CTAC Vessel Cargo Tank Overpressurization Subcommittee Working Document

Short Term Task (Due September 2001)

Review and evaluate current industry practices and procedures involving the introduction of pressurized gas from waterfront facilities to a vessel's cargo tanks during inerting, padding, purging, line clearing, and railcar transfer operations, and identify the hazards associated with these operations.

Definitions

1. Inerting:

    a. (ISGOTT 10.6.1) Introducing inert gas into a cargo tank, while venting the tank to the atmosphere, until the oxygen content throughout the tank is not more than 8% by volume, and maintaining that condition with positive pressure.
    b. (IBC 9.1.2.1) Filling a cargo tank and associated piping systems (and adjacent spaces when specified) with gas or vapor which will not support combustion and will not react with the cargo, and maintaining that condition.
    c. (Discussion) The purpose of inerting is to prevent the development of a flammable/explosive atmosphere within a tank during cargo loading, transport, discharge, and tank cleaning operations. In practice, oil tankers generally use inert gas systems (IGS), which generate inert gas from flue gas emissions, to inert cargo tanks. Chemical tankers generally use nitrogen to inert cargo tanks, but may use inert gas generators (IGG) to inert non-cargo spaces. Other inert gases that are used include carbon dioxide and oxygen poor air. Few chemical tankers have the capability to produce enough nitrogen to meet all inerting requirements on board. Thus, shore facilities commonly provide nitrogen to initially inert cargo tanks on chemical tankers while nitrogen produced on board is used to maintain the inert condition.

2. Purging (also called pre-purging):

    a. (ISGOTT 10.6.9) Introducing inert gas into a cargo tank, while venting the tank to the atmosphere, until the hydrocarbon content throughout the tank is not more than 2% hydrocarbons by volume, and maintaining that condition.
    b. (Discussion) Although the ISGOTT definition for purging is based on hydrocarbon concentration, it is common amongst members of the marine chemical transportation industry to define purging in terms of oxygen concentration. Thus, in practice purging is often defined as introducing inert gas into a cargo tank, while venting the tank to the atmosphere, until the oxygen content throughout the tank is not more than 2% by volume, and maintaining that condition. This is the definition adopted by this Subcommittee. Large volumes of nitrogen are needed to successfully purge a

tank. The nitrogen is generally supplied from shore via 2-4 inch hoses. As a rule of thumb, roughly four tank volumes of nitrogen are required to reach an oxygen content of 2% and approximately six tank volumes of nitrogen are required to reach an oxygen content of 0.5%. While purging, nitrogen generally enters the bottom of a tank through the pump stack or tank loading line and cargo manifold.

3. Padding (also called blanketing):

   a. (IBC 9.1.2.2) Filling a cargo tank and associated piping systems (and adjacent spaces when specified) with a liquid, gas, or vapor which separates the cargo from air, and maintaining that condition.
   b. (Discussion) Occasionally, water or oil may be used to pad a cargo. However, in most cases gaseous nitrogen is the preferred padding material. Nitrogen, maintained at positive pressure, is ideal for protecting cargoes that are sensitive to moisture, particularly as the cargoes cool. During inerting and purging operations, tanks are empty and the vents are open. In contrast, during padding operations, tanks contain cargo and tank vents are closed, leaving the pressure/vacuum (P/V) relief valves to act as the sole guard against overpressurization. The nitrogen is introduced via the pump stack or another connection at the top of the tank.

4. Topping Up:

   a. Introducing inert gas into a tank that is already in the inert condition to prevent an ingress of air by maintaining positive pressure.
   b. (Discussion) Oil tankers generally use IGS for topping up operations. Chemical tankers generally use nitrogen stored or made on board. Small volumes and low pressures of nitrogen are typically introduced in the tanks via a fitting at the top of the tank or through the vent piping.

5. Drying (similar to purging):

   a. (IBC 9.1.2.2) Filling a cargo tank and associated piping systems with moisture-free gas or vapor with a dew point of $-40^{o}C$ or below at atmospheric pressure, and maintaining that condition.
   b. (Discussion) During a drying operation, pure nitrogen (99.9% by volume) is generally supplied from shore and introduced into an open tank that is empty of cargo. Additional nitrogen may be added to a dry, closed tank containing cargo if the tank is opened for sampling purposes.

6. Line Clearing (also referred to as pigging and blowing lines):

   a. (Discussion) Compressed air or inert gas is used to push or move residual cargo though a line into a tank vessel, shore tank, or special receiving vessel such as a truck. Pigging is a form of line clearing in which an object, known as a pig, is inserted in the line between the product and compressed gas and forced to move through the line by the resulting pressure differential. During a line clearing operation, the residual cargo is pushed through the cargo line from the discharging tank to the receiving tank. Often, when nitrogen is used to clear a line, it is intentionally allowed to enter the tank to form a pad at the completion of the line clearing operation. Although 40 psig is generally considered to be the minimum pressure needed to move a pig, pressures as high as 100 psig are commonly used. Pigs come in several designs and may be constructed of foam, rubber, PVC, metal or other special material. There are several designs for catching a pig before it enters the receiving vessel. The most common design diverts the pig into a trap from which the pig may later be removed. Other designs cause the pig to be trapped in the line by a constriction forming a "snug fit", which then prevents the gas behind the pig from entering the receiving vessel.

7. Loading from Railcars:

   a. (Discussion) Compressed air or inert gas is used to "press out" a product from a connection on top of a railcar to a discharge line at the bottom of the railcar tank. A booster pump may or may not be used during this type of operation. Pressures vary, but can be as high as 80 psig in the railcar. The railcars may be grouped or interconnected and are commonly staggered to ease the load on the rail rack operator.

General Hazards Associated with Current Marine Industry Practices using Compressed Gases

Inattention to sound procedures and other failings on vessels and shore have resulted in the following consequences:

- Death
- Injury / chemical exposure
- Release of product in the air and/or water
- Product entering vapor control systems (risk of fire/explosion)
- Damage to equipment
- Structural damage to vessels

Although there have been industrial accidents associated with the use of compressed gases for many years, the increasing trend to conduct closed operations has been accompanied by an increase in the number of such accidents. In the chemical industry, the most common consequence of such accidents has been the release of product. However, with the advent of vapor control regulations for specific products and customer requests to control vapors for additional products, some of the latest incidents have resulted in product entering vapor control systems. In some cases, vessel tanks have been overpressurized, leading to equipment failure and buckling of bulkheads, which, in turn, impaired the overall structural integrity of the vessels.

Current Procedures and Hazards Associated with use of Compressed Gases

Subcommittee members agree that the types of equipment in use, company policies, and procedures differ between terminals, vessels, barges, and even between companies within the same transportation mode. This section contains a collection of procedures for marine vessel operations involving the use of compressed gas that are currently being used throughout industry.

1.0 Inerting / Purging Procedures:

a. Gas volumes and pressures are discussed during the pre-transfer conference. The tank venting capacity is calculated and compared to the shore supply. Pressure gauges and/or regulators are installed at the shore supply connection or at the connection point on the vessel.
b. The tank is emptied of residual cargo and all hatches, valves, and vents are left OPEN to the atmosphere. Any pressure sensors/alarms on the tank vessel are placed in operational mode.
c. The compressed gas line is connected to the vessel's manifold and gas is introduced into the tank via the pump stack or loading line.
d. Tanks are "tagged off" and marked with warning tape. All personnel in the vicinity of the tank vessel are made aware of the inerting operation and instructed to remain clear of the open hatch areas.

e. The operation begins slowly at a pressure well below the P/V relief valve setting. Once the tank vessel personnel have confirmed that the system is functioning properly, the pressure and volumetric flow rate of gas is increased to previously agreed upon levels.
f. The manifold valve on the vessel controls the volumetric flow of compressed gas into the tank. Direct communication between shore and vessel is maintained throughout the operation.

1.1 Inerting Hazards: Current procedures primarily call for open venting, which is acceptable for a tank that is free of product, and regulating equipment, which is not available at every terminal, to ensure a safe operation. Monitoring equipment, such as pressure gauges and alarms, coupled with operator intervention typically serves as a secondary means for ensuring a safe operation. Given these conditions, the principle hazards during an inerting operation are:

a) Tank over-pressurization may result if the supplied volumetric flow of gas exceeds the maximum venting capacity of the tank vessel.
b) Tank over-pressurization may result if the maximum venting capacity of the tank is not realized due to a failure to open all vents during the operation.
c) An oxygen deficient atmosphere may develop in the vicinity of open hatches in some weather conditions.

2.0 Padding (blanketing): This operation may be avoided all together by pre-purging an empty vessel cargo tank prior to conducting a closed loading operation. This effectively pads the cargo without having to conduct a padding operation. However, many customers insist that padding operations take place. When padding operations are performed, the following procedures are generally followed:

a) Gas volumes and pressures are discussed during the pre-transfer conference. The tank venting capacity is calculated based on the P/V relief valve size. Occasionally, a restrictive orifice or small-diameter hose may be fitted at the manifold, to reduce the volumetric flow of compressed gas to below the maximum capacity of the P/V relief valve. Pressure gauges and/or regulators maybe installed at the shore supply connection or at the connection point on the vessel.
b) In some cases, compressed gas is introduced into the tank vessel through a connection at the top of the tank feeding directly into the ullage space. In most cases, however, compressed gas is introduced into the tank vessel through the manifold or pump stack upon completion of the line clearing operation. The latter practice invites larger volumes of compressed gas at a given pressure and, therefore, creates a higher risk.
c) The compressed gas line should be fitted with a valve that can be closed / shut down by tank vessel personnel when the tank reaches a designated pressure.
d) Pressure gauges and sensors when fitted are closely monitored during the operation by the vessels crew.

e) Personnel monitor valves at the compressed gas connections on shore and at the vessel throughout the operation. The vessel PIC supervises the operation and maintains direct communication with the shore PIC throughout the operation.
f) The compressed gas supply valve is closed and the operation complete when the tank vessel pressure gauge indicates an arbitrary positive pressure that is less than the P/V relief valve setting.

2.1 Padding Hazards: Current procedures primarily call for operator intervention to ensure a safe operation. Monitoring equipment, such as pressure gauges and alarms, along with the insertion of supply flow rate restrictions, such as orifices, typically serve as secondary means for ensuring a safe operation. Given these conditions, the principle hazards during a padding operation are:

a) Tank overpressurization may result if the supplied volumetric flow of gas into the ullage space exceeds the maximum venting capacity of the P/V relief valve.
b) Contamination of VCS with liquid cargo and cargo overflow may result when dealing with viscous cargoes in which gas can form large bubbles that displace cargo through the vent risers.
c) Product can be blown into the P/V relief valve and freeze or block the system.
d) Personnel may be exposed to liquid cargo or cargo vapors if tank integrity is lost.
e) The valve at the supply side or manifold valve may inadvertently open or close due to pressure or vibration if unattended. The manifold valves are designed for liquid flow and are largely ineffective as a means to control gas flow.

3.0 Line Clearing (with or without pig) Procedures:

a) Topics such as gas volumes, pressures, method of line clearing, volume of residual cargo in the line, and the amount of ullage space that is available for the line displacement are discussed during the pre-transfer conference. The tank venting capacity is calculated based on the P/V relief valve size.
b) The manifold valve is closed at the completion of the loading operation and is not opened until the commencement of the line clearing operation. At the beginning of the line clearing operation, the pump stack or tank valve is opened. Then the manifold valve is opened and manually throttled (opened and closed repeatedly) to control the operation.
c) The vessel personnel controlling the manifold valve maintain direct communication with dock personnel during the entire line clearing operation.
d) The manifold valve is throttled in short bursts during the line clearing operation to facilitate the clearing process and in an effort to control the pressure in the tank. The manifold valve is never fully opened. Between bursts of compressed gas, the pressure in tank is allowed to equalize/dissipate. The type of manifold valve influences the quality of control during the line

clearing operation. Ball valves are more effective than butterfly valves when attempting to manually control the flow rate of compressed gas.

e) Lifting hoses, tapping lines, and feeling for "hot" cargo are methods used to indicate how well the line clearing operation is proceeding.

3.0.1 Line Clearing (with pig only) Procedures:

a) All procedures outlined in the preceding line clearing section apply to this section as well.
b) Once the pig reaches the pig trap there is a surge or sudden movement in the cargo line and the sound compressed gas passing through the line is often heard. At that time, the manifold valve is immediately closed. The shore operator typically communicates with the vessel when his sensors indicate that the pig has been caught.

3.1 Line Clearing Hazards: Current procedures primarily call for operator intervention to ensure a safe operation. However, some pig catcher designs allow the pig to seal the line, creating a "snug fit", preventing gas form entering the tank. Given these conditions, the principle hazards during a line clearing operation are:

a) Tank overpressurization may result if the volumetric flow of gas into the ullage space exceeds the maximum venting capacity of the P/V relief valve.
b) Contamination of VCS with liquid cargo and cargo overflow may result when dealing with viscous cargoes in which gas can form large bubbles that displace cargo through the vent risers.
c) Product can be blown into the P/V relief valve and freeze or block the system.
d) Personnel may be exposed to liquid cargo or cargo vapors if tank integrity is lost.
e) The pig may not form a perfect seal with the line as it travels thereby allowing gas to "blow by" into the tank.
f) Improperly made up lines may cause the hoses to blow off and injure personnel.
g) Residual pressure, which typically remains in the system, must be bled off prior to disconnecting the lines. Blocked drains may lead personnel to erroneously think that this residual pressure has been relieved when, in fact, it has not.
h) The pig may be damaged during the pigging operation. In some cases the pig may disintegrate and allow the full flow of gas to enter the tank.
i) The pig may become lodged in the line during the pigging operation. This invites shore personnel to increase the gas pressure or insert additional pigs.
j) In most systems that contain a pig trap, there are no mechanical devices in place to prevent the full flow of gas from entering the tank after the pig lands in the trap. Inattentiveness and communication failures when the pig enters the trap can lead to tank overpressurization.
k) Some tanks are outfitted with restrictive gauging (sounding pipes). It is common for gas to enter these sounding pipes during a pigging operation.

Excessive pressure in these sounding pipes may lead to product release when accessed by personnel (surveyors).

4.0 Loading from Railcar Procedures:

a) Topics such as gas volumes, pressures, line sizes, and method of communication are discussed during the pre-transfer conference. The tank venting capacity is calculated based on the P/V relief valve size. Railcar volumes are typically between 70-80 m^3. Pressures are typically between 35-100 psig. Transfer lines are typically 3-4 inches in diameter. The method of communication is particularly important when loading a marine vessel from a railcar since rail racks are generally not visible from the vessel. The three railcar types in use today are:

- General purpose (35 psig)
- Standard (75-100 psig)
- LPG (100+psig)

b) In most cases, cargo is “pressed out” of the railcar, by the introduction of compressed gas through a fitting at the top of the railcar, through the discharge line to a pump or directly to the marine vessel. The use of a pump reduces the required pressure applied to the railcar. Pressures typically range from 10-15 psig (with pump) to 30-40 psig (without pump).
c) Multiple railcars are generally discharged simultaneously with finish times staggered based on the railcars proximities to the collection manifold or pump.
d) Railcars have one or more operators (depending on the number of railcars) monitoring the operation. The operator monitors the discharge progress by checking the rail car springs, listening for the sound of compressed gas passing though the lines, listening for irregularities in the pump (if used), inspecting sight glasses, and monitoring pressure gauges. Once a railcar is empty, the valve to that car is closed.

4.1 Loading from Railcar Hazards: Current procedures primarily call for operator intervention to ensure a safe operation. The use of a pump allows for reduced pressure at the railcar without sacrificing time since a pump reduces the pressure drop between the rail rack and marine vessel. Given these conditions, the principle hazards during a padding operation are:

a) Tank over-pressurization may result if the compressed gas supply is not shut off once the railcar is empty and the volumetric flow of gas into the ullage space of the marine tank vessel exceeds the maximum venting capacity of the P/V relief valve.
b) Contamination of VCS with liquid cargo and cargo overflow may result when dealing with viscous cargoes in which gas can form large bubbles that displace cargo through the vent risers.
c) Product can be blown into the P/V relief valve and freeze or block the system.

d) Personnel may be exposed to liquid cargo or cargo vapors if tank integrity is lost.
e) Railcars are often handled in staggered fashion. Thus, if one railcar is becomes empty prior to the others, compressed gas may inadvertently enter the marine vessel unchecked through the empty railcar while the remaining railcars continue to be pressed out.
f) If pumps used are not of the positive displacement type (ie. centrifugal), they may allow compressed gas to pass into the marine tank vessel.
g) Excessive pressure in sounding pipes, on tanks with restrictive gauging, may lead to product release when accessed by personnel (surveyors).

Long Term Task (Due March 2002)

Provide recommendations for the development of an industry standard to address the prevention of cargo tank overpressurization during inerting, padding, purging, line clearing, and railcar transfer operations.

Areas of Emphasis

Subcommittee discussions regarding ways to prevent cargo tank overpressurization have focused on the following three areas:

1. Mechanical Safeguards (control at the source)
2. Operational Procedures
3. Education

Criteria for Evaluating Potential Solutions

Members of the Subcommittee have agreed that all potential solutions should be evaluated based on the following criteria:

1. Solution should not release additional unauthorized cargo vapor or have negative effect on the environment. During inerting, padding, purging, line clearing, and railcar transfer operations, P/V valves are designed for loading operations and are considered secondary or tertiary method of protection, not the primary method of protection from over-pressurization.
2. Solution should not create additional hazards, but should provide 'failsafe' solutions.
3. Economics should be considered. Specifically, the cost to implement the solution and any costs incurred by changing current operations (ie. slowing pace) should be considered.
4. Ideally there should be one standard that applies to all operations, which should utilize standard fittings on the vessel and shore.
5. Solution should include mechanical safeguards that are effective at controlling **gas** flow rates (not just liquid flow rates).
6. The level of difficulty in implementing the solution should be considered.

It should be noted that throughout this document, the words nitrogen, compressed nitrogen, and compressed gas have been used interchangeably. In many operations, compressed air or other gases may be used instead of nitrogen. Thus, although nitrogen is the gas that is most commonly used during inerting, padding, purging, line clearing, and railcar transfer operations, the information presented in this document applies when using any compressed gas.

Marine Operations Risk Assessment Guide - Background

At the Fall 2001 CTAC Meeting, the Prevention Through People (PTP) Subcommittee Chairperson suggested that the Marine Operations Risk Assessment Guide be used by this Subcommittee to aid in the completion of the long-term task statement. This Subcommittee agreed to use the process described in the risk guide to review current industry practices and generate recommendations. Although there are different practices and equipment being employed throughout industry, the operations are sufficiently common to allow fair assessments to be made. Many of the participating facilities have established procedures and/or installed equipment to manage the risk of accident when using high-pressure gases.
The Marine Operation Risk Assessment Guide uses the following ten steps process to:

1. Problem Definition. The Task Statement.
2. Selection of Experts. The Subcommittee.
3. Hazard Identification. The Subcommittee developed flow charts for the purging, line clearing and loading from railcars operations and them 'brainstormed' which hazards could occur during each step in the operations.
4. Probability Assignment. The Subcommittee used a scale from 1 (remote) to 5 (frequent) and subjectively assigned values to identified hazard.
5. Consequence Assignment. The subcommittee used a scale form 1 (negligible) to 5 (catastrophic) and subjectively assigned values to each identified hazard.
6. Calculation of Relative Risk. The Probability Assignment and Consequence Assignment values were multiplied. Highest-ranking hazards were then identified for continuing the process.
7. Development of Countermeasures. The Subcommittee 'brainstormed' counter measures for the highest risk hazards.
8. Estimation of Benefits. The Subcommittee used a scale of 1 (low) to 3 (high) and subjectively assigned values to each countermeasure.
9. Estimation of Cost. The Subcommittee used a scale of 1 (low cost) to 3 (high cost) and subjectively assigned values to each countermeasure.
10. Benefit-Cost (Value) Analysis. Estimation of Benefit value was divided by Estimation of Cost value. The higher the Benefit-Cost value, the better the countermeasure.

Marine Operations Risk Assessment Guide – Gathering Data

The Subcommittee reviewed each operation in detail. Process flow charts for purging, pigging, and loading from railcar operations are included in the appendices. The tables shown in this section list the high-risk steps associated with the use of compressed gas in each operation. In general, any step that could lead to a vessel tank overpressurization was deemed high-risk. The corresponding Benefit-Cost ratios range from 0.5 (marginal benefit for the cost) to 3 (high benefit for the cost). It is important to note that just because a particular item has a low Benefit-Cost ratio doesn't mean that it should not receive further consideration. An item with a high benefit value and a high cost, for example, will have a relatively low Benefit-Cost ratio. In such a case, the value added may very well be worth the cost.

Inerting / Purging / Drying

1. Failure to communicate: Although all participants noted that pre-transfer conferences are being conducted, it was felt that many conferences lacked with regard to discussions about personnel roles, identification of tanks being purged, connections, units of measure, gas flow rates, agreed upon pressure and gas volume, tank volume, and calculated time (duration) of operation. Language barriers have also been sited as factors in several overpressurization incidents.

Abatement Measure	Benefit-cost rating
ID critical equipment and awareness of all parties	3
Use of radios	3
Common language & terminology	3
Add to the DOI / pre-transfer checklist	2
Make specific written procedures	2
Training	1.5

2. Tank openings and lining up the operation: Vessel staff must ensure that there is sufficient venting capacity, that the correct number of vents are opened, and that the openings are of sufficient size. The P/V vents are designed for gas flow at 125% of the maximum load rate. Therefore, P/V vents will not provide adequate protection, even as a secondary or tertiary method of protection.

Abatement Measure	Benefit-cost rating
Correlate tank openings size vs. hose sizes & pressures	3
Create a ship specific table (hose size/pressure/opening size)	3
Use of regulators	1.5
Conduct training	1.5
Use of pressure gauges	0.5

3. Start-up: Vessel and shore personnel must not fully open valves until all verifications are made (e.g. lineup confirmed, alarms and sensors tested satisfactorily, gas confirmed to be flowing to correct tanks, etc.). Both vessel and shore personnel must acknowledge all verifications and agree to continue opening valves before doing so.

Abatement Measure	Benefit-cost rating
Conduct general training	1.5
Conduct specific training	1.5
Use proper valve (i.e. ball or gate – not butterfly)	1
Ensure adequate personnel (number and qualifications)	1
Eliminate distractions	0.5

4. Monitoring the operation: Vessel personnel must either monitor tank pressures or ensure adequate venting is provided during purging operations.

Abatement Measure	Benefit-cost rating
Create procedures for multi vs. single tank operations	2
Establish target times	1
Use pressure gauges and sensors	1
Install automatic shutdown devices	1
Establish periodic communications schedule	1

Padding / Blanketing

The Subcommittee agreed that these operations should be avoided except when, due to the inherent nature of the cargo, an additional nitrogen pad is required. If necessary, vessel or shore supplied (low volume / pressure) nitrogen with regulated pressure and flow may be introduced into the tank. The nitrogen must be introduced into the top of the tank and not blown through the pump stack or drop line.

Line Clearing / Pigging

1. Pre-transfer conference: Many pre-transfer conferences are inadequate because they lack discussions about personnel, equipment, connections, valve alignments, event sequence, pressure, volume, N2 flow rate, stop time, etc. Occasionally pig catchers are not added to the system due to communication failures.

Abatement Measure	Benefit-cost rating
Conduct training	3
Develop procedures / require use of forms	3
Test radios	3
24 Hr check of sensors and alarms	3
Periodic testing	3

2. Failure to detect arrival of pig by sound and pressure drop: If the pig enters the trap unnoticed, compressed gas is likely to enter the vessel tank at full flow.

Abatement Measure	Benefit-cost rating
Training	3
Develop procedures	3
Ensure proper pig selection	2
Install by-pass line / restrictive orifice	1.5
Do not pig to vessel / use isolation tank	1
Use self sealing pigs	1
Install pig signal (flag)	0.5
Install excess flow check valve	0.33

3. Failure to close shore/by-pass valve: Failure to immediately close the shore/by-pass valve after the pig enters the trap may allow compressed gas to enter the vessel tank at full flow.

Abatement Measure	Benefit-cost rating
Training	3
Develop procedures	3
Install pressure indicators on both sides of the pig trap	1
Use pig sealing device	1
Install auto closing valve	0.66
Install pressure sensor on vessel connected to shore	0.33

4. Failure to secure ship/shore manifold valve: Inadvertent openings/leaks could result in uncontrolled operations.

Abatement Measure	Benefit-cost rating
Training	3
Develop procedures	3
Use radios	1.5
Install valve indicators	1
Use interlocks	0.33

5. Insert pig improperly or insert the wrong size / type pig: Improperly inserting a pig our inserting a pig that is incompatible with the system may result in compressed gas blowing by the pig into the vessel tank.

Abatement Measure	Benefit-cost rating
Training	3
Develop procedures	3
Pig selection / inspection	3
Install pig guides in launcher / trap	2

6. Fail to verify movement of the pig: Movement can be verified by listening for the pig in the line and through valves). If the pig is not moving, compressed gas is likely to ‘blow by’ into the vessel tank.

Abatement Measure	Benefit-cost rating
Training	3
Develop procedures	3
Listen to sound of flow	3
Monitor pressure	3
Use smart pigs	0.33

7. Improperly work the vessel manifold valve during line clearing: Failure to properly work (open & close) the vessel manifold valve can result in an undesirable pressure build-up in the line.

Abatement Measure	Benefit-cost rating
Training	3
Develop procedures	3
Monitor pressure	2
Ensure correct type valve used	1

Loading from Railcars

1. Failure to 'pinch back' on the rack valve: Failure to pinch back on the rack valve (leaving it slightly open) while stripping the railcar may allow surges of compressed gas to enter the tank vessel.

Abatement Measure	Benefit-cost rating
Develop procedures	3
Training	1.5
Install sight glasses	1.5
Install phase indicator (ultrasonic or resistance)	1
Rely on railcar springs / level indicator	1
Use pumps to reduce N2 pressure	1
Increase attendance (ratio of people to cars)	0.67
Install orifice on the liquid side	0.67
Install pressure sensor on the vessel with auto shutdown	0.33

2. Failure to monitor flow rate, pressure, volume, and temperature during transfer: If the railcar becomes empty unbeknownst to those monitoring the operation, compressed gas may enter the tank vessel unchecked.

Abatement Measure	Benefit-cost rating
Develop procedures	3
Training	1.5
Install sight glasses	1.5
Install phase indicator (ultrasonic or resistance)	1
Rely on railcar springs / level indicator	1
Use pumps to reduce N2 pressure	1
Increase attendance (ratio of people to cars)	0.67
Install orifice on the liquid side	0.67
Install pressure sensor on the vessel with auto shutdown	0.33

3. Failure to hold an adequate pre-transfer conference: Failure to discuss and agree upon personnel roles, equipment, connections, pressure, volume, flow rates, and stop time may result in overpressurization.

Abatement Measure	Benefit-cost rating
Develop / use checklists	2
Audits and management oversight	0.67

4. Improperly perform open vent line up (open loading): Failure to open all appropriate vents or hatches places the vessel at risk of overpressurization.

Abatement Measure	Benefit-cost rating
Training	1.5
Audits and management oversight	0.67
Place sensors on vents	0.33

5. Improperly perform closed vent line up (closed loading): Failure to test P/V valves on the vessel may result in the use of a damaged or inoperable P/V valve that is ineffective at protecting the vessel tank from overpressurization.

Abatement Measure	Benefit-cost rating
Training	1.5
Audits and management oversight	0.67
Place sensors on vents	0.33

6. Failure to verify that flow is going to the correct tank. Failure to inspect hose line-ups and the tank vessel connection may result in compressed gas entering the wrong tank.

Abatement Measure	Benefit-cost rating
Develop procedures	3
Training	1.5
Use valves with automated sensors	1
Audits and management oversight	0.67

7. Connect hoses incorrectly or use wrong line: May result in unexpected volumetric flow.

Abatement Measure	Benefit-cost rating
Code lines	3
Ensure knowledgeable person in change	3
Training	1.5
Install locking system in flanges	1

8. Exceed agreed upon pressure and/or volumetric flow: When pressure / volume may be inadvertently supplied in excess of what dock personnel expect.

Abatement Measure	Benefit-cost rating
Discuss and pre-transfer conference	3
Develop procedures	3
Install N2 regulators	1.5
Set alarm limits	1
Audits / management oversight	.67

Marine Operations Risk Assessment Guide – Results and Analysis

Lack of communication was identified, for each of the practices reviewed, as being a primary contributor to vessel tank overpressurization incidents. It was noted that the pre-transfer conference is the appropriate time for vessel and shore personnel to exchange relevant information concerning each operation that they plan to perform. Key information that should be exchanged during a pre-transfer conference for inerting, padding, purging, line clearing, and railcar transfer operations includes, but is not limited to: roles of personnel, identification of tanks in use, connections, units of measure, maximum volume, maximum pressure, timing, equipment limitations, event sequence, emergency signals and procedures, and anticipated stop time. Many lengthy operations require a shift change in personnel prior to the completion of the operation. It is vitally important that the relieving shift be fully briefed before assuming responsibility for the operation. In addition to discussions at the pre-transfer conference, dock and vessel Persons in Charge (PIC) must discuss all critical operations before they commence.

The act of continuously monitoring each operation as it unfolds was also identified as a key step in preventing vessel tank overpressurization. Specific equipment and events that should be monitored during the various operations include, but are not limited to: tank pressure, valve integrity, P/V valve performance, pig movement, the possibility of 'blow-by', regulator settings, and cargo levels in railcars. An adequate number of experienced personnel must be present during these operations to ensure that all of the equipment used to protect the tank vessel from overpressurization is functioning properly, the system is properly lined up, and proper connections are made.

During this Subcommittee's first meeting, three areas of emphasis were identified and subsequently used to categorize all recommendations that were made to prevent overpressurization. Some of the key recommendations that were made while the Subcommittee was engaged in the Marine Risk Assessment Guide process were:

1. Mechanical Safeguards: Install and/or use pressure gauges, pressure indicators, pressure sensors, gas flow regulators, valves suitable for controlling gas flow, valves suitable for controlling liquid flow, automatic shutdown devices, pigs that seal in the pig trap, orifices that provide flow limitation, alarms, interlocks, sight glasses, phase indicators, and level indicators.

2. Education (training): Ensure all personnel thoroughly understand pre-transfer procedures, hazards of the operations, gas laws, proper use of equipment, how to monitor operations, emergency procedures, how to deal with equipment malfunctions (e.g. freeing a pig that is stuck in the line), and record keeping.

3. Operational safeguards: Ensure that an adequate number of experienced and trained personnel are participating in all operations. Ensure accurate written procedures are available to all involved personnel. The written procedures should be available for all operations that involve the use of high-pressure gas and they should address safety, equipment, and overpressurization hazards.

Some of the Subcommittee members expressed concern about adding to the volumes of written procedures that already exist in the vessel and shore communities. The Subcommittee, while not desirous of adding to the bulk of written information already in existence, recommends that companies review existing procedures, with the findings of this Subcommittee in mind, and make their procedures simple yet comprehensive in describing the important steps in operations involving compressed gases.

Recommended Practices

Inerting / Purging / Drying

1. Topics such as personnel roles, identifying tanks to be purged, gas volumetric flow rates (max and min), pressures, method of line clearing, volume of residual cargo in the line, the amount of ullage space that is available for the line displacement, equipment to be used, connections, valve alignment, event sequence, units of measure, language / terminology, and anticipated stop time must be discussed during the pre-transfer conference.

2. Adequate venting capacity on the vessel must be provided to safely vent tanks at the agreed upon maximum flow rate of the gas based on the shore supply pressure and volume. The necessary tank venting capacity must be determined or calculated based on the pressure of the compressed gas and the size of the compressed gas supply hose. A pre-calculation table can be made for each tank to simplify subject matters for personnel. Applicable industry guides or the tables found in the appendix can be used as well.

3. Once the maximum venting capacity is determined, the shore supply must be regulated to less than the agreed upon flow rate. Pressure gauges and/or low-pressure / high-flow regulators must be installed at the shore supply connection. The supplier of the compressed gas must not exceed the vessel's venting capacity. Radios capable of communication between shore and vessel PICs must be used.

4. All persons should be evacuated from the vessel tank. The tank should be tagged or otherwise marked as "NOT SAFE FOR ENTRY".

5. The tank to be purged should be empty of all cargo. An adequate number (size) of vents, hatches, and valves should remain open to the atmosphere until the purging operation is complete. Pressure sensors/alarms (if equipped) on the tank vessel should be placed in operational mode. A responsible person should check all vents, openings and alarm/sensors prior to startup.

6. The compressed gas line should be connected to the appropriate vessel's manifold under the supervision of a responsible person. If multiple tanks are to be purged at once, proper lineup must be verified.

7. The tank should be "taped off" or otherwise marked with warning tape. All personnel in the vicinity of the tank vessel must be made aware of the inerting operation and instructed to remain clear of the open hatch areas.

8. The operation should begin slowly at a volumetric flow rate that is well below the P/V relief valve setting. Once the tank vessel personnel have confirmed that the system is functioning properly, and gas is flowing to the correct tanks. The volumetric flow of gas can be increased to the previously agreed upon maximum

rate. The pressure and volumetric flow rate of the shore-supplied compressed gas must be regulated onshore so as not exceed the pressure and volume settings of the vessel's P/V valves.

9. Vessel personnel should monitor the pressure in the tank while purging and stop the operation maximum agreed upon pressure is exceeded or if one or more P/V valves open. In such a case, vessel personnel may immediately close the manifold or tank valve safely since there is no hammer effect with compressed gases.

10. The purpose of a vessel's manifold valve is to direct the flow of material into a specific tank. A manifold valve is simply inadequate as a means to control the flow rate of a compressed gas. Regulator valves, either on shore or on a vessel's manifold, are highly effective at controlling the flow rate of compressed gas.

11. Direct communication between shore and vessel personnel must be maintained throughout the operation. Effective communication is particularly important as the operation comes to an end.

12. Gas supply must be stopped prior to closing vessel valves. Vessel manifold valves should be closed on completion of purging.

Padding / Blanketing

This operation should be avoided all together by pre-purging an empty vessel cargo tank prior to conducting a closed loading operation. This effectively inerts the cargo tank and provides a pad without having to conduct a padding operation after loading. However, if the tank is opened to the atmosphere after loading, cargo quality is dependent upon an additional pad, or if customers insist on padding their cargo after loading, the pad should be supplied by the vessel or shore using a low volume / low pressure source (bottles of stored nitrogen). If a shore supply is used, it must be at pressure and volumetric flow rate less than the maximum capacity of the vessel's P/V valve. In any case, if padding does take place, the following procedures should be used:

1. Compressed gas should be introduced into the vessel tank through a connection at the top of the tank feeding directly into the ullage space. Compressed gas must not be introduced into the vessel tank through the manifold or pump stack since doing so invites relatively larger volumes (and higher pressures) of gas, thus creating increased risks of displacing cargo into the venting system and overpressurizing the vessel.

2. The compressed gas supply line should be fitted with a quick closing valve that can be closed by tank vessel personnel when the tank reaches a predetermined pressure.

3. Vessel personnel should closely monitor pressure gauges and sensors, when fitted, during the entire operation.

4. The operation is complete and the compressed gas supply valve must be closed when the vessel tank pressure gauge indicates an arbitrary positive pressure that is less than the P/V relief valve setting.

Line Clearing (without pig)

1. Topics such as personnel roles, gas volumetric flow rates, pressures, method of line clearing, volume of residual cargo in the line, the amount of ullage space that is available for the line displacement, equipment to be used, connections, valve alignment, event sequence, units of measure, language / terminology, and anticipated stop time must be discussed during the pre-transfer conference.

2. The tank venting capacity should be determined based on the P/V relief valve size. The vessel venting capacity must not be exceeded.

3. A regulator should be installed at the compressed gas connection line to control the volume of gas such that it is less than the vessel venting capacity. In some special cases (i.e. asphalt barges have small, undersized vent lines), the venting capacity may need to be exceeded to effectively clear the line. In these cases alternative means of preventing overpressurization must be used. Such alternative means may include using additional venting capacity, relying on gravity through the use of a crane to clear lines, or blowing lines back to the shore tank.

4. The manifold valve is closed at the completion of the loading operation and is not opened until the commencement of the line clearing operation. At the beginning of the line clearing operation, the pump stack or tank valve is partly opened. Then the manifold valve is opened and manually throttled (opened and closed repeatedly) to control the operation. The valve operator needs to listen for the sound of flowing cargo or gas in the line, and close the valve when a flow of gas is heard. An experienced operator should be in control of the valve during the line clearing operation.

5. The operator in control of the manifold valve must maintain direct communication with dock personnel during the entire line clearing operation.

6. The manifold valve is throttled in short bursts during the line clearing operation to facilitate the clearing process and to control the pressure in the tank. The manifold valve should never be fully opened. Between bursts of compressed gas, the pressure in tank should be allowed to equalize/dissipate. The type of manifold valve being used has a significant impact on the quality of control during the line clearing operation. Ball and gate valves are more effective than butterfly valves when attempting to manually control the flow rate of compressed gas.

7. Lifting hoses, tapping lines, and feeling for "hot" cargo are methods used to indicate how well the line clearing operation is proceeding. The pressure in the line must be allowed to 'bleed off' prior to disconnecting hoses.

8. In no case should the P/V vents be restricted or closed while line clearing to the vessel.

Line Clearing (with pig)

1. Topics such as personnel roles, gas volumetric flow rates, pressures, volume of residual cargo in the line, the amount of ullage space that is available for the line displacement, equipment to be used, connections, valve alignment, event sequence, units of measure, language / terminology and anticipated stop time must be discussed during the pre-transfer conference.

2. The system should be designed so that the pig seals in the line during the operation and in the trap once the operation is complete. A restrictive orifice sized to cargo venting capacity may also be used. Sensors and alarms may be installed to detect 'blow by' and pig disintegration. Sight glasses and operator monitoring personnel improve the ability of detecting problems in line clearing operations. Procedures must be in place to insure the correct pig (type and size) is used.

3. The system should be lined up with the vessel manifold valve closed. Responsible personnel should verify the lineup and ensure that all safeguards are operational.

4. The pig should be introduced at the pig launcher. Care must be taken to ensure that the pig is properly positioned in the launcher. The pressure should be equalized between the line and the pig launcher.

5. The vessel should open it's manifold valve part way. Compressed gas should be introduced into the launcher, behind the pig, to begin moving the pig through the line. Personnel should monitor the flow of cargo and the movement of the pig throughout the operation and communicate this information to each other. Once the pig enters the pig trap, the shore valve and vessel manifold valve should be closed immediately. The line and hoses from shore to vessel manifold should then be cleared directly as described previously.

Loading from Railcars

1. Topics such as personnel roles, identifying tanks to be purged, gas volumetric flow rates, pressures, volume of residual cargo in the line, the amount of ullage space that is available for the line displacement, equipment to be used, connections, valve alignment, event sequence, units of measure, language / terminology, and anticipated stop time must be discussed during the pre-transfer conference.

2. The tank venting capacity should be calculated based on the P/V relief valve size. The volume of gas should be calculated based on the size of the load line and pressure.

3. The method of communication is particularly important when loading a marine vessel from a railcar since rail racks are generally not visible from the vessel. The system should be designed to allow personnel to monitor the cargo volume remaining the railcar, monitor if gas or cargo gas mixture is flowing in the load line, and to allow for quick shutdown of the system.

4. Cargo should be “pressed out” of the railcar, by the introduction of compressed gas through a fitting at the top of the railcar. The cargo should pass through the discharge line to a pump or directly to a marine vessel. The use of a pump reduces the required pressure on the railcar and provides indication (by sound) to the operator if gas passes through. Otherwise, a phase detector or device to restrict the gas flow to less than the P/V capacity must be installed. Devices such as ultrasonic flow meters and resistant meters can detect gas flow and may be connected to alarms and automatic shutdowns.

5. Multiple railcars are generally discharged simultaneously with finish times staggered (normally started 15 minutes apart) based on the railcars in proximity to the collection manifold or pump.

6. Railcars should have sufficient operations personnel to ensure effective monitoring of the operation. The operator monitors the discharge progress by checking the cargo level in the railcar, listening for the sound of compressed gas passing though the lines, listening for irregularities in the pump (if used), inspecting sight glasses (if installed), and monitoring pressure gauges. Phase change sensors may also be installed at the railcar manifold to alert the operator of gas passing through the line. As the railcar transfer operation nears completion, the valve to that car is pinched closed. Once the railcar is empty or if gas passes into the lines, the gas valve and railcar valve must be immediately closed. Upon completion of the operation all vessel and shore valves should be closed.