The operation of climbing on and off the top of a tank container or Swap-tank is performed routinely by workers worldwide in many different environments without any fall protection. Tank containers are at least 2.5m high, and are often accessed while on a road trailer when the top of the tank can be around 4m above ground level.

The task of climbing and descending a vertical ladder and transferring to and from a horizontal walkway, without the presence of handrails or hand-holds is not a straightforward one. The ladder-climbing element alone is risky, but the transfer component is considered to be the most hazardous.

Considering the range of ladder and walkway configurations seen, and the possible range of environmental conditions in which tank-top activities can be performed, the activity of accessing the top of a tank container, using only the facilities typically provided on the tank itself, presents a high risk of serious injury.

The normal hierarchy of risk control starts with avoidance. From discussions with industry representatives, it seems that given the wide range of tank container applications, avoiding all tank top access is not a practical option, not least because of the requirements for hazardous goods in terms of not allowing bottom fill/discharge. The next step is to control the risk. At present only one tank-based system has been identified which could effectively prevent or protect a worker from the consequences of a fall while on the ladder or from the top of the tank, and this is only suitable for limited tank container applications.

There are established guidelines for ladder and walkway design, but these are not included in the standards for the construction of tank containers and Swap-tanks. There are a number of improvements that can be made to the ergonomics and the safety of access systems provided on tank containers. These improvements will not prevent falls occurring; however, they may serve to reduce the likelihood of a fall. These measures may be sufficient to bring the risks of injury associated with working at height on a tank container to a level comparable with that of working on a road tanker.

Swap-tanks appear to offer the most scope for design improvements to the access arrangements within Europe. Indeed it appears that many of these tanks have been improved to a level approaching that now adopted for road tankers.

In order for the risk of falls from tank containers to be effectively controlled, fall prevention/protection systems are required. Given the practical difficulties associated with basing such systems on the tanks themselves the conclusion has to be that fall prevention/protection systems external to the tank container are preferable, and provided at the locations where tank top access is required.

However, it is believed that avoidance of top access may be possible in some circumstances. For example, when considering the requirement for the safety of the load for road travel to be established, it is not clear that tank top access by personnel is necessary. The standards for tank containers suggest that secure closure of openings can be indicated visually, and the ADR states that a visual inspection for safety, along with documentation constitutes a sufficient assessment of load safety. The CDG Regulations use the concept of *so far as is reasonably practicable*. It may be that design characteristics can be established for hatches, manlids, valves etc., which will provide a clear indication of a secure state of closure. Tags are already used, and it may be that their use can be expanded to indicate secure closure. A detailed examination of these possibilities, as well as the legislative requirements is recommended in order to establish exactly what is expected of haulage drivers, and others, when dealing with tank containers.

8 RECOMMENDATIONS

Means of safe access and fall prevention/protection should be provided at the sites where tank top access is required. This will typically be in the form of access stairs and gantry with fall arrest system, or guardrails. The design guidelines provided below can be used, but for guidelines more specific to stair and gantry structures, refer to BS 5395-3:1985 Stairs, ladders and walkways.

If the use of fold up and/or temporary handrails is to be continued, these should be sufficiently strong to protect a worker falling against them. This may need further investigation.

8.1 RECOMMENDATIONS FOR TANK BASED ACCESS SYSTEM FEATURES

Tank containers are used worldwide by a range of populations with varying body sizes in a range of environments. It is therefore important to consider this variability, to design for the widest range of users and the range of clothing and PPE that personnel accessing the top of tank containers may be wearing/using. It is usual to accommodate the 5th to 95th percentile operators (as defined in EN 3411) including various populations.

The following guidelines may be used to help standardize the access arrangements for tank containers, and represent collated 'good practice' from relevant sources worldwide. Further details are provided in Appendix 2.

- It is important to allow enough clearance for thick gloves on hands, large footwear, and to consider reduced mobility as a result of wearing thick clothing.

- Correct and appropriate use of the designed access features should be self evident without special training, and should not overly constrain workers to use a particular method of climbing.
- Also, access may be made in less than ideal lighting conditions, and there it is recommended that the access system elements on the tank container are colour coded to indicate their presence and in high contrast colour to aid their identification especially in difficult conditions. For example, the ladder rungs, any additional handholds, and the handrail and it operating handle.

- The access system should be designed to enable the user to use simultaneously two hands and one foot, or two feet and one hand while ascending descending or moving about.

- Provide handholds/rails on both sides of the ladder wherever possible.

- Design handholds/rails to keep as clean as possible, and consider a facility to clean footwear prior to ascent.

- Consider the operation of hatches, etc., and the postures and actions these will require, and how this will influence where people need to stand when designing walkways.

- Consider the biomechanical/strength requirements for actuating safety features such as fold up handrails, as well as anthropometrics during design.

8.1.1 Ladders

- The ladder should be conventional and consistent. It should preferably have round stiles on both sides that can be grasped (allow 75mm all round clearance for gloved hands)

- The stiles should be round or at least a rounded rectangular cross section as rectangular cross sections are hard to grip.

8.1.1.1 Ladder angle

- The recommended angle for a ladder is generally in the range 70 to 90 degrees from horizontal.

8.1.1.2 Ladder width

- At least 300mm where both feet may be placed on the same rung
- Around 400mm is preferred.
- Footholds for a single foot, at least 200mm wide

8.1.1.3 Rung/step spacing

- Between 200 and 400mm vertically.
- 300mm is preferred
- Spacing must be consistent throughout the ladder to minimise tripping.

8.1.1.4 Rung dimensions

- Between 20mm and 60mm diameter/depth.

8.1.1.5 Rung style

Smooth round rungs offer least grip for feet.
Round rungs provide most flexibility in climbing posture on a vertical ladder.
High friction surface is best – punched holes/welded mesh.
If flat rung treads are used they should be horizontal.

The stiles should form the handholds rather than being the rungs, but if the rungs must be used they should be round or rounded square section – at least 2mm radius on corners, or 2mm x 2mm chamfer.

Consideration should be given to means of avoiding contamination with dirt/grease from footwear etc.

- On balance it is recommended that round rungs are used on vertical ladders, but if possible with a non-slip surface that does not compromise hand grasping if the rungs must be used as handholds.

8.1.1.6 Height of the bottom rung above the ground / vehicle bed.

The first step should be reachable by the shortest person and at least 2 hand holds should be available for them at this position – on each side of the ladder.

- Between 400 and 760mm
- 400mm is most suitable bottom rung height for the wide range of users.

8.1.1.7 Toe clearance behind ladder rungs

Space behind the rung is needed to enable the foot to placed securely, minimize slipping, and the moment at the ankle.

- 150mm minimum
- 190mm preferred.

8.1.1.8 Extension of ladder stiles above walkway

For transfers between a vertical ladder and a horizontal surface, it is recommended that the ladder extend above the surface by at least 250mm to provide a means of support until the feet are on the new level. It might be possible to provide a similar support on tank containers in the form of a slide up support, perhaps extending the ladder stiles, but with a wider base so that the worker can move between them.

- Between 250mm and 1000mm, but ideally linking with handrail at 1100mm.
- The gap between any extensions or raised handholds should be at least 450mm to allow the worker to move between them – preferably 600mm min to 700mm max.

8.1.1.9 Minimise obstructions

Such as from the end frame, especially within the upper quarter of the ladder where footing is most crucial during the transfer between the ladder and the walkway.

8.1.1.10 Distance from ladder rung to supporting surface

This is where lateral body movement is necessary from a ladder rung or other foothold.

- 300mm maximum spherical radius to edge of the supporting surface.

8.1.2 Walkways

8.1.2.1 Width

- Minimum 400mm
- 450 to 600mm is preferred.

There is no maximum width as the walkway will probably only have a handrail on one side. The need to be able to reach both handrails is irrelevant. The walkway should be as extensive as possible. It should be consistent in surface and there should be no changes in level. Where the walkway is to be restricted, its size and distribution should reflect the needs of the workers who are gaining access in terms of the operations that will be carried out, and integrate well with the operation of hatches etc., i.e. avoid workers over-reaching, adopting awkward postures, or stepping off the walkway to opening hatches etc..

8.1.2.2 Space to manoeuvre

This recommendation applies to the walkway surface area at the top of the ladder where people manoeuvre when climbing and descending.

- 600mm x 600mm minimum area.

8.1.2.3 Walkway surface

The walkway surface should be non-slip. The following are considered to be non-slip surfaces:

- Diamond tread – closed surface plating with raised diamond shaped patterns or lugs on the surface;
- Open-grip – grating with raised perforated buttons;
- Open-grip – grating with open diamond pattern having serrated edges;
- Sandcoat – surface coated with sand-containing paint or paint to which sand has been applied before drying;
- Flex-tread – high friction textured adhesive sheet material, comprised of a plastic film coated with silicon carbide abrasive particles.

The slope of the walkway should not exceed 10 degrees (this may have implications for accessing the tank top while on a road trailer).

A border or 'toeboard' is recommended to prevent a foot slipping off the side if a slip should occur.

8.1.2.4 Handrails/guardrails

Should have at least one mid rail and a toeboard.

8.1.2.5 Height of top rail above walkway

- Between 1000 and 1100mm.
- 1100 preferred.

8.1.2.6 Intermediate rails

Although the use of flexible elements is discouraged by some sources, for this application they probably represent a reasonable compromise, and are believed to be effective in preventing a fall provided they remain taut.

- Height of intermediate rail above toeboard – 400mm max.
- Distance of intermediate rail below top rail – 500mm max..

The 400mm maximum dimension is to prevent a person falling through the gap below the intermediate rail and above a 100mm toeboard. This introduces an interesting problem, given that a 100mm high toeboard is an impractical proposition. The recommendation is therefore to have 2 intermediate rails/wires to meet the above dimensions and the handrail height requirement.

8.1.3 Handholds

Where separate handholds are to be provided, they should be provided and oriented in a way that is consistent with the movement. They should be provided equally on both sides of the ladder so as not constrain the worker to a particular posture or technique (unless this is specifically required). For example if a handhold is provided in the mis-stacking plate near to the corner casting, this will force the worker to use the hand on that side, which may not be the preferred side.

- Clearance of 75mm should be allowed around a handhold for gloved hands.

- Handholds should not be more than 200mm from the ladder.

8.1.3.1 Handhold/vertical handrail diameter

- Between 16 and 40mm diameter for handrail type handholds.
- 25mm diameter preferred.

8.1.3.2 Handhold size

- At least 150mm long/wide for a single hand

8.1.3.3 Location above ground

- Handholds become useful above 1000mm
- First handholds should not be higher than 1600mm.

8.1.4 Footholds

For footholds separate from the ladder. Care should be taken to minimise the build up of debris. Non-slip surfaces preferred.

8.1.4.1 Width and depth

As for ladder rungs and toe clearance.

8.1.4.2 Height of aperture

- 150mm minimum
- 190mm preferred

8.1.4.3 Height at depth

- 100mm minimum

9 APPENDIX

9.1 ACCIDENT REPORT

A review of accident statistics and details was not performed as part of this study, but this single example was identified during searches for information relating to tank containers generally. It is suggested that an industry review of accident and incident data (ideally extending beyond the UK) may be revealing in terms of informing better design of safety features.

FALL OFF A CONTAINER

1 – THE ACCIDENT

A serious accident occurred on August 05th, 2003 during the unloading of a container in an facility.

An operator climb on a tank container and for an unknown reason, it fell on the ground.

The operation consisted in transferring a trade product by the bottom of the tank container. The opening and the lock of the dome was the responsability of the truck driver.

This tank container is fitted with a ladder and with a removable guardrail in upper position at time of the facts. The top of the tank container is partially covered with duckboards.

According to the relevant procedure, the transfer of product was begun for approximately half an hour in ¾ the hour.

The driver, standing approximately 15 meters (50 feet) of his vehicle, saw the operator, responsible for the operation, climbing on the container, then looked somewhere else. By looking again at the container ; he did not see any more the operator on the top of the container but saw him lying at ground behind the container. No witness attended the fall and his circumstances.

The driver went to the victim, then ran to warn a 2nd operator.

The rapidity of the alert allowed the nurse to be within 2 minutes for the first care. At the same time an ambulance was called by plant guards. The victim was evacuated to local hospital and later by helicopter to a main hospital (60 km away)

The victim was operated in the evening for a fractured skull. He also suffers from a fracture of 6 or 7 coasts with pneumothorax and the fracture of the right shoulder.

Page 1

2 –CAUSES OF THE ACCIDENT

To date the causes of this accident are not determined, knowing that there was no witness of the fall of the operator.

We do not know either why the operator climb on the container (check of the tank level?)

This container is fitted with a handrail required by the factory to take into account the risk of fall. Unfortunately the presence of this handrail did not prevent the fall of the operator. That is why it is necessary to pursue the analysis of the accident. An inquiry is in progress.

Container handrail and duckboard. Duckboard do not cover all the surface of container.

3 – RETURN OF EXPERIENCE

The access to the dome of tank trucks and containers is a hazardous operation. Accidents are frequent and often serious (fall of more than 3 m (10 feet))

The use of handrail is a good thing, but are mostly of small height or do not cover the entire tank.

For unloading operation, the access to the dome must be limited to the driver. It is him who has to open manholes. The operators of our company do not have to climb on the truck.

For loading operation, use a fixed footbridge, provided with handrails.

There are cases where this solution is not possible (variable size of tank trucks), or not economically realistic (exceptional loading which can not justify heavy investments).

In that case there are the other solutions to secure the access on a tank truck.

- Harness and life line: but there is a risk that the operator do not carry it for a very short intervention

Source: Provided by a company during an inspection visit.

9.2 LITERATURE/GUIDELINES ON ACCESS SYSTEMS IN SIMILAR SITUATIONS AND DESIGN CRITERIA

There are a number of relevant Standards dealing with the design of access systems. These appear to represent the current best knowledge in terms of design criteria, many of which are considered to be directly applicable to the tank container/swap-tank situation.

9.2.1 Specific

1. BS 5395-3:1985 Stairs, ladders and walkways – part 3. Code of practice for the design of industrial type stairs, permanent ladders and walkways.
This gives detailed design guidelines for access ladders, walkways handrails etc…

2. BS EN ISO 2867:1999 / BS 6912-15:1999. Earth moving machinery – Access systems
This standard gives detailed design guidelines for the , steps, ladders, handrails, handholds, reach distances, etc., for access to the cabs of large vehicles.

3. BS 3441: 1995. Specification for tanks for the transport of milk and liquid milk products.
This standard present design guidelines for the steps, handrails, and platforms for access to the tank top hatches on milk tankers. The preferred access method is only to a level halfway up the side of the tank.

4. Draft BS prEN 13586. Cranes – Access
Presents design guidelines for ladders, steps handrails etc., for access to crane operating cabs.

5. HID Semi Permanent Circular, Jan 2003 SPC/Tech/Gen/04. Prevention of falls from road tankers – Enforcement standards.
This document deals with the standards of protection expected in relation to access to the top of road tankers in the petroleum and chemical sectors. It also lays out the legal situation, which would appear to apply equally to access to tank containers and swap tanks.

6. FOD Sector Information Minute SIM 3/2001/07 & SIM 5/2001/23. Work at height on car transporters.
Similarly lays out the legal situation and gives a specific interpretation in relation to car transporters. Some useful recommendations are presented for hand/guard rails, decking surfaces and ladder access.

7. FOD Operational circular OC 537/5 Access to the tops of road tankers in the flour milling industry.
This document does not give any detail but refers to a Guidance Note issued by the Incorporated National Association of British and Irish Millers (NABIM).

8. Working on top of chemical tankers. Chemical Industries Association.1999.
As well as setting out general principles for safe access, risk reduction and accident prevention, this document provides detailed recommendations on ladder and walkway design.

9. Access to the top of road tankers. The Institute of Petroleum 1997.

This document contains a review of accidents, and sets out risk control measures in general terms, including steps to reduce the need for top access. Non-prescriptive general recommendations are made for risk control measures:

9.2.2 General

Accidents on ladders and stairways are of course a common problem worldwide, and there are many papers dealing with accident statistics.

There is quite a body of research literature on the biomechanics of climbing ladders and stairs. However, there appears to be little concerning the transition between vertical (or at least steep) ladders and a horizontal walkway, with or without a handrail.

Perhaps the most useful source is a review of stair and ladder climbing biomechanics by Bloswick in the book Biomechanics in Ergonomics (1999).

9.2.2.1 Ergonomics and ladder climbing

Research suggests that although there is variation in climbing technique, there are two main approaches that people employ:

The lateral gait, where hands move synchronized with the foot on the same side;
The diagonal gait where the hands move with the foot of the opposite side, similar to that in normal walking.

The lateral gait is reported to be more common, with around 60% of people employing it (Hammer and Schmalz 1992, McIntyre 1983). However, Hammer and Schmallz also reported that people changed their technique between and even within bouts of climbing.

Dewar (1977) and Hakkinen et al (1988) report that people refereed to grip the ladder sides (strings / stiles) as opposed to the ladder rung. Indeed BS EN ISO 2867:1999 (Earth moving machinery – Access systems), states that the step tread surface shall not be intended for use as a handhold.

Various sources quote the aim of maintaining three points of contact with the ladder at all times, however, in fact it seems that this is not particularly realistic advice. McIntyre (1983) reports that only two points of contact are maintained for periods within both the diagonal and lateral climbing gaits, and Hammer and Schmalz (1992) report that for climbing a vertical ladder, three points of contact are achieved for approximately 52% of the time.

9.2.2.2 Balance / stability

When climbing a vertical or steep ladder, the centre of mass of the body is well away from the points of contact, however, this does not necessarily mean that the position is unstable, provided the points of contact are secure, i.e. good hand grasp and no slipping at the feet.
It has been noted that the centre of mass is further away from the ladder during descent than ascent (Kinoshita et al, 1984).

For stability the consensus for the width of a ladder is around 400mm(16inch), rather than the more common 380mm (15 inch).

9.2.2.3 Strength considerations

On moderate/normally inclined ladders (70-75) degrees from horizontal, the legs provide the majority of upward force, and the hands are used mainly for balance. Lee et al report a total hand force contribution of approximately 25% of body weight. As the incline steepens, and the centre of mass moved outside the base of the points of contact, the role of the arms/hands changes. For example on vertical ladder climbing Ayoub and Bakken (1978) report the force exerted at each hand was between 20% and 36% of body weight. Bloswick and Chaffin (1990) report a single hand exertion of 24.5% of body weight.

Bloswick highlights that this is approaching (and may well exceed) the maximum grip capability for some individuals (on a ladder rung diameter of 2.2cm). Therefore there is a relatively high potential for loss of handgrip on vertical ladders, and it is especially important to provide suitable hand holds in terms of stile size and shape.

9.2.2.4 Forces at the feet

Peak foot force can reach 170% of body weight in the vertical, and 40% in the horizontal (Chaffin and Stobbe 1979), with average single foot forces of around 50-60% of body weight (McIntyre 1979). Of relevance to the likelihood of slipping on the ladder rung is the horizontal component. The highest potential for a forward slip on a ladder rung is reported to be associated with vertical ladders (Bloswick and Chaffin, 1990) where a coefficient of friction between ladder and footwear greater than 0.4 may be required to resist a slip. There does not appear to be a consideration of sideways slipping.

The ability to exert (upward) force through the feet is also reported to be an important factor for consideration. Based upon the capability to exert force through a moment at the ankle (in supporting body weight and or moving the body upwards), by flexing the foot downwards (plantar flexion) or resisting the opposite movement the ladder should enable as much as possible of the foot to rest over the rung (reducing the required moment at the ankle). The minimum clearance behind the ladder should therefore be approximately 15.5cm (Bloswick and Chaffin, 1990), and 16.5 cm (Bloswick 1999). Toe clearance behind rungs on tank container ladders are frequently far less then this.

9.2.2.5 Energy consumption

Ladder climbing has been found to be similar to rowing and running in terms of energy requirements While this may not appear to be directly relevant to the climbing of the short ladders found on tank containers, it may be of relevance to any personnel who perform access on a routine and repetitive basis.

Vertical rung separation has an impact on the level of fatigue. 35.6 cm (14 inch) separation s have been found to be more fatiguing than 30.5 cm (12 inch).
The design specifications relevant to tank container ladders, walkways and handrails contained within the above references, along with criteria from the general sources are collated and presented below.

Access system design feature	Design Criteria	Source
Ladders		
Ladder width	380 min 450 max.	BS 5395-3:1985 Stairs, ladders and walkways
	381 mm (15 inch)	Bloswick
	400mm (16inch	Bloswick
	300mm minimum – for both feet together 200mm minimum – for a single foothold	EN ISO 2867:1999 Earth moving machinery
	Stepped ladder 450mm min	BS prEN 13586 Cranes Access
	300mm min.	BS prEN 13586 Cranes Access
	300mm for both feet 200m for one	Queensland Government road freight transport guide 2000.
Rung separation	225 min 255 max	
	300mm maximum	CIA – Working on top of tankers
	30.5 cm (12 inch)	ANSI
	230mm min 300 preferred 400 max	EN ISO 2867:1999 Earth moving machinery
	Stepped ladder or runged ladder 230mm min. 300mm max.	BS prEN 13586 Cranes Access
	305mm preferred 400mm max.	Society of Automotive Engineers Handbook 1977 (SAE J185)
	200mm min. 300mm max.	Hansson (1999)

	300mm preferred 230mm minimum 400 maximum	Queensland Government road freight transport guide 2000.
Rung dimensions	20mm minimum diameter	CIA – Working on top of tankers
	1.9 cm (0.75 inch) minimum diameter	
	19mm min diameter or width 60mm preferred diameter or with	EN ISO 2867:1999 Earth moving machinery
	16mm dia min. diameter 40mm dia max. diameter	BS prEN 13586 Cranes Access
Rungs – other properties	Smooth round rungs offer least grip, but round rungs provide most flexibility on a vertical ladder Round rungs are the most acceptable type to be used as hand holds High friction surface is best – punched holes/welded mesh	
	Tread depth min 130mm 200mm preferred	EN ISO 2867:1999 Earth moving machinery
	Slip resistant and do not retain liquid (or presumably other contaminants)	BS prEN 13586 Cranes Access
	The step tread surface shall not be intended for use as a handhold.	EN ISO 2867:1999 Earth moving machinery
	Rungs for ladders greater than 75 degree	BS prEN 13586 Cranes Access
	Preferably all steps should be wide enough for both feet simultaneously	Queensland Government road freight transport guide 2000.
Bottom rung height	550mm from ground	CIA – Working on top of tankers
	400mm (700mm max)	EN ISO 2867:1999 Earth moving machinery
	600mm max.	BS prEN 13586 Cranes Access
	762mm max. 406mm preferred	Society of Automotive Engineers Handbook 1977 (SAE J185)

	400mm max.	Hansson (1999)
	400mm from ground At least 2 hand holds should be available for the user at this position – one each side of the ladder	Queensland Government road freight transport guide 2000.
Stiles		
	20mm minimum diameter	CIA – Working on top of tankers
Stiles – other properties	Gap in stiles if they are discontinuous Gap size between 10-50mm not permitted	BS prEN 13586 Cranes Access
	Stiles extend 250mm above walkway (where no other hand holds)	CIA – Working on top of tankers
	Stiles extend 838mm min above top of ladder	Woodson 1981
	Extension of stile or vertical handrail above the top of the ladder 1000mm min.	BS prEN 13586 Cranes Access
	Stiles extend 1100mm min. above walkway level, widen out and join handrail. Width between them 600mm min, 700mm max.	BS 5395-3:1985 Stairs, ladders and walkways 6.5
Toe clearance		
	230mm	BS 5395-3:1985 Stairs, ladders and walkways
	17.8cm	ANSI 1992
	15.5cm	Bloswick and Chaffin (1990
	16.5cm	Chaffin et al 1978 & Bloswick 1999
	150 min 190 preferred	EN ISO 2867:1999 Earth moving machinery
	150mm min.	BS prEN 13586 Cranes Access
	200mm preferred 150mm minimum	Queensland Government road freight transport guide 2000.
Other ladder properties		
	Distance between axis (mid line) of ladder and lateral obstacle 300mm min.	BS prEN 13586 Cranes Access

	Top rung should be replaced at the same level as the walkway to which access is provided by either: A flat supported plate / flooring Additional rungs in a horizontal plane (max. separation 75mm)	BS 5395-3:1985 Stairs, ladders and walkways 6.3 – Figure 3 (continued).
Walkways		
Width	450mm min light duty 750mm general duty	BS 5395-3:1985 Stairs, ladders and walkways
	900mm wide for all round access 600mm wide for single side access	CIA – Working on top of tankers
	300 min 600 preferred	EN ISO 2867:1999 Earth moving machinery
	300mm (12”) min	(Woodson 1981)
	450mm min.	BS prEN 13586 Cranes Access
Other walkway properties	Non slip The following are considered to be non-slip surfaces: Diamond tread – closed surface plating with raised diamond shaped patterns or lugs on the surface Open-grip – grating with raised perforated buttons. Open-grip – grating with open diamond pattern having serrated edges Sandcoat – surface coated with sand-containing paint or paint to which sand has been applied before drying Flex-tread – high friction textured adhesive sheet material, comprised of a plastic film coated with silicon carbide abrasive particles.	BS prEN 13586 Cranes Access
	Step placement from ladder – spherical radius 300mm	EN ISO 2867:1999 Earth moving machinery
	Where lateral body movement is necessary from a ladder rung to another surface, maximum distance between the step/rung and the surface 300mm spherical radius	BS prEN 13586 Cranes Access
	A mid-rail shall be placed mid-way between the top rail and the walkway	EN ISO 2867:1999 Earth moving machinery

	Wherever a foot could slip from a walkway or platform, a foot barrier should be provided	EN ISO 2867:1999 Earth moving machinery
	The slope should never exceed 10 degrees	BS 5395-3:1985 Stairs, ladders and walkways
	Platforms on which people manoeuvre should be 600 x 600mm minimum.	BS prEN 13586 Cranes Access
Handholds and vertical handrails		
Separation (where body passes between)	450mm min.	BS prEN 13586 Cranes Access
Size	16mm min. diameter 40mm max. diameter	BS prEN 13586 Cranes Access
	25mm diameter preferred	Queensland Government road freight transport guide 2000.
Length	150mm min for single hand	BS prEN 13586 Cranes Access
Clearance around	75mm min	BS prEN 13586 Cranes Access
	75mm	Queensland Government road freight transport guide 2000.
Distance to rung	200mm max	BS prEN 13586 Cranes Access
Locations	Height above floor 1000mm min. 1600mm max.	BS prEN 13586 Cranes Access
Handrails		
Height	1100mm min.	CIA – Working on top of tankers
	1000 mm min. 1100 mm max. and preferred	EN ISO 2867:1999 Earth moving machinery
	1100mm	BS3441:1995 Tanks for the transport of milk and liquid milk products
	1000mm min.	BS prEN 13586 Cranes Access
Distance between toeboard and the intermediate rail	400mm max. (toeboard 100mm high minimum)	BS prEN 13586 Cranes Access
Distance between the top of intermediate rail	500mm max.	BS prEN 13586 Cranes Access

and the handrail		
Other properties	Have smooth surfaces Edges shall have radii – 2mm min, or be chamfered – 2mm x 2mm min	BS prEN 13586 Cranes Access
	Stops shall be provided at the ends of handholds and footholds	BS prEN 13586 Cranes Access
	Gap between discontinuous sections 50mm min. 200mm max.	BS prEN 13586 Cranes Access
	There should be not less than 2 rails in the same vertical plane.	BS 5395-3:1985 Stairs, ladders and walkways
	Lateral loading: Single person – 0.36kN/m General duty – 0.36 kN/m	BS 5395-3:1985 Stairs, ladders and walkways
	Folding guardrails shall be fitted to the sides and non-access end of the tank..	BS3441:1995 Tanks for the transport of milk and liquid milk products
	The use of flexible elements such as chains, ropes.. is not permitted for side protection	BS prEN 13586 Cranes Access
Footholds		
Width	300mm (for both feet)	BS prEN 13586 Cranes Access
	300m both feet 200mm one foot	
Depth	150mm min.	BS prEN 13586 Cranes Access
	130 min 200 preferred	EN ISO 2867:1999 Earth moving machinery
Height of aperture	150mm min	BS prEN 13586 Cranes Access
	150mm min. 190 preferred	EN ISO 2867:1999 Earth moving machinery
Height at depth	100mm min	EN ISO 2867:1999 Earth moving machinery
Other properties	Minimise accumulation of debris and aid in the cleaning of mud and debris from shoe soles.	Queensland Government road freight transport guide 2000.

General Principles

The access system shall accommodate the 5^{th} to 95^{th} percentile operators – as defined in EN 3411	EN ISO 2867:1999 Earth moving machinery
Correct use of the access system shall be self evident without special training.	EN ISO 2867:1999 Earth moving machinery
The access system should be designed to enable the user to use simultaneously two hands and one foot, or two feet and one hand while ascending descending or moving about.	EN ISO 2867:1999 Earth moving machinery
Provide handrails rather than handholds wherever possible	Systems Concepts Report
Handhold/rail locations should take account of the range of users. Wherever possible 5^{th} to 95^{th} percentiles should be accommodated	Systems Concepts
Provide handholds/rails on both sides of the ladder wherever possible	Systems Concepts
Design handholds/rails to keep as clean as possible	Systems Concepts
Avoid using rungs of ladders as handholds	Systems Concepts
Anti-slip surfaces on all places where workers will move, stand, work etc..	Systems Concepts
Facility to clean footwear prior to ascent;	Access to the top of road tankers. The Institute of Petroleum 1997
Consider the operation of hatches etc and the postures and actions these will require, and how this will influence where people need to stand when designing walkways.	Author
Use colour coding to clearly indicate the features of the access system and intended route	Author
Consider the biomechanical/strength requirements for actuating safety features such as fold up handrails, as well as anthropometrics during design.	Author

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