Safety review

Loading and unloading of road and rail tankers — hazards, good practice and case studies

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Summary

This article focuses on the subject of loading and unloading of tankers used for carrying liquids that are normally transported either on flat rail trucks or on detachable road trucks coupled to a cab tractor unit. Some of the typical hazards are discussed, supported by case studies and recommendations on how to guard against them including:

- safe access to tanker valves, instruments and other equipment;
- unloading a tanker into the wrong plant tank;
- tankers being driven away while still connected to the plant pipework;
- overfilling of a tanker;
- safe designs for loading/unloading gantries;
- static electricity hazards.

Additionally, the importance of a rigorous risk assessment prior to the commencement of loading or offloading is emphasised, as is the need for clear and concise information about good safety practices to be communicated to the workforce.

Keywords: Loading, unloading, tanker

Introduction

The subject of ensuring safety in the use of tanks and tankers is a very wide-ranging topic, covering items including various categories of tank, for example fixed or floating roof, operating at, below or above atmospheric pressure, open-topped tanks and other facilities, as well as mobile tankers, which are the subject of this article. All of these have some safety features and requirements in common, but at least as many that vary from category to category. To cover all of these in a single article would not be a practicable objective, but reference 1 is a very useful source of information about these other categories and also contains a list of references for further reading. This article focuses on the subject of loading and unloading of tankers used for carrying liquids, that are normally transported either on flat rail trucks or on detachable road trucks coupled to a cab tractor unit. A range of case studies illustrates some of the hazards, and how to guard against them. Some types of liquid (for example, LPG and those which require very specific precautions due to their toxicity or biochemical properties) are not covered in this article; however, it is not practicable to give a comprehensive list of such exclusions.

Tanker loading and unloading procedures

Tankers are generally loaded and unloaded from gantries that enable the operator to access the top of the tanker, and any valves, easily and safely. Top or bottom loading and unloading systems are used and can be either with or without vapour recovery systems. It is not usual for tanker drivers to need to wear personal protective equipment (PPE) except possibly goggles and/or protective handwear for connection of the tanker, as they will not be in the vicinity during the actual loading or unloading process. However, for plant operatives engaged in the process, full PPE, as specified for the particular operation, is essential.

Top loading

A filling pipeline is extended to the bottom of the tanker by use of an articulating arm through a hatch on the tanker top. The liquid is introduced via this pipeline, usually by pumping. This is known as open (to atmosphere) loading and there is usually no vapour recovery system. The main hazard associated with this is exposure of operators above the tanker to fumes, so it is not permissible when there are restrictions arising from the use of volatile organic compounds (VOCs) or toxic/flammable chemicals. To avoid the hazard that this presents, closed configuration loading must be used. This can be done by introduction of liquid from the tanker top via a fixed pipeline and valve, with the tanker connected to an extraction system to maintain a safe internal pressure. Also, it is very important that the filling pipe reaches the bottom of the tanker to avoid splashing that can generate static electricity.

Bottom loading

A filling pipeline (hose or permanent metal or plastic pipe) is attached to a valve at the base of the tanker. Liquid is introduced by pumping via this valve and this is an example of closed configuration loading. The safety advantages compared to top loading are:

- no liquid splashing;
- reduced chance of use of incorrect filling lines;
- no chance of debris falling into the tanker from above;
- reduced vapour generation;
- no need for an operator above the tanker;

On the other hand, the method requires a reliable tanker level indicator linked to a filling pump cut-out system to avoid tanker overfilling. Care also needs to be taken to ensure adequate dissipation of static electricity within the tanker. Also, a top

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loading tanker can be designed without any flanges or valves at the bottom, thus effectively eliminating the possibility of loss of tanker contents by leakage and gravity.

Tanker unloading

This also can be carried out from either the top or bottom of the tanker, using, in effect, the reverse of the techniques employed for loading. Alternatively, unloading can be achieved by means of a permanent "dip leg" fitted to a flange on the tanker top and extending nearly to the base of the tanker. Gas pressure, for example nitrogen, can be applied to the surface of the liquid via a pipeline to force the liquid up the dip leg and out of the tanker. However, awareness of the danger of over-pressurising the tanker must be maintained, with the possible consequence of wall, or joint, failure. Also, if other pressurising gases are used, flammable or other hazardous atmospheres can be generated. On the other hand, emptying by pumping can lead to vacuum and implosion unless the pressure is controlled.

In summary, optimum tanker design might incorporate the advantages of closed loading and unloading from the top, an appropriate extraction system, and elimination of bottom valves and flanges, though it is important to emphasise that no single system will be suitable for all cases.

Case study: Acid leak from a tanker unloading flange

About 10-20 kg of anhydrous hydrofluoric acid (AHF) leaked from a skewed flanged gasket connection in the AHF tanker offloading line while the tanker was being unloaded. The leak arose from poorly aligned flanges at a joint resulting from a difficult positioning manoeuvre of the tanker, which was not of ISO standard. The cause of the leak was lack of nitrogen pressure testing of the joint prior to AHF unloading. The method of "proving" joint integrity was to check for leakage of residual AHF from joints, using appropriate PPE. The leak time was extended because an instrument valve in the nitrogen supply to the tanker safety valve had been closed, thereby preventing the latter from closing. This instrument valve had been installed without a HAZOP study. The investigation recognised the need to introduce nitrogen testing of joints and connections and subject key modifications to HAZOP[2].

Other matters that influence safe loading and unloading

The Health and Safety Executive, Great Britain (HSE) provides guidance for its inspectors on the subject of all aspects of tanker loading and unloading (which they refer to as off-loading) and many of these are relevant to the safety of such operations[3]. They have also published an Approved Code of Practice for Unloading Petrol from Road Tankers[4], which although aimed specifically at the motor fuel delivery industry still contains much advice which has a wider applicability. Using these sources, together with reference 1, a list of topics which might influence safe operations, in addition to the actual (un)loading operation itself, can be drawn up. This list of topics is now discussed, noting that others may exist. The case studies illustrate how some of them have been associated with accidents.

Access to tanker valves, instruments and other equipment

Access is normally gained from a gantry situated next to where the tanker operation is to take place. The main hazard is falling from the gantry to the ground or onto the tanker. To guard against this, a range of measures is appropriate. These would include:

- adequate space for positioning and manoeuvring tankers and cabs;
- a walkway, with handrails, above the tanker;
- good ventilation;
- safe stairs and ladders with non-slip treads and fall protection;
- good lighting;
- good housekeeping, for example no trip hazards;
- easy access to tanker and plant valves;
- drip collection and drainage systems to reduce the chance of slipping;
- easily accessible shower, eyewash and emergency shutdown systems.

Figure 1 shows a common example of an unsafe practice where many of the above features are absent. The operator is standing on the tanker top.

There is also a risk of fire where flammables are being loaded or unloaded. Some of the above measures will guard against

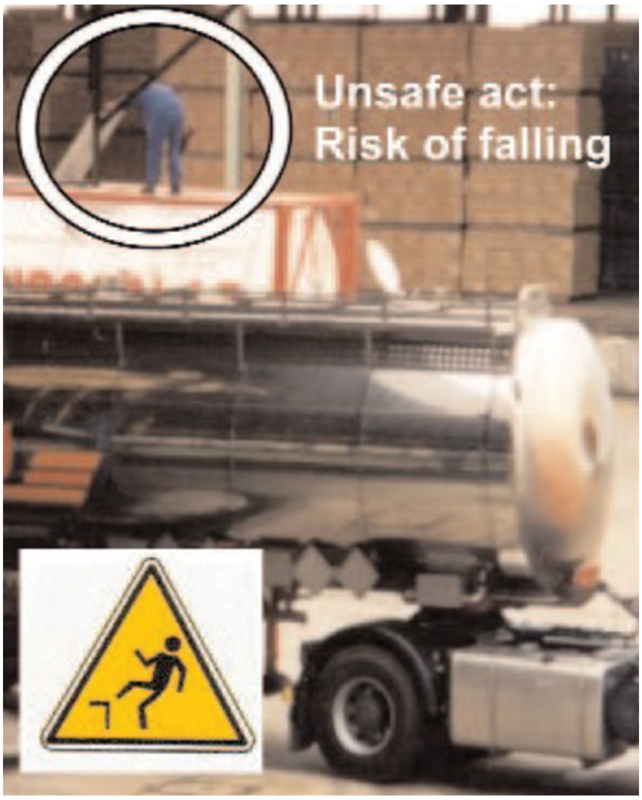

Figure 1 – Operator standing on tanker top

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this hazard but, in addition, no ignition sources should be permitted on the gantry and adequate fire-fighting equipment should be provided.

Unloading a tanker into the wrong plant tank

One of the case studies demonstrates that this hazard, though rare, is not impossible. To prevent this happening:

- the contents of tankers must be rigorously confirmed by means including supplier's paperwork, tanker markings and driver's confirmation, taking account of the possibility that the driver might not speak the native language;
- in some cases, sampling and analysis of tanker contents prior to unloading may be appropriate;
- plant valves and pipework should be correctly labelled and the labelling kept up to date;
- any modifications to valves, pipework or other relevant equipment must be approved, clearly indicated on the plant and made clear to operators;
- a high standard of operator training and understanding of operations, reviewed and updated as necessary, is essential;
- monitoring of the operation, for example from a control room or by a supervisor, is essential.

It is also possible for a tanker to be filled with the wrong liquid and the precautions against this are analogous.

Case study: Unloading into the wrong tank[5]

Approximately two tonnes of 35% ammonium hydroxide solution were incorrectly unloaded into a nitric acid storage tank, which contained several tonnes of 60% nitric acid. This caused an exothermic reaction and a release of ammonia fume. One employee suffered slight discomfort from the fumes but returned to work the following day. The plant operator had been transferred from an adjacent plant and had not been trained in the correct procedure. He went to the wrong offload station, which was a nitric acid offloading point although the signage did not clearly indicate that. The operator and tanker driver realised that the tanker connections were incompatible with the plant unload point, but they made an ad hoc modification to allow the tanker to be offloaded. The lessons learned were:

- full training of new operators is essential;
- signage on plants should be clearly visible from all directions;
- modifications should never be carried out without first going through the specified approval procedures.

Another incident involving offloading into the wrong tank is described in detail in reference 6. This resulted in an uncontrolled chemical reaction between two incompatible chemicals, a series of explosions and significant plant damage, and was due to the tanker delivery documentation being wrong.

In yet another such excursion, contamination of a tank containing acetone by butyl glycol ether was detected by measurement of boiling point – fortunately, before any mishap occurred[7].

Tankers being driven away while still connected to the plant pipework

There have been cases of this happening after a tanker has been filled, after one has been emptied, and even during filling or emptying. The consequences can be extreme. Flammable liquid can be released, leading to fire and/or explosion. Release of a toxic liquid could lead to exposure to plant personnel or members of the public. Significant damage to plant might occur. The root cause is usually human behavioural failure. To guard against such events:

- The tanker driver must be briefed about the sequence of loading/unloading procedures so that he/she understands when it will be safe to move the tanker. Provision should be made for the possibility that the driver does not speak the native language.
- The plant operators must check that it is safe to move the tanker before they allow the driver to move it. All tanker-to-plant connections must be checked to ensure that they have been broken.
- The loading/unloading line(s) should be self draining.
- Physical barriers and systems to prevent tanker movement should be installed. These could include requiring the tanker driver to hand over the tractor cab ignition key for safekeeping by plant personnel, but the possibility that he/she has a second key cannot be discounted. Furthermore, this precaution would be impractical for rail transport.
- Installation of a robust swing barrier, similar to those at car park entrances and exits, to "box in" the tanker should be considered. The key to open and close this barrier would be kept in a safe with a key code known only to the plant management and supervisors(s).
- Chocks can be placed under the tanker wheels.
- Consideration should be given to installation of an electrical interlock system. For example, between the tractor cab start-up electrics and the tanker earth proving unit. Again, this is not practical for rail tankers.
- "Dry-break" couplings in the loading/unloading line(s) should be considered.
- Consideration should be given to the use of closed circuit television, with recording, though this would usually only be of value in investigating an incident or for training. In the latter respect, its use could extend to any of the operations dealt with in this article.

Case study: Road tanker driven away while still connected[8]

A road tanker had been loaded with 40% hydrofluoric acid and the system depressurised. The tanker driver had confirmed with plant personnel that the loading procedure was complete and assumed that the tanker was ready to be driven away. However, it had not been disconnected from the plant filling line so, when it was started up and moved, the line came apart at a flange and a quantity of residual acid was spilled onto the floor. Nobody was injured but it was a potentially serious incident. No barriers to movement of the tanker were in place and the driver was in possession of his own ignition key. These, and other precautions to ensure full draining of the loading line before tanker movement and to guard against human error, were put in place to prevent a recurrence.

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Overfilling of a tanker

The hazards of this are broadly the same as those for tanker drive-away while connected – fire, explosion or toxic release. Measures that should be taken to prevent overfilling include:

- Installation of high liquor level alarms that link to the filling system and shut it down. This might be by tripping out the feed pump, or closing the feed valve and diverting the liquor flow back to the supply vessel or to a suitable other vessel.
- Installation of level sensors which monitor and, if necessary, record the liquor level as the tanker fills. The sensors would interact with the high level alarms.

The consequences of overfilling also include immediate hazards to the operators and any other personnel in the vicinity. Longer term dangers may develop for persons further away from the accident if the liquor is toxic or flammable. For these reasons, additional escape and shutdown facilities should be available. These should include:

- more than one escape route;
- emergency stop buttons that, if necessary, will override the automatic systems described above — one of these should be remote from the tanker, at a distance of, say, 30 metres;
- liquor feed isolation valves located where they can be easily reached in the event of fire or toxic release;
- "fail safe" emergency systems for example, valves to close in the event of failure of power or tanker pressurising systems.

All the above relates to overfilling to the point of spillage. A tanker can also be "overfilled" beyond a specified (e.g. regulatory) level without spillage. This can lead to overweight loads with dense liquids, and introduce a new hazard of control when the tanker is driven away. Further guidance on this can be found in reference 9.

Case study: Fatal fire caused by failed level sensor[1]

A road tanker compartment already contained 4,900 litres of gasoline when it entered the loading area. The driver thought it was empty and set the fill meter accordingly. Due to failure of the liquid level sensor, the compartment was overfilled, a spillage occurred and gasoline vapours were released. A second vehicle entered the loading area and ignited the vapours, engulfing the entire area in flames. One person was killed and eight others injured. The lessons learned were:

- in the event of a spillage, it is vital to stop the flow of liquid immediately;
- movement of other vehicles into the area must be suspended until the area has been made safe again.

Design of loading/unloading gantries

Gantries are structures that facilitate the loading or offloading of liquors to or from road and rail tankers. They are the working environment of the operators and to some extent the tanker

Figure 2 – Road tanker access with handrail

drivers. As such, they need to be designed and operated with the safety of these personnel at the forefront. Measures to minimise the potential for accidents, in addition to those set out above for access to valves and other equipment, include:

- a roof or canopy for protection against bad weather;
- ensuring that the roof has adequate space for the operator(s) and for manoeuvring the tanker and its cab;
- comprehensive training for operators;
- updating of procedures following engineering or operational modifications;
- adequate supervision;
- regular scheduled inspection and maintenance of overfill protection, (un)loading lines and earthing systems;
- ensuring that the overall gantry design is compatible with the tankers that it services, for example, in length, height and other features;
- fall protection such as harnesses with inertia reels;
- drive through capability for the tankers, which is preferable to reversing out as it reduces collision risks.

Figure 2[10] shows a well-designed access platform, with handrails, albeit lacking a roof.

Case study: Road tanker damages a fuel line on a loading gantry and causes a fire[1]

An empty road tanker was being manoeuvred into position to load motor spirit at a loading gantry bay when it struck a valve on the motor spirit line. The valve sheared at a flange, releasing approximately 560 litres of spirit over the front of the vehicle. The driver immediately switched off the engine, but it continued to run at an abnormally high speed. He jumped clear just before ignition, followed by a severe fire, ensued. The intense heat of the fire caused extensive damage to equipment and the gantry and resulted in further spillage of spirit product. There was insufficient clearance between the gantry pipe system and the vehicle. The source of ignition was probably either the diesel engine overspeed, or the sheared off valve striking the battery box, splitting the fibreglass box cover, and arcing across the terminals. The driver might very easily have fallen and injured himself.

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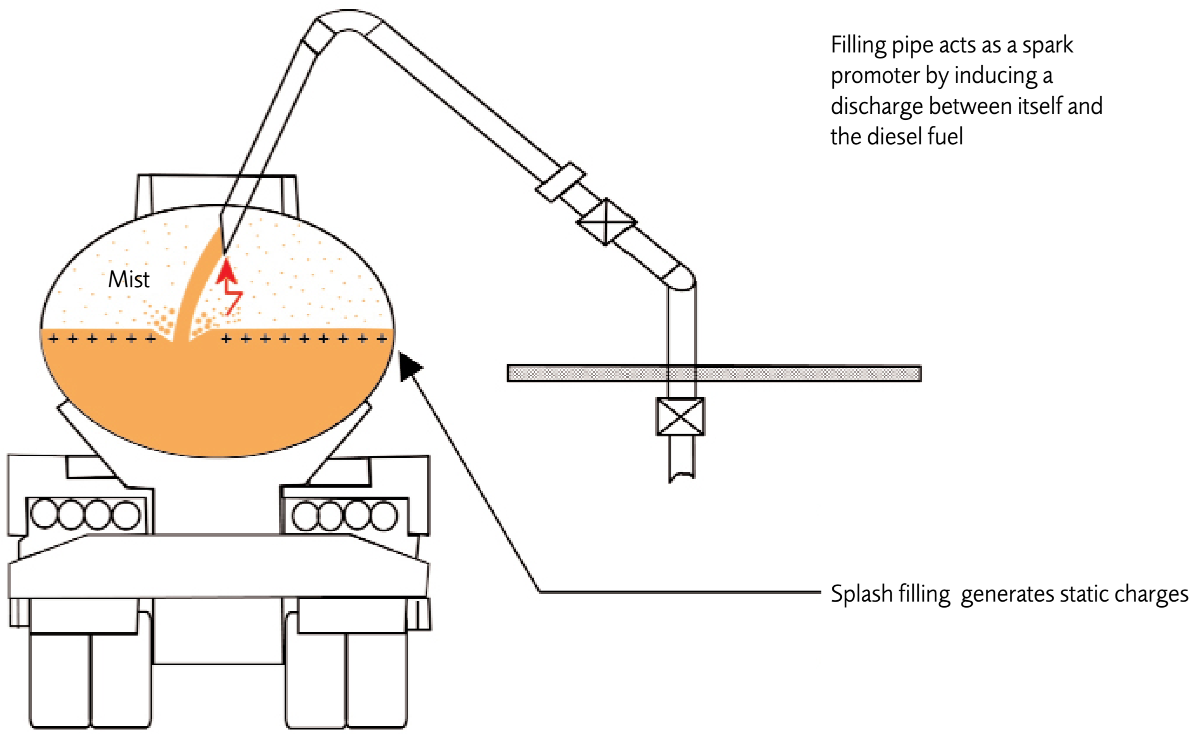

Figure 3 –Bad practice

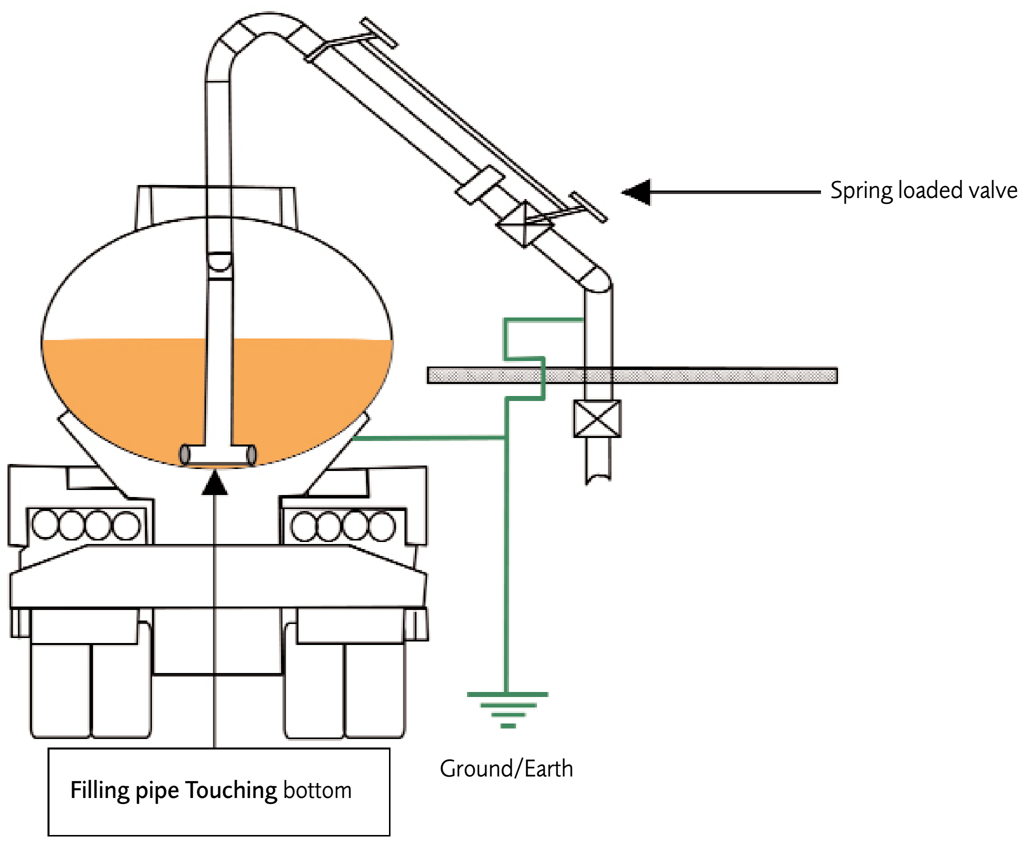

Figure 4 –Good practice

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Static electricity

Rail tankers have adequately low resistance to ground via their rail lines. This prevents accumulation of any electrostatic charge of sufficient voltage to cause an incendiary spark. Thus, the tanker and rails do not need to be bonded to the fill pipe. Stray currents can be controlled by bonding the loading lines to the rails.

For loading/unloading road tankers, however, static electricity is a very important consideration. Tankers need to be connected to earth/ground with bonding connections properly made. This affords protection from sparks due to static charge accumulation that can be an ignition source. Static electricity hazards can be caused by splash filling, switch loading, sampling, dipping or taking temperatures. Measures to guard against these hazards include:

- ensure adequate grounding before loading/unloading is started and that there is visual indication of this;
- grounding systems can have an interlock to prevent pumping if the earth is not made — note, however, that it is possible to override this by connection to any metal fitting;
- do not exceed the specified or recommended liquor flow rates;
- when loading a multi compartment tanker via a fill pipeline, ensure that only the compartment being filled is open, so as to reduce the emission of any flammables;
- avoid dropping items into the tanker;
- ensure that the fill pipe is located centrally and extends as near as possible to the bottom of the tanker or compartment;
- after loading is complete, allow sufficient time for charge dissipation before removing the fill pipe;
- ensure that no ignition sources are brought onto the gantry.

The use of fill line filters, for example to prevent suspended solids entering the tanker, should be approached with caution. The finer the filter, the higher the static charge generated. Further advice on protection against hazards from static electricity is contained in reference 11.

Case study: Static electricity caused an explosion and a fatality[1]

The driver was top loading diesel fuel into an open topped road tanker using a hose that did not reach the bottom. The end of the flexible hose was 0.75 m above the bottom of the tanker compartment (figure 3). The driver was observing the filling from the top of his vehicle when an explosion and fire occurred. His clothing caught fire and, although he managed to climb down from the tanker to enable fellow workers to smother the flames, he died from his burns two days later. The fire was caused by ignition of flammable vapours by static electricity generated due to "splash filling." Additionally, the vehicle was not earthed. Adequate grounding or earthing, together with a fill pipe long enough to avoid splashing and excessive static generation, would have prevented this accident and were installed to avoid a recurrence (figure 4). The use of a spring loaded valve handle, sometimes known as a "deadman's handle," prevents overfilling by closing unless the operator constantly holds the valve handle in the "open" position. If, for example, the operator leaves the job, the valve will close.

Summary and conclusion

In summary, this article has discussed the significant safety features of one aspect of tanker operations and offered some recommendations and procedures aimed at avoiding accidents. These are not necessarily comprehensive, as no two situations are exactly alike. On the other hand, similar features and factors do recur from one situation to another. Thus, a rigorous risk assessment, taking account of the generic and specific particulars of each operation, is an essential requirement prior to the commencement of loading or offloading. This should take account of the features discussed above and all other factors pertinent to the operation to be carried out. Another vital factor common to all situations, is the need for clear and concise information about good safety practices to be communicated to the workforce. This can be done in many ways, including checklists, team talks, publicity posters and others. Temperature control during all operations is another common safety requirement for dealing with volatile liquids.

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