CDOIF

Chemical and Downstream Oil Industry Forum

Guideline

Automatic Overfill Prevention Systems for Terminal Loading Racks

Foreword

In promoting and leading on key sector process safety initiatives, CDOIF has developed through its members a guideline on automatic overfill prevention systems for terminal loading racks.

It is not the intention of this document to specify the detailed design of overfill prevention systems, nor replace any existing corporate policies or design standards. The intent is to provide a reference for those organisations developing or wishing to review their existing terminal loading rack overfill prevention architectures.

There are no limitations on further distribution of this guideline to other organisations outside of CDOIF membership, provided that:

1. It is understood that this report represents CDOIF's view of common guidelines as applied to overfill prevention systems at terminal loading racks.
2. CDOIF accepts no responsibility in terms of the use or misuse of this document.
3. The report is distributed in a read only format, such that the name and content is not changed and that it is consistently referred to as "CDOIF Guideline – Automatic Overfill Prevention Systems for Terminal Loading Racks".
4. It is understood that no warranty is given in relation to the accuracy or completeness of information contained in the report except that it is believed to be substantially correct at the time of publication.

This guidance is not intended to be an authoritative interpretation of the law, however Competent Authority (CA) inspectors may refer to it in making judgements about a duty holders compliance with the law. This will be done in accordance with the CA's published enforcement policies (refer to www.hse.gov.uk/pubns/hse41.pdf) and it is anticipated that this document will facilitate a consistent national approach.

It should be understood however that this document does not explore all possible options for overfill prevention, not does it consider individual site requirements – Following the guidance is not compulsory and duty holders are free to take other action. If the duty holder does follow the guidance they will normally be doing enough to comply with the law. Health and Safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Contents

1. Executive Summary

A number of overfilling incidents have occurred during the loading of gasoline into road tankers. Overfilling has occurred due to the failure of people and equipment, resulting in an uncontrolled flow and significant quantities of gasoline being lost from containment[1]. In each case there were unrecognised deficiencies in the architecture of the loading system which were exposed by a single failure. The deficiencies in the loading system have included the inability of the emergency shutdown system to stop gasoline flow. The majority of these occurrences were due to failure of the flow control valve.

Personnel have been exposed to risks of serious injury during overfilling incidents due to their presence in the spill area. In some cases personnel have purposely entered the spill area during attempts to diagnose faults and to stop the flow of gasoline.

The target Audience for this document is primarily operators of fuel distribution terminals, including terminal managers, engineering managers, HSE/SHE managers, C&I and risk control engineers. Suppliers of equipment/packages and system integrators may also find the guidance provided in this document informative.

A working group was commissioned under CDOIF to develop a guideline for overfill prevention systems at terminal loading racks. This guideline is not intended to be prescriptive in defining the detailed design criteria for these systems, but aims to raise awareness within industry of existing good design practice, and highlight where appropriate key areas against which duty holders may review their existing systems.

A second working group was commissioned to look into hazard awareness of tanker drivers and terminal personnel during filling operations, the guidance for which can be found in the CDOIF publication entitled ‘CDOIF Guideline – Terminal Loading Operations Hazard Awareness’.

Note 1

Each tank compartment’s overfill prevention sensor is set to provide ullage of not less than 150 litres between the point of it being tripped and overfilling. This is to ensure that all the product passed by the gantry flow control valve from the triggering of the overfill prevention sensor until flow is ceased will be contained within the compartment (even if the event is triggered at the maximum flow rate)

Note that the overfill prevention system plays no part in ensuring that the tanker is not overloaded nor in ensuring that the maximum degree of filling (ADR 4.3.2.2) has not been exceeded

2. Scope

This document provides guidance on the architecture of loading systems for delivering gasoline into bottom loaded road tankers.

This guideline does not cover toxic hazards, fuels that are below their flash point at normal loading temperatures and atmospheric pressures, non ignition risks. This document does not comment on the safety integrity level (SIL) of any measure or system used to prevent the overfilling of road tankers, or the measures necessary to control risk during any recovery operation following an overfill. The need for, and definition of, any additional layers of protection should be completed as part of an operator’s standard design processes for hazard identification, risk assessment and SIL determination, where necessary.

For the purposes of this guidance overfilling means filling a compartment to the point that gasoline flows out of that compartment, for example into a vapour recovery system or through a pressure relief valve.

3. Overview

Overfilling can occur for a variety of reasons, including:

- filling a compartment that already contains gasoline that the driver is unaware of or does not take account of,
- filling the wrong compartment,
- failure of equipment intended to automatically stop gasoline flow.

Where a flow control (or metering) valve fails there is often very little time from the onset of the failure before the compartment overflows. This is because compartments have a limited ullage of about 5% (for transport), and because high flow rates can continue even if the pump has been turned off. The high flow may continue under flow control valve failure conditions because of the momentum of the flow in the pipe work, and the large liquid head arising from the tall supply tanks at many installations.

An example of an automated road tanker loading system can be seen in figure 1 below.

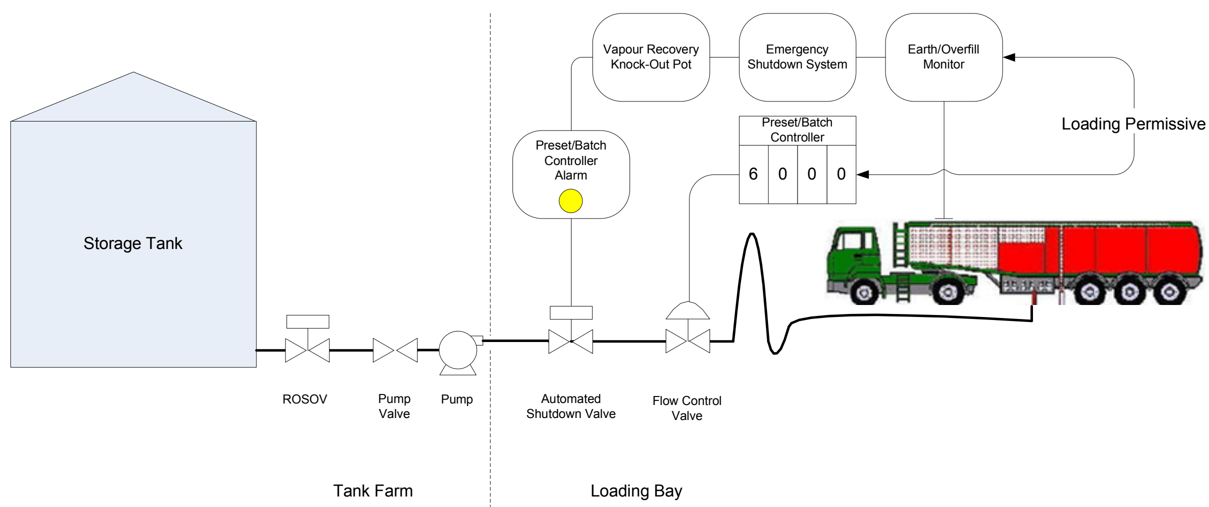

Figure 1 – Example road tanker loading system

3.1 Causes of Overfills

Flow control valves are generally considered to be reliable. However, flow control valves have failed to close when expected either because the flow control valve itself has failed, or because a pilot valve has failed. Valves have failed due to damage to elastomer materials as a result of changes in gasoline blends, due to the ingress of foreign material preventing closure, or due to physical wear. In each case the failure has been sudden; there were few clear signs of performance deterioration.

Many incidents have occurred because there is no automated shutdown valve. In these cases, a failure of the flow control valve has led to an uncontrolled flow of gasoline that can only be stopped by the closure of a manual isolation valve. This requires a fast response. Experience has showed that it is not realistic to expect overfilling to be prevented by a person closing a manual valve (see table 2 on the response times required).

A number of incidents have occurred even where there is an automated emergency shutdown valve that can close in the event of the failure of the flow control valve. This has been because the emergency shutdown valve was not triggered to close by the overfill event, the automated emergency shutdown valve closed too slowly, or the emergency shutdown valve was triggered too late to prevent an overfill.

Failure to trigger the emergency shutdown valve has been caused by a reliance on an overfill signal that may not occur in certain circumstances, such as a high liquid level in the vapour recovery line knock out pot.

A rule of thumb applied to valve closure speeds is that it takes approximately one second per inch diameter for a valve to close, but some valves may close more slowly than this. A limitation of the speed of closure is the ‘hammer’ effect caused by the momentum of the fuel which can increase pipe pressure to dangerous levels if the flow rate is slowed too quickly.

The emergency shutdown valve may be triggered too late for a number of reasons including where human action is relied on to quickly identify the developing overfill and respond.

3.2 Overfill Prevention System Goal

The goal of an overfill prevention system is self-evidently to prevent the overfilling of a road tanker or any of its compartments. In this context overfilling means exceeding the capacity of a compartment to the point that gasoline flows out of that compartment (including into the vapour recovery system). The extent to which overfill prevention measures are implemented is subject to formal risk assessment as described in section 4.

4. Risk Assessment

It is essential that the risks arising from all road tanker loading operations are assessed, and measures put in place to ensure these risks are, 'as low as reasonably practicable'. This includes any risks that may arise from potential component failures or design inadequacies in the engineering architecture. Risks may include risks to people, risks to installations, and risks to the environment.

4.1 Assessing the Suitability of Road Tanker Loading System Architectures

The adequacy of the measures used to control risks during filling operations should be assessed. This can be achieved by asking a number of questions regarding the architecture of a loading system.

1. Is the flow control valve, and any associated pilot valves, correctly specified for the function it is expected to perform? (refer to 4.1.1)
2. In the event of a failure of the flow control valve, is there an automated shutdown valve to stop gasoline flow? (refer to 4.1.2)
3. Is an automated shutdown valve triggered in response to identified faults or failures(refer to 4.1.3)
4. Is an emergency shutdown automated valve able to prevent or mitigate against overfilling of a road tanker, taking into account realistic scenarios? (refer to 4.1.4)
5. Are automated shutdown valves tested at a suitable frequency, according to specific criteria? (refer to 4.1.5)?
6. Are automated shutdown valves maintained according to appropriate instructions? (refer to 4.1.6)?
7. Are indications of failures recorded and assessed, and actions to address these taken? (refer to 4.1.7)

Any dependencies between risk control measures should be identified, and eliminated if possible. It is good practice to be able to detect the failure of a measure as soon as possible after it occurs, preferably by automated means, so that adequate risk control is maintained.

4.1.1 Specification of Valves

Site operators should document the design requirements for the different valves in the loading system, and should ensure suitable valves are installed. Design requirements should include compatibility with the gasoline being loaded and number of operations.

Valve failures have occurred due to;

- Excessive number of operations. Manufacturers produce specifications regarding the maximum number of cycles a valve should be expected to perform, depending upon the conditions the valve is operating under. For example, it is common for pilot valves to operate many times during each loading operation, and, if rate adjustment valves are not correctly set, for excessive pilot valve cycling to occur. Consideration should be given to the use of any extended diagnostic functionality that may be available.

- Product incompatibility. Valve failures have occurred because of incompatibility between gasoline and seal elastomers, so it is important that valves are suitable for the gasoline to which they are exposed (especially gasoline/ethanol blends with ethanol content, even as low as 5%). Further investigation on compatibility of materials used in handling ethanol and gasoline/ethanol blends has been undertaken by the Energy Institute, reference to the latest manufacturer's guidance on material compatibility should also be sought. Any significant change in gasoline formulation should trigger an assessment to verify valves continue to be suitable, and any remedial action required. This should be part of a suitable Management of Change process.

- Incorrect selection. Valves have failed because they have been incorrectly selected for use based on sales literature that was incomplete, not more detailed technical specifications. Personnel responsible for device selection should have a design requirement specification for each device, and the competence to assess the potential impact of any deviation.

- Incorrect pressure specifications. Whilst working pressures in many loading systems are relatively low, large pressure spikes may be experienced as a result of fast changing flow rates, such as those experienced towards the end of a filling operation.

Valve specifications should be archived so that they can be used by competent staff to select a new valve in the event of a replacement being required at some time in the future.

Spare valves in stock should be clearly labelled to ensure the correct replacement valve can be selected.

4.1.2 Automated Shutdown Valves

Correct specification, operation, and maintenance will reduce the risk of a flow control valve failure. However, the range of challenges to a particular flow control valve means this risk cannot be eliminated. An automated shutdown valve when triggered prevents uncontrolled flow of gasoline in the event of a failure of the flow control valve. Use of an automated shutdown valve has been shown to be a reasonably practicable way of managing this risk. A manually operated secondary valve has been shown to be ineffective in preventing overfill and loss of containment.

A means of regularly testing the required functions of the automated shutdown valve should be incorporated into the design, including the ability of the valve to actually stop liquid flow. Information on this is given in section 4.1.3.

4.1.3 Initiation of Automated Shutdown Valves

Automated shutdown valve closure should be initiated as soon as possible after a loss of control. Detection may be via a number of means, and a combination of means may be necessary to adequately control risk. Closure of automated shutdown valves may be initiated by several, or all, of the following;

- An alarm resulting from the preset/batch controller detecting a flow rate outside that programmed for the phase of loading
- An alarm resulting from the preset/batch controller detecting an overrun beyond the programmed amount
- A detection of high level in the road tanker
- An emergency shut-down button being pressed
- Gasoline detection in the vapour recovery system
- Action being taken from a remote location such as a control room

Other initiators may be available from a variety of engineered systems and human sources.

The initiator at the top of the list above is likely to provide the fastest response to a loss of flow control, and the initiator at the bottom of the list is likely to provide the slowest response. The overfill prevention system should be designed so the automated shutdown valve closure is initiated as soon as possible after the loss of flow control. This reduces the chance that gasoline will be lost from containment.

The initiators listed above depend upon a range of mechanical, electrical, electronic and programmable electronic systems. These should be effective for a range of different failure scenarios such as failure of the preset/batch controller electronics (that may have caused the loss of control in the first place), and variations in the mechanical arrangement of the vapour recovery system. Some measures, such as human responses, and desktop computers should not be expected to provide significant amounts of risk control.

The effectiveness of each initiator for automated shutdown valves should be tested on a regular basis using tests that confirm the correct operation of as much of the system as possible. More frequent partial checks may be appropriate where more complete tests are intrusive.

Effective management processes should be in place to ensure the operability and continued maintenance of the high level probe in each road tanker compartment which is connected to the earth/overfill monitor. Management processes may include participation in a scheme which aims to control the hazards associated with road tankers when they are loaded at distribution terminals such as the Safe Loading Pass Scheme, or other similar initiatives.

4.1.4 Effectiveness of Emergency Shutdown Valves

Emergency shutdown valves should be effective in preventing a loss of containment when triggered by an engineered system such as the high level detection system in the road tanker. This should take into account the time between the loss of flow control, to the flow reaching zero. An example of timings is shown in figure 2.

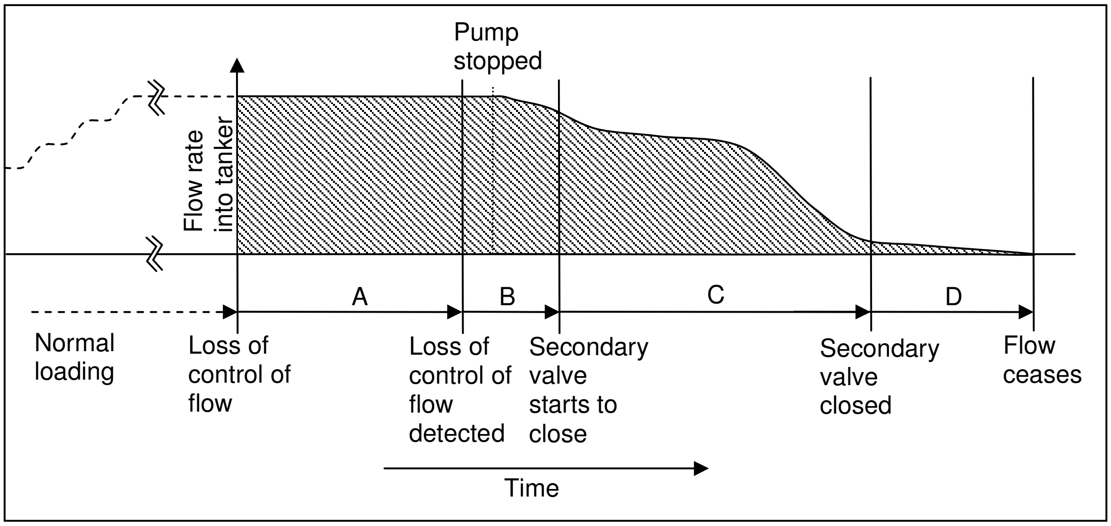

Figure 2 – Time to stop flow on loss of flow control

Definition of times:

A. Time between loss of control and detection of the loss of control.

B. Time between the detection of the loss of control and closure initiation of the automated shutdown valve. This includes any delays caused by logic.

C. Time that the automated shutdown valve takes to close. A rule of thumb is one second per inch diameter of the valve, but certain automated valve types may take longer.

D. Time between the emergency shutdown valve becoming fully closed, and cessation of all flow.

The total time to stop flow using the automated shutdown valve after a loss of flow control is A+B+C+D. The exact timing of each of the components A, B, C, and D will depend upon the configuration of the loading system, and what has led to the loss of flow control. Refer to appendix 1 for examples of factors that may influence response times.

4.1.5 Testing of Valves

Valves should be tested at a frequency that is appropriate, according to the extent that the valve is being relied upon for risk control. Test frequencies should be set so that there is little chance of valves failing between two tests.

Valve tests should cover as much of the functionality of the valves as possible. This may include speed of response and the actual ability of the valve to shut against an upstream pressure.

Some valve functions may be automatically tested during their cycling in normal operation through a control system. This may significantly improve confidence that the valve will continue to perform correctly, and a failure may trigger a very early response that may minimise risk.

Where there are indications of deterioration of a valve, action to correct the fault should be taken. The frequency of tests should be managed, and may need to be changed in response to a significant number of test failures.

Valve test records should be kept as part of the maintenance process providing evidence of the tests conducted, results of the test and any remedial actions carried out.

4.1.6 Maintenance of Valves

Valves should be maintained according to the specification from the manufacturer. In addition, certain aspects of maintenance may be specified locally, in order to manage risks. Locally originated maintenance should be specified by a person who is competent, who may need to liaise with the valve manufacturer regarding the particular valve usage.

Valves have failed because:

- Maintenance has not been carried out
- Maintenance has as not been carried out correctly
- Faults have been identified but not remedied

Personnel who maintain valves should be competent to do so, and should know when to refer difficulties to other personnel with the appropriate knowledge and skills for correction. Senior staff should be competent to direct others such that the risk is adequately managed.

4.1.7 Management of Risk

Risks must be managed using appropriate means, and should be regularly re-assessed. It may be necessary for indications of failures to be recorded and assessed, so changes can be made to prevent failures that could lead to overfills.

5. System Design and Operation

The following sections provide a high level overview of the equipment that may form part of an overfill prevention system for a terminal loading rack, and the interactions between those components as part of an overall control philosophy.

Note that this represents one design philosophy; it should not be considered as the only or the preferred solution. This will be dependent on the individual site requirements, and in consideration of the risks and appropriate measures discussed in section 4.

5.1 Overfill Prevention System Equipment

Typical equipment that may be incorporated into a loading rack control and overfill prevention system is provided below. Reference should be made to figure 1, Example road tanker loading system contained in section 3.

1. **Loading Rack Control System** – the loading rack control system is the PLC/SCADA system which provides control operation for the terminal or the loading rack, or both. In some instances, interlocks and permissives may be hardwired via relays, and not via the loading rack control system. Where risk assessment has determined that the overfill prevention system requires a further layer of protection, this functionality may be provided by an independent safety related logic solver.

2. **Electronic preset/batch controller** – the system which controls loading operations. The electronic preset/batch controller accepts earth and overfill interlocks (hardwired from relays or via the loading rack control system), which provides a permissive for pump demands, flow control and controls flow rates. The electronic preset/batch controller should prevent or stop loading on loss of interlocks or on detection of abnormal conditions (such as high or low flow, batch quantity overrun)

3. **Earth/overfill monitor** – the system monitors tanker earth integrity and tanker overfill detectors. Outputs from the monitor should be hardwired via relays or via the loading rack control system, providing the interlock signal to the electronic preset/batch controller, and allowing automatic closure of the automated shutdown valve(s). Faults detected on the monitor should allow unit to fail safe.

4. **Flowmeter** – connected to the electronic preset/batch controller to provide flow signal. Typically the flowmeter type will be positive displacement or turbine.

5. **Flow control valve** – connected to the electronic preset/batch controller, controls flow rates and stops/starts the batch flow.

6. **Vapour knockout pot high level detector** – monitors fluid level at lowest point in vapour system as close as possible to the tanker vapour hose/arm. The signal should be hardwired from relays or via the loading rack control system providing the interlock signal to the electronic preset/batch controller, and allowing automatic closure of the automated shutdown valve(s).

7. **Emergency shutdown pushbutton** - hardwired via relays or via the loading rack control system, providing the interlock signal to the electronic preset/batch

controller, and allowing automatic closure of the automated shutdown valve(s). Faults detected on the pushbutton, or loss of power should allow unit to fail safe.

8. **Automated shutdown valve(s)** – the automated shutdown valve should automatically close on detection of fault conditions, either through hard wired relays or from the loading rack control system. The automated shutdown valve should ideally be located at ground level on loading bay. There may be one valve per arm, or one valve per grade depending upon the individual site requirements. The automated shutdown valve may be either motor, hydraulic or gas operated and should be fail safe closed under fault/loss of power condition.

5.2 Overfill Prevention System Control Philosophy

Reference should be made to the simplified cause and effect diagram provided in figure 3 as an example control philosophy for overfill prevention.

Note: automated shutdown valve may be per bay or per grade

	Close FCV - Bay A	Close FCV - Bay B	Close FCV - Bay C	Close S/D Valve - Bay A	Close S/D Valve - Bay B	Close S/D Valve - Bay C
Meter Overrun - Bay A	X					
Meter Overrun - Bay B		X				
Meter Overrun - Bay C			X			
Earth/Overfill Monitor - Bay A						
Loss of Earth Signal	X					
High Level Detected	X			X		
Earth/Overfill Monitor - Bay B						
Loss of Earth Signal		X				
High Level Detected		X			X	
Earth/Overfill Monitor - Bay C						
Loss of Earth Signal			X			
High Level Detected			X			X
Vapour K-O Pot High Level - Bay A	X			X		
Vapour K-O Pot High Level - Bay B		X			X	
Vapour K-O Pot High Level - Bay C			X			X
Site ESD Initiated	X	X	X	X	X	X

Figure 3 - Simplified cause and effect diagram

Note that pumps have been excluded from the cause and effect diagram in figure 3. Determining what action to take for pumps should form part of the risk assessment and design process.

1. **Electronic Preset/Batch controller** – a healthy earth/overspill interlock from the earth/overfill monitor provides a healthy permissive signal allowing pump demand

and flow control valve outputs. Loss of the interlock removes the permissive and stops flow by closing the flow control valve. Depending on the preset/batch controller type, various internal parameters (for example high/low flow, additive high/low flow, loss of flowmeter pulses) can be configured to operate an internal alarm relay, which may be used to indicate "preset/batch controller overrun" and remove the permissive stopping flow by closing the flow control valve and/or closing the automated shutdown valve.

2. **Earth/overfill monitor** –

    a) Loss of the earth signal should remove the earth/overspill input from the preset/batch controller, hence removing the permissive signal and stopping flow by closing the flow control valve.

    b) Loss or activation of overfill signal should remove the earth/overspill input from the preset/batch controller, hence removing the permissive signal and stopping flow by closing the flow control valve. Additionally the overspill signal should close the automated shutdown valve(s) on the loading bay the overfill signal was generated on; all other loading bays can remain operational.

3. **Flow control valve** – the preset/batch controller will close the flow control valve on loss of earth/overspill signal, activation of preset/batch controller alarm relay (where available to indicate preset/batch controller overrun) or end of batch.

4. **Vapour knockout pot high level detector** – the vapour knockout pot high level should be part of the electronic preset/batch controller permissive. Activation of the high level detector should remove the permissive, thereby closing the flow control valve on that loading bay. Additionally the automated shutdown valve(s) on the loading bay that the knockout pot high level signal was detected on should close. All other loading bays can remain operational.

5. **Emergency shutdown pushbutton** – activation of any of the tanker loading bay emergency shutdown pushbuttons should remove the permissive for all electronic preset/batch controllers thereby closing the flow control valves and automated shutdown valves.

6. **Automated shutdown valve(s)** – automated shutdown valve(s) should close on activation of the road tanker overfill signal via the earth/overfill monitor, vapour knockout pot high level signal associated with that loading bay or activation of any terminal ESD pushbutton.

Abbreviations

Abbreviation	Description
CA	Competent Authority
C&I	Control and Instrumentation
CDOIF	Chemical and Downstream Oil Industry Forum
ESD	Emergency Shut Down
FCV	Flow Control Valve
HSE	Health, Safety and Environment; Health and Safety Executive
K-O	Knock Out
PLC	Programmable Logic Controller
ROSOV	Remotely Operated Solenoid Valve
S/D	Shutdown (Automated Shutdown Valve)
SCADA	Supervisory Control and Data Acquisition
SIL	Safety Integrity Level
SHE	Safety, Health and Environment

Glossary of Terms

Loading	Loading is synonymous with the ADR related term 'filling'
Flow control valve	The valve used to accurately meter gasoline into road tankers, sometimes referred to as a metering valve.
Automated Shutdown valve	The valve used to shutdown the flow of gasoline on detection of fault or overfill conditions
Gasoline	low flashpoint liquid fuel, also known as petroleum spirit or petrol, including where blended with ethanol, where there is a significant probability of flammable vapour present at normal loading temperatures and pressures.
Metering valve	See flow control valve.
Overfilling	For the purposes of this guidance overfilling is considered to be filling a compartment to the point that gasoline flows out of that compartment, for example into a vapour recovery line or through a pressure relief valve .
Overflow	The point at which a compartment is overfilled to the extent that the addition of more liquid will result in liquid beginning to flow out of the compartment.

Other Relevant Publications

Further information relating to road tanker installations can be found in the following publications.

1) HSG 176 [1998]
2) EI Model Code of Safe Practice - Marketing safety code [1978 – revised in 1998, and again in 2005.
3) EI Model Code of Safe Practice – Design, construction and operation of petroleum distribution installations [September 2005]
4) API RP 1004 [Eighth Edition, January 2003].

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0	All	First Issue	05-Jan-2011	PSD
1	All	Update following working group comments	04-Feb-2011	PSD
2	4.1.1	Update following CDOIF comments	06-May-2011	PSD

Appendix 1 – Examples of factors that may influence response times

Examples of factors that may influence the times;

A.
- Where the loss of flow control has been caused by a failure of the flow control valve and is detected in the preset/batch controller, and this detection feature has been correctly configured, time A may be short.
- Where the loss of control is detected by a high level detection in the road tanker, time A will be longer.

B.
- The time between the detection of the loss of control of flow and the initiation of the closure of the automated shutdown valve will normally be short. This time could be longer or may vary where there is significant electronic processing prior to the close signal being given, or where the initiation is delayed by, for example, the dumping of pneumatic pressure.
- The rate of flow will generally reduce after the pump is stopped. However, where a centrifugal pump (or other non positive displacement pump) is used, then any upstream pressure, such as that caused by fluid head in the storage tank, will continue to drive the gasoline at a constant flow rate. The flow rate will depend upon the upstream pressure and the diameter and configuration of pipe work and any orifices.
- Some preset/batch controller systems are designed to delay the stopping of the pump until the flow control valve has closed. Depending upon the exact arrangement, this may delay the stopping of the pump so this occurs later than shown on the diagram.

C.
- The speed of closure of the automated shutdown valve will depend upon its design and configuration. Larger valves generally take longer to close than smaller valves. Closing a valve too quickly can cause high pressures to be developed upstream of the valve, with the subsequent risk of damage that could lead to leakage.
- The momentum of the gasoline will tend to continue driving the gasoline out of the pipe work due to the initially high linear speeds of the gasoline at maximum loading rates.

D.
- This time between the complete closure of the emergency shutdown valve and the cessation of all flow will depend on the physical arrangement of the loading system and the road tanker. For example, fuel may enter the vapour recovery pipe work from the tanker vapour recovery manifold. A table of example pipe work capacities for pipe diameters and lengths is given in table 1.

The amount of gasoline stored in pipe work can be estimated using the following formula:

Volume (litres) = (Pipe diameter (inches) / 2 * 2.54)^2 * 3.14 * pipe length (metres) /10

Example volumes of pipe work are given in table 1

Pipe length (metres)	Pipe diameter (inches)						
	3	4	6	8	10	12	14
	Volume (litres)						
10	45.604	81.073	182.41	324.29	506.71	729.66	993.15
20	91.207	162.15	364.83	648.59	1013.4	1459.3	1986.3
30	136.81	243.22	547.24	972.88	1520.1	2189	2979.4
50	228.02	405.37	912.07	1621.5	2533.5	3648.3	4965.7

Table 1 – Liquid volume of pipe work (litres)

The total amount of gasoline that will flow into the road tanker, for the various detection routes, will be the area under the graph in figure 2, which will be unique for each loading arrangement. Whether the road tanker becomes overfilled, or gasoline is lost from containment depends on how much empty volume there is in the tanker compartment when the control of flow is lost, and whether gasoline flows into other unfilled compartments and the vapour recovery system. Experience has shown that whilst gasoline from an overfilled compartment does flow into other unfilled compartments, and into the vapour recovery line, it preferentially flows out of containment. Consequently, when estimating whether a configuration will be able to prevent a loss of containment, no claim should be made that gasoline can flow into other compartments or the vapour recovery system.

The time between the high level detection in a tanker compartment and overflow occurring depends on the size of the compartment, and the flow rate. Table 2 shows example times based on a range of flow rates and compartment sizes.

Flow rate after failure (litres/min)	Compartment size (litres)						
	7600	7000	6000	5000	4000	3000	2500
	Approximate remaining volume in compartment at high level detection point (litres) @ 95% full						
	380	350	300	250	200	150	150*
	Time to loss of containment after high level detection (seconds)						
2500	9.1	8.4	7.2	6.0	4.8	3.6	3.6
2200	10.4	9.5	8.2	6.8	5.5	4.1	4.1
1900	12.0	11.1	9.5	7.9	6.3	4.7	4.7
1700	13.4	12.4	10.6	8.8	7.1	5.3	5.3
1500	15.2	14.0	12.0	10.0	8.0	6.0	6.0
1200	19.0	17.5	15.0	12.5	10.0	7.5	7.5
1000	22.8	21.0	18.0	15.0	12.0	9.0	9.0
800	28.5	26.3	22.5	18.8	15.0	11.3	11.3
500	45.6	42.0	36.0	30.0	24.0	18.0	18.0
300	76.0	70.0	60.0	50.0	40.0	30.0	30.0

Table 2 – Time before overflow of a tanker compartment

* The minimum remaining ullage volume at the high level detection point is normally 150 litres.

Additional measures may have to be taken to prevent risks arising from gasoline entering the vapour recovery system. This document does not comment on these