Project Report Supplemental Information

Project No. CM-138-12-1

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Qualitative Risk Analysis

Qualitative Risk Analysis (Process Hazard Analysis) Overview

The study team members were guided through a systematic approach using guidelines set for in Standard Practice for System Safety, MIL-STD-882E, developed by the Department of Defense and a PHA-Pro™ template developed by AcuTech for the review. The review was conducted over two sessions – October 15, 2013 and December 16/17, 2013

The methodology used for the qualitative risk assessment is the Hazard and Operability (HAZOP) technique. HAZOP is a structured means of systematically reviewing the process to identify potential hazards, understand potential consequences and impacts, evaluate current safeguards, estimate the level of risk, and determine appropriate risk mitigation measures to reduce or eliminate the likelihood or severity of the hazards to a tolerable level of risk. HAZOP is recognized as an accepted methodology by industries and regulatory agencies worldwide. This includes both OSHA PSM (29 CFR §1910.119[e]) and EPA RMP (40 CFR Part 68) regulations in the United States, as well as Seveso II Directive; Control of Major Accident Hazards (COMAH); IEC 61511; ANSI/ISA S84.00.01 internationally. In addition, the American Petroleum Institute (API RP 750 and API RP 14J) and the American Institute of Chemical Engineers (*Hazard Evaluation Procedures*, 2nd Edition) recognize the value of this methodology in analyzing process hazards.

The HAZOP study proceeds sequentially, studying each section of the process included in the project scope. The process under review is partitioned into "nodes," where there is a distinct intention for process parameters (for example, a specific intended temperature, pressure, or flow rate, or operation type).

The HAZOP technique is based on the premise that hazards and operability problems stem from deviations from design intent. To facilitate the review of each node in a structured manner, guidewords are used to capture the ways in which process parameters can deviate from design intent such as; No, More, Less, Misdirected, Reverse, etc. Other guidewords will be defined and used as necessary. The guidewords are systematically combined with the relevant process parameters to yield deviations (e.g., No Flow, High Temperature, Low Pressure, etc.). For each deviation credible causes are developed to define:

- Consequences
- Safeguards
- Risk Level
- Recommendation to Mitigate Risk, as deemed necessary

HAZOP is intended to be a team review of the process, hazards, consequences of deviation, safeguards, and need for additional risk reduction. Therefore, to conduct the HAZOP proposed in this task, a team of individuals from CRC and the RA/HA team with knowledge of the process and hazards participated.

The PHA team consisted of members of the CRC Project Panel and a study facilitator/scribe from AcuTech Consulting Group. The PHA was documented using a PHA template created for IHS's PHA-Pro™ software program.

Table 1: Risk Assessment/Hazard Analysis Team Members

Full Name	Company	Oct. 15, 2013	Dec. 16/17, 2013
Colin D Armstrong	AcuTech Consulting Group	X	X
Brent Bailey	Coordinating Research Council	X	
Dennis Boyd	BP America	X	X
Lew Gibbs	Consultant	X	
David Heller	AcuTech Consulting Group		X
Gary Herwick	Transportation Fuels Consulting	X	X
Jerry Horn	Chevron	X	
Dehong Kong	AcuTech Group Inc.	X	
Jim Simnick	BP America	X	
Chris Tennant	Coordinating Research Council	X	X
Marie Valentine	Toyota	X	X
Bill Woebkenberg	Mercedes Benz	X	
Kristi Moriarty	NREL		X
Scott Mason	Phillips 66		X

PHA Methodology

The guideword HAZOP technique is a means of systematically reviewing a process to identify potential hazards and operability problems resulting from credible deviations from design intent. A HAZOP study is conducted by a team of individuals with knowledge in engineering, operations, safety, and maintenance.

For the service station system, the study proceeded sequentially through the pieces of equipment that make up the system under study. Each part of the process was partitioned into "nodes" (Table 2) that are composed of one or more pieces of equipment where there is a distinct intention for process parameters (e.g., intended temperatures, pressures, levels, flow rates).

Table 2: Qualitative Hazard Analysis (PHA) Nodes

Nodes	Design Conditions/Parameters
1. Unloading a Tanker Truck to a UST	Tanker trucks are unloaded into Underground storage tanks at service station to refill the USTs with fuel. Tanker trucks are connected to the UST fill line and may unload the full contents of the tanker, or in the event of a "Split Load" may only unload some of the tanker contents. "Split Loads" are less frequent occurrences as compared with standard tanker unloading. In order to begin filling the UST, the driver must first maneuver the tanker truck to the unloading site. With the truck in place, the driver verifies the correct location and tank for the fuel delivery. Next, the driver verifies that the tank has sufficient free space for the delivery to be made. The UST taking delivery of the fuel may be equipped for Stage 1 vapor recovery. Stage 1 vapor recovery uses a vapor return connection to allow displaced vapors from the UST to be vented into the tank truck headspace during the filling operation. Vent lines from the UST are generally 12 ft. above grade, with a rain cap and/or pressure/vacuum (P/V) valve.
2. UST Gauging	Remote/Electronic or manual gauging is used. The manual method involves gauging the tank with a wooden stick with a metal tip and gauge paste. The manual gauging of tanks is performed through the fill line of the tank. Manual gauging may be inaccurate if the tank pressure is above or below atmospheric due to a manometer effect in the dip tube. Manual gauging may be performed before each delivery if the site does not have an electronic gauge. Risks associated with opening the UST caps/connections are the same as the UST, but the person performing the task is not a driver, but a station employee.
3. Dispensing	A submersible turbine pump in the UST pressurizes the piping connections to all dispensers. When engaged, the fuel flows to the dispenser, through a fire shut-off valve. The fire shut-off valve closes in the event it is heated, or the piping downstream in the dispenser is

Nodes	Design Conditions/Parameters
	sheared. The fuel flows through a fuel filter, then to the flow meter, and to the flow control valves, then blending valves. All fill line connections and the stage 2 vapor connection, if in place, are fitted with impact, shear, and fire safe valves
4. Stage 2 Vapor Recovery System	Balanced stage 2 vapor recovery systems provide a path for vapor flow to the UST from the vehicle fuel tank through a coaxial fill hose. The balanced stage 2 vapor recovery accepts vapor displaced by the vehicle refueling. An advantage of the balanced system is that it does not ingest lean air when used on an ORVR vehicle. Vacuum pump assisted stage 2 vapor recovery: A vacuum pump in the dispenser draws flow from the vehicle fuel tank, this may ingest lean air in an ORVR vehicle. The vacuum pump draws air from the nozzle and pumps it to the UST. The UST in a system with vac-assist tends to operate at a slightly positive pressure. Engaging the trigger on the nozzle for fuel dispensing opens the vapor pathway for the stage 2 vapor recovery (balanced or vac-assisted).

The guideword HAZOP is based on the premise that hazards and operability problems stem from deviations from design intent. Guidewords capture the ways in which process parameters can deviate from design intent, e.g. No/Low, High, Other Than, Reverse, Misdirected. These guidewords are systematically combined with process parameters (Level, Temperature, Pressure, and Flow) to yield appropriate deviations that are then judged for credibility. If credible causes exist the deviations are examined further to determine the consequences, assuming that the deviations were to occur, and what, if any, safeguards currently exist. Safeguards are equipment, systems, and/or human interaction that are intended to detect, prevent, or mitigate the hazard scenario.

Worksheet Entries

For deviations that the PHA team found to be credible, the following were recorded in the PHA (HAZOP) worksheets: Deviation, Causes, Consequences, and Potential Safeguards. The qualitative risk assessment was designed to identify those scenarios which were determined by the team to pose the greatest apparent risk and require additional study as part of the Quantitative Risk Assessment (QRA). As a result, severity and likelihood values were not documented. These values were left for determination as part of the QRA. Each of these worksheet entries, as well as other worksheet information relevant to the study, is explained in the following section. The completed worksheets are provided in Appendix A.

Guidewords

Guidewords are typically used to describe the ways in which process parameters can deviate from the design intent. Typical guidewords are No, More, Less, As Well As, Reverse, Part Of, Misdirected, and Other Than. These guidewords are systematically combined with relevant process parameters to develop meaningful deviations. The deviations are then judged to determine whether credible causes of the deviation exist. If credible causes exist, the deviations are examined further to determine the potential consequences, safeguards, and any recommendations. The team used other guidewords when they were useful and provided a clearer understanding of the deviation. Since the guidewords are part of the deviation they have not been explicitly assigned a worksheet column.

Parameters

A parameter is a physical or chemical property associated with the process, for example, temperature, pressure, level, and flow. However, in the worksheets, only those parameters considered relevant for the particular node are usually documented as well as any additional parameters that the PHA team felt was relevant. Since the parameters are part of the deviation they have not been explicitly assigned a worksheet column.

Deviations

A "deviation" is an excursion in operating conditions outside the normal range. It is derived by combining a guideword and a process parameter. For example, the guideword "More" combined with the parameter "Temperature" yields the deviation "Higher Temperature". For example “High Level” is relevant to a tank or vessel but not to a pipeline. Other deviations were considered on a case-by-case basis as appropriate to the specific node.

Causes

Causes are the specific events or failures that result in a deviation from design intent for a process parameter. For example, "No Flow" may be caused by "pump failure". Detailed root causes (for example, "pump not turned on due to operator error", or "coupling failure due to excessive vibration") are sometimes listed if this is necessary to determine the consequences or safeguards. General types of causes include equipment failure, human error, and external events. Equipment failures are flaws in the equipment design or fabrication that result in predictable failures, where the predictability is formed by the history of the equipment in its given service and environment. Human errors include errors of both omission and commission. External events include both naturally occurring events (e.g., weather induced events), man-made events (e.g., transportation related events), and utility failures (e.g. loss of electrical power) that occur outside the process being studied but have an impact on the process. In general, causes were only considered from within the node under study. All credible causes were listed for the deviation under consideration. The team then reviewed the consequences and safeguards for each cause as a separate scenario.

Consequences

The consequences are stated in short, numbered sentences to document each of the potential hazards or operability problems that could result directly from the Cause, starting with the most

immediate and followed by subsequent events that result from the initial problems to the worst likely outcome. The consequences considered credible in the study must fall within the defined objectives of the PHA. For example:

Deviation: Low/No Flow

Cause: Manual valve in pump discharge closed

Consequences:

- loss of flow to column (operability issue)
- deadhead pump resulting in seal damage and
  - release of flammable liquid to area
  - possible fire from ignition of leak
  - potential personnel injury and equipment damage

Consequences should be followed beyond the node under consideration to the furthest reasonable extent that problems may arise, both upstream and downstream, so that the hazards are fully realized. For example, if High Level is being considered as a deviation for a flammable hydrocarbon storage tank, the consequences of "possible overfilling and fire" should be documented. This may assume that several protection devices may fail, if realistic. If this is not assumed the hazard of overfilling may be overlooked and not documented.

Safeguards

All existing measures that detect or warn of a cause of a deviation or consequence, prevent a cause or consequence, or mitigate the effects of a consequence should be entered in this column. This includes hardware, software, and certain procedural/administrative safeguards. For example, written checklists to reduce the risk of human error, a flammable gas detection system with alarms, or a pressure relief valve are all safeguards if they are available and reliable. Safeguards must be fully functional, well-maintained, and applicable to the scenario for which they are credited. Safeguards were identified for all hazard scenarios i.e. those involving safety, health, property, downtime, or environment-related consequences.

Severity and Likelihood Ratings

Hazard scenarios identified in the PHA were rated on the severity of the consequences and the likelihood of the scenario occurring, in accordance with a PHA Risk Matrix and associated tables. The risk matrix utilized was based on severity and likelihood definitions from MIL-STD-882E, Standard Practice for System Safety. The consequence severity was rated regardless of the likelihood and, in general, assumed the failure of all safeguards. First, a four-level Order-of-Magnitude scoring system was used to rank Impact Severity.

Table 3 provides the definitions of Severity used in the study.

The overall Likelihood of the scenario is based on the sum of 1) the likelihood of the initiating cause and 2) the likelihood of failure of the identified safeguards to prevent the potential worst-case consequences. Five levels of potential likelihood were utilized.

Table 4 presents definitions of the five likelihood categories.

A qualitative Risk Ranking Matrix was used to assign a risk level to the hazard scenarios, based on the scenario severity and likelihood. The Risk Ranking Matrix has risk levels ranging from 1 (highest risk) to 4 (lowest risk). The risk levels help the team determine the need for additional recommendations and assist in prioritizing any recommendations made. The risk values are a numerical distribution across a pre-selected number of risk values, and not a mathematical calculation. The qualitative Risk Ranking/Recommendation Prioritization Matrix is shown in Figure 1.

Table 3: Definitions of Severity

Severity Level	**Definition**
1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M
2	Could result in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M
3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M
4	Could result in one or more of the following: injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K

Table 4: Definitions of Likelihood

Likelihood	A	B	C	D	E
Description	Likely to occur often in the life of an item ($L \geq 10^{-1}$ per year)	Will occur several times in the life of an item ($L \geq 10^{-2}$ but $< 10^{-1}$ per year)	Likely to occur sometimes in the life of an item ($L \geq 10^{-3}$ but $< 10^{-2}$ per year)	Unlikely, but possible to occur in the life of an item ($L \geq 10^{-6}$ but $< 10^{-3}$ per year)	Unlikely, but can reasonably be expected to occur. ($L < 10^{-6}$ per year)

Figure 1: Risk Ranking Matrix

	Likelihood (L)				
Severity (S)	**A**	**B**	**C**	**D**	**E**
1	**1-A**	**1-B**	**1-C**	**1-D**	**1-E**
2	**2-A**	**2-B**	**2-C**	**2-D**	**2-E**
3	**3-A**	**3-B**	**3-C**	**3-D**	**3-E**
4	**4-A**	**4-B**	**4-C**	**4-D**	**4-E**

Results

Based on the results of the qualitative risk assessment, and discussions with the Project Panel representatives the following set of seven scenarios were detailed for further study as part of the QRA. The potential causes of the scenarios are detailed as well.

1. Large spill to grade during unloading (tanker truck hose rupture, or similar event that results in large spill).
    - Causes
        - Vehicle impact
        - Human error
        - Mechanical Failure
2. Ignition of UST vent stack vapors, with flashback through the vent connection and UST detonation
    - Causes
        - Surface fire/brush fire overwhelms tank vents
        - Ignition from lightning
        - Intentional defeat of stage 1 vapor recovery
        - High rate of vapor release during UST filling

3. Ignition of vapors vented at grade in UST area, with flashback and UST detonation
    - Causes
        - Human Error
            - Venting of vapors from UST at grade (loose stage 1 connection or dry break propped open)
        - Ignition by static
        - Ignition by vehicle
4. Direct Ignition of UST headspace
    - Causes
        - Ignition by electrical malfunction
5. Uncontrolled spill of fuel to grade in the dispensing area
    - Causes
        - Human Error
        - Mechanical Failure
6. Nozzle fire with flashback potentially into the gas tank headspace if flammable
    - Causes
        - Static Ignition
        - Human Error creating ignition source
7. Detonation of vapors in an AST tank associated with CA tank pressure management systems (consider in conjunction with UST detonation consequences)
    - Causes
        - UST Detonation Scenarios described in items 2-4.

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Appendix A – HAZOP Worksheets

Node 1: Unloading Tanker Truck to UST

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
1. No Flow	1. Vent line blocked/plugged or PV valve closed	1. Tanker truck connected to UST, fill line is wetted, head pressure of tanker truck open to UST, unable to unload truck, potential for wetted hose to be disconnected, spill of ~20 gal of fuel to grade, potential for ignition of flammable pool	1. ignition source may be present as driver is statically charged by walking the hose	2	E	1. Truck driver checks level in truck and hose prior to disconnect 2. Driver walks hose to drain into UST prior to disconnecting, able to feel weight of liquid.

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. High level in UST has engaged ball float or flapper	1. Tanker truck connected to UST, fill line is wetted, head pressure of tanker truck open to UST, unable to unload truck, potential for wetted hose to be disconnected, spill of ~20 gal of fuel to grade, potential for ignition of flammable pool	1. ignition source may be present as driver is statically charged by walking the hose	2	E	1. Truck driver checks level in truck and hose prior to disconnect
						2. Driver walks hose to drain into UST prior to disconnecting, able to feel weight of liquid.
	3. Stage 1 vapor recovery line blocked or not connected	1. High flow rate of flammable vapors from the vent line during unloading (no vapor returned to truck), potential for ignition of vapors from the vent line, potential for ignition of flammable vapors, and potential for flashback of flame to vent line		1		1. Area classification around the vent stack, Class I, Div1 within 5 ft. of vent location, Class I, Div2 within 10 ft. of vent stack

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						2. Tank vent lines are elevated at least 12 ft. above grade
						3. Vent stacks may be grounded
						4. Guarding around the base of vent stacks, barriers to prevent access to the area
	4. Drop tube blocked/plugged	1. Tanker truck connected to UST, fill line is wetted, head pressure of tanker truck open to UST, unable to unload truck, potential for wetted hose to be disconnected, spill of ~20 gal of fuel to grade, potential for ignition of flammable pool	1. ignition source may be present as driver is statically charged by walking the hose	2	E	1. Truck driver checks level in truck and hose prior to disconnect

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						2. Driver walks hose to drain into UST prior to disconnecting, able to feel weight of liquid.
	5. Submersible pump in the UST running without dispensing	1. Potential for overheating of the submersible turbine pump, potential to create an ignition source, potential for detonation of UST		1		1. Thermal shutoff on the pump motor
						2. PLC with shutoff to stop pump after set period of time running deadheaded
2. Less Flow	1. No additional causes identified, see no flow					
3. More Flow	1. Dual fill connection to UST	1. Tanker truck connected to UST with two fill lines, increased	1. Dual fill connections are common in	1		1. Stage 1 vapor recovery

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		rate of vapors vented from the vent stack, High flow rate of flammable vapors from the vent line during unloading (no vapor returned to truck), potential for ignition of vapors from the vent line, potential for ignition of flammable vapors, and potential for flashback of flame to vent line	markets with tractors and trailers, high volume markets			2. Area classification around the vent stack, Cass I DivI within 5 ft. of vent location, Class I Div II within 10 ft. of vent stack
						3. Tank vent lines are elevated at least 12 ft. above grade
						4. Vent stacks may be grounded
						5. Guarding around the base of vent stacks, barriers to prevent access to the area

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. High pumping rate into ASTs	1. High flow rate of fuel into an AST from a truck pump, potential for increased venting rate from the AST vent, high flow rate flammable vapors from the vent line during unloading (no vapor returned to truck), potential for ignition of vapors from the vent line, potential for ignition of flammable vapors, and potential for flashback of flame to vent line	1. Dual fill connections are common in markets with tractors and trailers, high volume markets	1		1. Stage 1 vapor recovery
						2. Area classification around the vent stack, Cass I DivI within 5 ft. of vent location, Class I Div II within 10 ft. of vent stack
						3. Tank vent lines are elevated at least 12 ft. above grade
						4. Vent stacks may be grounded

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						5. Guarding around the base of vent stacks, barriers to prevent access to the area
4. Misdirected Flow	1. Stage 1 vapor recovery dry break connection propped open	1. Dry break vapor connection is propped open, release of vapors from the tank at grade level, potential for ignition of vapors from the vent line, potential for ignition of flammable vapors, and potential for flashback of flame to vent line		1		1. Unloading area around tight vapor connection is class I Div I within 5 ft., and 10 ft. for loose connection.
			2. Commonly occurs in industry			2. Safety cones may be used to restrict entry into the area
5. Reverse Flow	1. No issues identified					
6. Other Than Flow	1. No issues identified					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
7. High Pressure	1. Undersized vent line	1. Not assumed to be a credible cause of high pressure due to venting rate requirements during gravity drop				
8. Low Pressure	1. Failure to remove dust cap from truck prior to unloading without stage 1 vapor recovery	1. Low pressure in the truck, potential to pull a vacuum below the minimum allowable pressure, potential for mechanical failure of the truck, not expected to result in failure of the tank truck and fuel spill				1. P/V valves installed on the truck open to prevent low pressure/vacuum
9. High Temperature	1. No issues identified					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
10. Low Temperature	1. Low ambient temperature	1. low ambient temperature in the summer will result in the vapor space becoming flammable				
		2. potential for freezing, resulting in LOPC to soil, no safety consequence	1			
11. High Level	1. Overfill of UST - improper gauging prior to unloading or faulty level gauge	1. High level in the UST, potential overfill of the UST through the stage 1 vapor recovery connection(cap opened, not connected), potential for large spill from remaining liquid in tanker truck,	1. USTs may be gauged manually and checked with a conversion chart, or checked with a manual level gauge (potential for gauge failure, error in gauging, or wrong chart to be used)	1	D	1. Ball float or shutoff in the stage 1 vapor drop 2. High level alarm (ball floats are being removed from current standard).

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						3. Shutdown valve activated by driver with switch located at the end of the truck (DOT requirement)
						4. Driver is present within 25 ft. of connection (DOT requirement)
						5. Site may be graded to drain to a swale, but this is not required
	2. Spill bucket filled with fuel					
	3. Spill bucket drain failure					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	4. Failure to shutoff flow to the UST during a 'Split Delivery'	1. High level in the UST, potential overfill of the UST through the stage 1 vapor recovery connection(cap opened, not connected), potential for large spill from remaining liquid in tanker truck,	1. USTs may be gauged manually and checked with a conversion chart, or checked with a manual level gauge (potential for gauge failure, error in gauging, or wrong chart to be used)	1	D	1. Ball float or shutoff in the stage 1 vapor drop
			2. Split load deliveries are less frequent			2. High level alarm (ball floats are being removed from current standard).
						3. Shutdown valve activated by driver with switch located at the end of the truck (DOT requirement)

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						4. Driver is present within 25 ft. of connection (DOT requirement)
						5. Site may be graded to drain to a swale, but this is not required
12. Low Level	1. UST level below bottom of fill tube	1. Flame front pathway present to allow ignition of tank vapor space through the fill line connection, potential for ignition and UST detonation	1. There are many potential sources of spark generation at the hose connection point, truck may be charged, tank may not be grounded, there may be no cathodic protection,			1. Unloading area around tight vapor connection is class I Div I within 5 ft., and 10 ft. for loose connection.
						2. Safety Cones may be used to restrict entry into the area
						3. Hose continuity may be checked regularly

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						4. Extend the fill tube to a level below the level of the pump suction
	2. UST level below suction of the submersible turbine pump	1. Potential for overheating of the submersible turbine pump, potential to create an ignition source, potential for detonation of UST		1		1. Thermal shutoff on the pump motor
						2. PLC with shutoff to stop pump after set period of time running deadheaded

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
13. High/Low Composition	1. Connection of ethanol and diesel or conventional gasoline tank vapor spaces through a common vent header	1. Potential to create a flammable atmosphere in the diesel/conventional tank headspace, potential for ignition of the headspace(diesel filling and pumping has an increased risk of spark generation due to static), potential fire/explosion	1. gauging practices in the tank may not take precaution against flammable vapor spaces	1		1. Ethanol and diesel vent headers are not interconnected 2. Diesel UST is considered to be Class I Div I

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		2. Potential to create a flammable atmosphere in the diesel/conventional tank headspace, potential for venting of flammable vapors from the diesel tank vent stack, potential for ignition and flashback				
	2. Weathered Fuel	1. Decreased vapor pressure of fuel, increased UEL, greater likelihood of vapor space being in the flammable range				
	3. Phase Separation	1. No causes of concern				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
14. Human Factors	1. No additional issues					
15. Facility Siting/Layout	1. No additional issues					
16. Corrosion/Erosion	Out of Scope					
17. Utility Failure	1. No additional issues					
18. Mechanical Failure	1. Filling hose leak - hose	1. Liquid spill, potential for pool fire				
	2. Filling hose leak - coupling misconnected/loose	1. Liquid spill, potential for pool fire				
	3. Filling hose failure - hose failure	1. Liquid spill, potential for pool fire				
	4. Filling hose failure - coupling failure	1. Liquid spill, potential for pool fire	1. Unloading fittings may be damaged by being thrown or kicked (RP1007)			
	5. Stage 1 Vapor hose leak - hose	1. vapor release at grade, potential for flash fire and flashback				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	6. Stage 1 Vapor hose leak - coupling misconnected/loose	1. vapor release at grade, potential for flash fire and flashback				
	7. Stage 1 Vapor hose failure - hose failure	1. vapor release at grade, potential for flash fire and flashback				
	8. Stage 1 Vapor hose failure - coupling failure	1. vapor release at grade, potential for flash fire and flashback				
	9. Leak from truck tank	1. Liquid spill, potential for pool fire				
	10. Tank truck backed into object/vehicle	1. Liquid spill, potential for pool fire				
	11. Failure of the stage 1 vapor recovery dry-break	1. vapor release at grade, potential for flash fire and flashback	1. Not an issue during the unloading if stage 1 vapor recovery is connected			
19. Emergency Situation Hazards	1. Vehicle Impact	1. Liquid spill, potential for pool fire				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. External Fire					
20. Ignition Sources	1. Violation of restricted area by the public, vehicle present, smoking, or other ignition source present					
	2. Driver is statically charged	1. Driver touches the hose which is grounded, resulting in a spark				
		2. Driver is charged by handling a charged hose used in the unloading of a non-conductive fuel				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		3. Conductive footwear or required discharge of the driver to a grounded piece of equipment				
	3. Truck is statically charged	1. Truck may be charged when it reaches the service station, truck discharges through the tires but may remain charged when the connection to the tank is made				1. Relaxation time prior to making filling connections (not in current practice, but could be considered)

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	4. Nonconductive hose in use	1. Nonconductive hose moved by the driver or impacted by wind/debris accumulates static charge and discharges to connection				
		2. Nonconductive hose charged by use in gasoline service				
	5. Concrete in the loading area is not conductive	1. Unable to discharge truck static prior to fill connection, potential for static discharge upon nozzle connection				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	6. Unloading to multiple USTs	1. Potential for generation of static charge in the truck by unloading a non-conductive fuel, potential for discharge of the accumulated charge when a second connection is made to a grounded connection on a separate UST				
	7. Presence of ignition source from a failure of the submersible pump					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
21. Step Skipped	1. Failure to return fill tube manhole cover/cap	1. potential for vapor release and ignition, potential for flashback to the UST and detonation				
	2. Failure to return Stage 1 Vapor Return manhole cover/cap	1. potential for vapor release and ignition, potential for flashback to the UST and detonation				1. Dry break connection prevent venting of vapors from the connection without a hose connected
	3. Fill hose not connected to fill line					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	4. Stage 1 Vapor Return line not connected to truck	1. Release of vapors from the UST filling displacement at grade level, potential for ignition of vapors from the vent line, potential for ignition of flammable vapors, and potential for flashback of flame to vent line		1		1. Unloading area around tight vapor connection is class I Div I within 5 ft., and 10 ft. for loose connection.
			2. Commonly occurs in industry			2. Safety Cones may be used to restrict entry into the area

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	5. Stage 1 Vapor Return line not connected to UST	1. Low pressure in the truck, potential to pull a vacuum below the minimum allowable pressure, potential for mechanical failure of the truck, not expected to result in failure of the tank truck and fuel spill				1. P/V valves installed on the truck open to prevent low pressure/vacuum
		2. High flow rate flammable vapors from the vent line during unloading (no vapor returned to truck), potential for ignition of vapors from the vent line, potential for ignition of flammable vapors, and potential for flashback of flame to vent line		1		1. Area classification around the vent stack, Cass I DivI within 5 ft. of vent location, Class I Div II within 10 ft. of vent stack

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						2. Tank vent lines are elevated at least 12 ft. above grade
						3. Vent stacks may be grounded
						4. Guarding around the base of vent stacks, barriers to prevent access to the area
	6. Failure to isolate truck tank from fill hose prior to disconnecting from UST	1. Potential for ignition of vapors in the tanker truck hose, and flashback to the tanker truck, potential for tanker truck detonation	1. Other compartments in the truck may be liquid full	1		1. Unloading area around tight vapor connection is class I Div I within 5 ft., and 10 ft. for loose connection.

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	7. Failure to isolate truck tank from Stage 1 Vapor Return hose prior to disconnecting from UST	1. Potential for ignition of vapors in the tanker truck hose, and flashback to the tanker truck, potential for tanker truck detonation	1. Other compartments in the truck may be liquid full	1		1. Unloading area around tight vapor connection is class I Div I within 5 ft., and 10 ft. for loose connection.
	8. Failure to drain hose prior to disconnecting from the fill line	1. Small spill of fuel to grade, ~20 gals, potential for ignition and pool fire		1		
22. Step Out of Sequence	1. No additional issues					
23. Step Too Long	1. No issues identified					
24. Step Too Short	1. No issues identified					
25. Step Performed on Wrong Equipment	1. Fuel loaded into the wrong tank or at wrong service station	1. High level in the UST, potential overfill of the UST through the stage 1 vapor recovery connection(cap opened, not connected), potential for large spill from remaining liquid in tanker truck,				1. stage 1 vapor recovery connection prevents release of liquid to grade

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						2. Ball float or shutoff in the stage 1 vapor drop
						3. High level alarm (ball floats are being removed from current standard).
						4. Shutdown valve activated by driver with switch located at the end of the truck (DOT requirement)
						5. Driver is present within 25 ft. of connection (DOT requirement)
						6. Site may be graded to drain to a swale, but this is not required

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		2. Contamination				
	2. Fill line connected to vapor return connection	1. Splash filling of the UST, no recovery of vapors from the stage 1 connection, potential to pull vacuum on truck, see low pressure				1. Liquid and vapor connections are not interchangeable, different sizes
		2. Splash filling of the UST, no recovery of vapors from the stage 1 connection, venting of vapors from UST vent stack, potential for ignition and flashback to UST				1. Liquid and vapor connections are not interchangeable, different sizes

Node 2: UST Gauging

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
1. No Flow	1. No issues identified					
2. Less Flow	1. No issues identified					
3. More Flow	1. Vapor flow out of gauging connection, tank at slight positive pressure	1. tank at positive pressure at start of gauging operation, outflow of vapor, potential for ignition of vapors				
4. Misdirected Flow	1. No issues identified					
5. Reverse Flow	1. No issues identified					
6. Other Than Flow	1. No issues identified					
7. High Pressure	1. No issues identified					
8. Low Pressure	1. No issues identified					
9. High Temperature	1. No issues identified					
10. Low Temperature	1. No issues identified					
11. High Level	1. No issues identified					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
12. Low Level	1. No issues identified					
13. Human Factors	1. No issues identified					
14. Facility Siting/Layout	1. No issues identified					
15. Corrosion/Erosion	1. No issues identified					
16. Utility Failure	1. No issues identified					
17. Mechanical Failure	1. No issues identified					
18. Emergency Situation Hazards	1. No issues identified					
19. Ignition Sources	1. Spark created by gauging of UST	1. spark generation by removing cover				
		2. spark generation due to discharge of static from wooden gauging stick				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. Electronic gauge creates an ignition source due to failure or installation error	1. Gauges may fail though they are rated for Class1 div 1 service, gauge may be the source of ignition for tank headspace	1. gauges in use may be susceptible to increased failure rates in ethanol service due to the increased concentration of chlorides in ethanol fuels			
20. Step Skipped	1. No issues identified					
21. Step Out of Sequence	1. No issues identified					
22. Step Too Long	1. No issues identified					
23. Step Too Short	1. No issues identified					
24. Step Performed on Wrong Equipment	1. No issues identified					

Node 3: Dispensing

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
1. No Flow	1. Dispenser pump deadheaded	1. Covered in the UST node				
2. Less Flow	1. Dispenser filter plugging	1. Reduced flow rate of fuel to the dispenser nozzle, the dispenser nozzle auto shut-off fails to operate properly, potential for overfill of fuel to grade, potential for spill, potential ignition and pool fire		1		1. Emergency shut-off switch

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. Low tank level in the UST	1. Reduced flow rate of fuel to the dispenser nozzle, the dispenser nozzle auto shut-off fails to operate properly, potential for overfill of fuel to grade, potential for spill, potential ignition and pool fire		1		1. Emergency shut-off switch

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	3. Failed submersible pump in the UST	1. Reduced flow rate of fuel to the dispenser nozzle, the dispenser nozzle auto shut-off fails to operate properly, potential for overfill of fuel to grade, potential for spill, potential ignition and pool fire		1		1. Emergency shut-off switch

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	4. High demand of fuel	1. Reduced flow rate of fuel to the dispenser nozzle, the dispenser nozzle auto shut-off fails to operate properly, potential for overfill of fuel to grade, potential for spill, potential ignition and pool fire		1		1. Emergency shut-off switch
3. More Flow	1. High discharge rate into vehicle fuel tank	1. potential for nozzle to be ejected from the tank, resulting in spill of fuel to grade				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		2. Increased risk of nozzle fire due to the increased rate of vapor vented from the vehicle tank fill line				
		3. Risk of fouling the carbon canister				
4. Misdirected Flow	1. Dispensing into an unsuitable container	1. Potential for spill to grade or ignition of vapors due to static discharge				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. Mis-fueling, high ethanol fuel into a conventional fuel vehicle	1. potential for flashback in a vehicle that was not designed to handle ethanol fuels, if flame arrestors are added to vehicles, there is an increased risk of flashback in vehicles without flame arrestors				
5. Reverse Flow	1. Drain down of fuel to the UST during maintenance	1. Fuel is drained back to the UST during maintenance of dispensing equipment, potential for flame pathway from the dispenser to the UST				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
6. Other Than Flow	1. Internal failure of stage 2 vapor recovery dispensing hose	1. Leak of fuel from the liquid fill line into the vapor recovery line, loss of vapor flow rate in stage 2 vapor recovery system, or liquid to the vacuum pump in the stage2 vapor recovery system				
	2. Stage 2 vapor recovery pulling suction other than from fuel tank	1. Connection not made with fuel tank, creates the potential for a flammable mixture in a fuel that is not normally in the flammable range				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		2. Lean air is pulled into the stage 2 vapor recovery through ORVR vehicles, creates the potential for a flammable mixture in a fuel that is not normally in the flammable range				
7. High Pressure	1. High discharge pressure from submersible turbine pump	1. Potential for failure of piping component, shear valve, or within dispenser, release of ethanol and potential for ignition in the dispenser				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		2. Potential for hose failure or failure of breakaway under high pressure, potential for release of fuel to grade				
8. Low Pressure	1. Increased filter plugging, low pressure at dispenser	1. High pressure drop across the filter, potential for failure of filter, release of particulate matter into the dispenser, potential for failure of control valve in the dispenser, dispenser fails to shut-off flow at pre-determined set point, continued flow of fuel to vehicle, potential for overfill of vehicle fuel tank at reduced flow rate(control valve in dispenser leaking by)				1. Nozzle auto-shutoff engages when the fuel tank is filled

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
9. High Temperature	1. Thermal expansion of fuel in piping	1. Potential for component failure, small leak of fuel in dispenser or in piping				
10. Low Temperature	1. freezing of water in fuels	1. small concentrations of water in fuel may result in mal-operation of controls in the system, not expected to result in significant consequence				
11. High Level	1. Customer overfills vehicle tank	1. spill of fuel to grade from the fill line, potential for ignition and pool fire				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
12. Low Level	1. Low level in vehicle fuel tank	1. Low level condition in a tank present the maximum risk of headspace ignition and static generation				
13. Human Factors	1. Customer spills fuel	1. Human error, release of fuel from nozzle		1		1. Emergency shut-off switch 2. Nozzle is designed to shut-off when dropped, UL listed 3. Class 1 Div 2 within 20 ft. of the dispenser
	2. Customer drives away during fueling	1. Spill of fuel to grade, potential for ignition and fire	1. Average occurrence of a drive away = 1/wk. at every site	1		1. Emergency shut-off switch 2. Break-away connection on the hose
	3. vehicle drives over hose, hose left on ground	1. Hose damaged by vehicle, potential for hose failure to occur,		1		1. Emergency shut-off switch

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
		leak of fuel during dispensing				2. Periodic inspection of dispensing hoses and nozzles
	4. Container refueled when not on ground	1. generation of static in ungrounded container, potential for ignition of fuel in container				
14. Facility Siting/Layout	1. No additional issues					
15. Corrosion/Erosion	1. External corrosion of dispensing equipment					
16. Utility Failure	1. Power failure					
17. Mechanical Failure	1. Leak from dispenser	1. Leak of fuel into the dispenser cabinet, potential for ignition, fire/explosion	1. Gasoline dispensers are designed to UL87, ethanol dispensers to U87A			1. Area classification Class 1 div 1 within the dispensers

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	2. Filling hose failure - coupling failure	1. Spill of fuel to grade, potential for ignition and fire				
	3. Filling hose failure - hose failure	1. Spill of fuel to grade, potential for ignition and fire				1. Emergency shut-off switch 2. Periodic inspection of dispensing hoses and nozzles
	4. Filling hose leak - coupling misconnected/loose	1. Spill of fuel to grade, potential for ignition and fire				
	5. Filling hose leak - hose	1. Spill of fuel to grade, potential for ignition and fire				
	6. Bellows failure - Stage 2 vapor recovery nozzle	1. increased risk of nozzle fire due to venting of vapors at fill point				1. Periodic inspection of dispensing hoses and nozzles
	7. Filling nozzle auto shut-off failure	1. Spill of fuel to grade, potential for ignition and fire				1. Emergency shut-off switch

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
						2. Periodic inspection of dispensing hoses and nozzles
18. Ignition Sources	1. Ignition source present at the nozzle (static discharge, smoking, etc.)	1. Potential for nozzle fire if stage 2 vapor recovery is not in use. Potential for flashback into vehicle or storage tank.				
	2. Instrumentation in stage 2 vapor recovery systems	1. If instruments are not designed for Class 1 div 1 service, the instruments may be an ignition source for fuel/air mixtures				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	3. Static discharge from customer	1. Potential for nozzle fire, increased likelihood if stage 2 vapor recovery is not in use. Potential for flashback into vehicle or storage tank.				
	4. Smoking	1. Potential for nozzle fire, increased likelihood if stage 2 vapor recovery is not in use. Potential for flashback into vehicle or storage tank.				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	5. Engines operating during refueling	1. Potential for nozzle fire, increased likelihood if stage 2 vapor recovery is not in use. Potential for flashback into vehicle or storage tank.				
	6. Portable electronic device in use in the area of fueling	1. Potential for nozzle fire, increased likelihood if stage 2 vapor recovery is not in use. Potential for flashback into vehicle or storage tank.				
	7. lightning					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
	8. Accumulation of static in the vehicle being refueled, or vehicle charged at the commencement of static					
19. Emergency Situation Hazards	1. Vehicle impact with dispenser, dispenser dislodged/moved	1. Release of fuel from the fuel supply to the dispenser, potential for ignition and fire				1. Shear valve below grade on the inlet line to the dispenser closes to prevent fuel flow 2. Bollards/guarding
	2. Emergency responders not properly trained or equipped	1. Standard fire-fighting foam does not extinguish ethanol fire, potential for prolonged fire				
20. Step Skipped	1. Nozzle not fully engaged prior to starting flow of fuel	1. spill of fuel to grade, small spill of fuel				

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
21. Step Out of Sequence	1. No issues identified					
22. Step Too Long	1. No issues identified					
23. Step Too Short	1. No issues identified					
24. Step Performed on Wrong Equipment	1. No issues identified					

Node 4: Stage 2 Vapor Recovery System

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
1. No Flow	1. Failure of the vac pump	1. Loss of stage 2 vapor recovery, venting of fuel vapor from vehicle fill line				1. Vac-pump fault alarm into supervisory system
	2. Liquid trap in the stage 2 vapor recovery line or in the hose	1. Loss of stage 2 vapor recovery, venting of fuel vapor from vehicle fill line				1. Lines between the dispenser and the UST are sloped to be free-draining
2. Less Flow	1. Reduced rate through vac pump	1. Reduced stage 2 vapor recovery, venting of fuel vapor from vehicle fill line				
3. More Flow	1. Increased rate of flow through stage 2 vapor recovery	1. Increased lean air ingestion into the UST				
4. Misdirected Flow	1. No issues identified					
5. Reverse Flow	1. No issues identified					
6. Other Than Flow	1. No issues identified					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
7. High Pressure	1. No additional issues					
8. Low Pressure	1. No additional issues					
9. High Temperature	1. Vac-assist pump running without flow, PLC error or nozzle failure(fails to open)	1. High temperature in the vacuum pump, potential for ignition source from high temperature surfaces				1. Thermal shutoff on vac pumps
10. Low Temperature	1. No issues identified					
11. High Level	1. No issues identified					
12. Low Level	1. No issues identified					
13. Human Factors	1. No issues identified					
14. Facility Siting/Layout	1. No issues identified					
15. Corrosion/Erosion	1. No issues identified					
16. Utility Failure	1. No issues identified					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
17. Mechanical Failure	1. Failure of piping or component in the stage 2 vapor recovery system	1. Leak of fuel vapors in the dispensing area, or within the dispenser, potential for ignition of vapors and flashback				1. tightness test of the system, including the UST, part of annual certification
18. Ignition Sources	1. Vac pump as an ignition source					
	2. Instrumentation in stage 2 vapor return line as an ignition source					
19. Emergency Situation Hazards	1. Vehicle impact to dispenser	1. Potential for fire in the dispensing area, potential for flashback through the stage 2 vapor recovery				1. shear valve on vapor connection
20. Step Skipped	1. No issues identified					

Deviation	Causes	Consequences	Remarks	Mitigated Risk		Safeguards
				S	L	
21. Step Out of Sequence	1. No issues identified					
22. Step Too Long	1. No issues identified					
23. Step Too Short	1. No issues identified					
24. Step Performed on Wrong Equipment	1. No issues identified					