A CCPS-EPSC Alliance

RAST

Risk Analysis Screening Tool

Rail Car Unloading Case Study

Hazard Identification and Risk Analysis using RAST

An AIChE Technology Alliance

CCPS

Center for Chemical Process Safety

EPSC

THE PROCESS SAFETY NETWORK

Version: 1.0
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Document Owner: Louisa Nara, CCPS Global Technical Director

Process Description

Chlorine gas is liquefied by the application of pressure at reduced temperatures to form a clear, amber-colored liquid. Liquid chlorine (a liquefied compressed gas) is more economical to ship and store. Other than at large production facilities, liquid chlorine is typically stored and shipped in 150-pound cylinders, 1-ton containers, or 55- and 90-ton tank cars. One volume of liquid chlorine, when vaporized, yields about 460 volumes of gas.

A chlorine repacking operation involves unloading liquid chlorine rail cars into smaller cylinders and totes. The chlorine repackaging process operation involves the following:

- Connecting a 90-ton (180,000 pounds) chlorine tank car to one of three unloading stations.
- Transferring liquid chlorine from the tank car through the process piping system to filling stations.
- Loading the filled 150-pound cylinders and 1-ton containers onto trucks for distribution.
- Cleaning and preparing empty cylinders and containers for reuse.

The chlorine repackaging process is a one-shift operation, typically running from 6:00 am to 4:00 pm, Monday through Friday. At the end of the day, a packager climbs the ladder to the top of the tank car and closes all car valves manually. Residual chlorine in the piping system is directed to the bleach production process. A vacuum is pulled and the system is left under negative pressure. The chlorine transfer hoses remain connected to the tank car overnight. Leak testing (by spraying small amounts of ammonia solution around possible leak points) is performed prior to startup the next day.

Equipment and Site Description

Railcars are typically 180,000 gallon capacity and rated for 375 psig. They are equipped with 1 inch diameter unloading hoses and automated shut off valves.

The site is located 35 miles south of downtown St. Louis and 3 miles south of both the Festus and Crystal City town centers. Festus and Crystal City have a combined population of 14,000. Nearly 1,500 people live and work within a 1-mile radius of the site. Approximately 200 people live in a mobile home park directly adjacent and southwest of the site (approximately 500 ft from the rail car unloading area). The area beyond the mobile home park (2500 ft away) is sparsely populated. Goodwin Brothers Construction and Intermodal Tire Retreading are located about 100 feet to the east (approximately 500 ft from the rail car

unloading area) separated from the site by Highway 61. Each business has about 18 full-time employees. Interstate 55 is 0.5 miles to the east.

Inputs for RAST

Chemical data for the materials used in this example is in the RAST chemical database as provided from CCPS. The RAST chemical data input sheets for chlorine are shown below. An operating pressure of 8 bar has been entered to ensure the physical state is liquid at an ambient temperature of 25 C.

Ensure Physical State remains Liquid (Saturation Temperature < Operating Temperature)

Chemical Data Input

<< Go To Main Menu | Enter New Chemical | Save All Input to Equipment Table | Clear Input | Go To Process Conditions > | Go To Plant Layout >

Equipment Identification:
Equipment Type:
Location: Outdoor Assumed
Enter Equipment Identification and Equipment Type on Study Menu Worksheet

Operating Temperature =	25	C
Operating Pressure (gauge) =	8	bar
Saturation Temperature =	30.4	C
Physical State =	Liquid	

Key Chemical: Chlorine
Reference:
Chemical Comments:
Reg. Agency Considers Toxic?

Chemicals (the first chemical listed is the 'key' chemical)	Wt Fraction Feed	Second Liq Phase	Wt Fraction Vapor	Relative Volatility	Molecular Weight	ERPG-2 (ppm)	ERPG-3 (ppm)	LFL (vol %)
Chlorine	1.000		1.000	1.0000	70.91	3	20	
Sum =	1.00		Vapor Mixture Properties:		70.9	3.0	20.0	

Mixture azeotrope? No

Standard Mixture (the key chemical has been defined as a mixture)	Wt Fraction Feed	Second Liq Phase

Model as a single Pseudo-Chemical?

Summary of Chemical Properties

Estimated Boiling Point =	-34.0	C
Vapor Pressure at Operating Temp =	7.709	atm
Liquid Density at Operating Temp =	1.38	gm/ml
Liq Heat Capacity at Op Temp =	0.25	cal/gm C
Liq Heat Capacity at Boiling Point =	0.22	
Heat of Vaporization at Op Temp =	60	cal/gm
Heat of Vaporization at Boiling Point =	69	
Boiling Point at Relief Set or MAWP =	79.5	C
Boiling Point at Burst Pressure =	119.4	C

Mixture Properties

	Mixture Estimates	User Values	
Melting Point =	-101		deg C
Flash Point =			deg C
Est Mixture Flash Point =			
Not "Sustained Burning"?			
AutoIgnition Temperature =			deg C
Ease of Ignition =			
Fuel Reactivity =			
Dermal Toxicity =			
Aquatic Toxicity =			
High Viscous Material (for F&EI)?			
Mixture NFPA Flammability =	0		
Mixture NFPA Health =	4		
Reactivity Category =			
Mixture NFPA Reactivity =	0		
Liquid Conductivity =	Non-Conductive		

Dust Characteristics

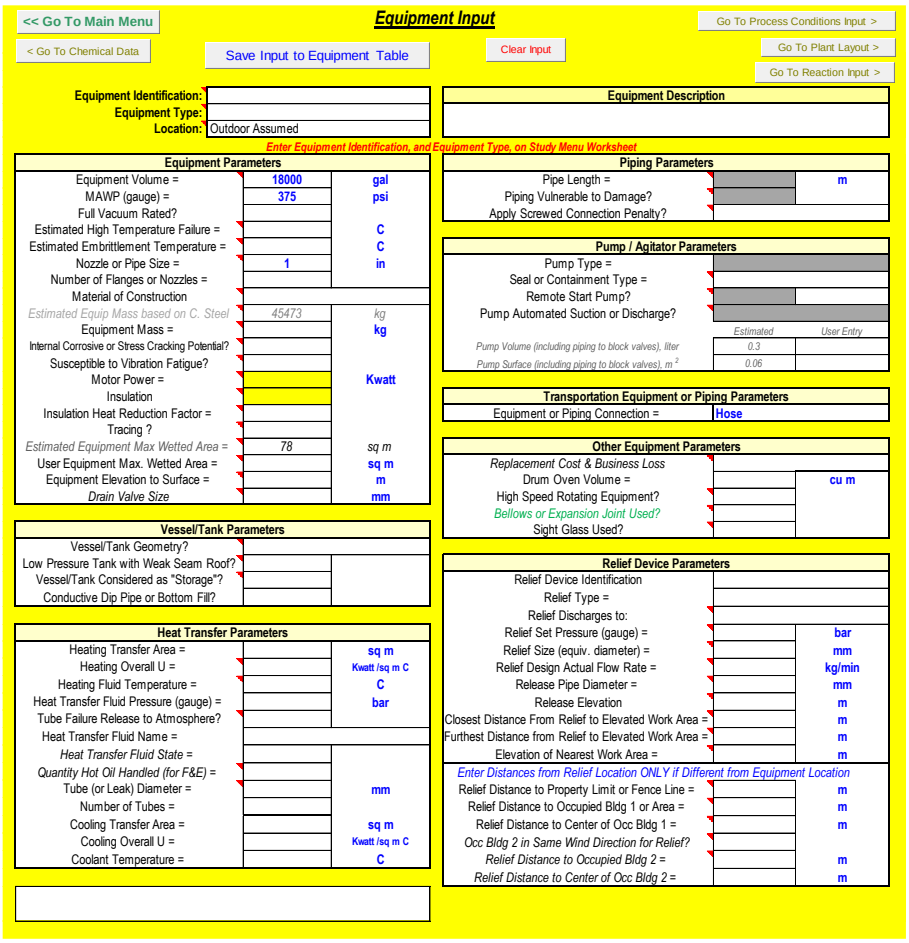
Dust/Solids Hazard Class =		
Solids Mean Particle Size =		micron
Particle Size at 10% Fraction =		micron
Dust Min Ignition Energy =		mJoule
Dust-flammable hybrid?		
Solids Bulk Density >160 g/liter (>10 lb/ft^3)?		

From the above vapor composition: Estimated 1 hour LC_1 = 74.3 ppm Estimated 1 hour LC_{50} = 404.3 ppm

	Name	State	Mol Weight	ERPG-2 (ppm)	ERPG-3 (ppm)	LFL (vol %)	Flash Pt (C)
Pad Gas Properties		Vapor	29				
Heat Transfer Fluid							

Show Chemical Details | Hide Chemical Details

Equipment Data Entry is entered on the Equipment Input worksheet. Note that there are few required fields and information may be added later to improve results. Relief device information has not yet been entered.



Equipment Input

<< Go To Main Menu | < Go To Chemical Data | Save Input to Equipment Table | Clear Input | Go To Process Conditions Input > | Go To Plant Layout > | Go To Reaction Input >

Equipment Identification:
Equipment Type:
Location: Outdoor Assumed

Enter Equipment Identification, and Equipment Type, on Study Menu Worksheet

Equipment Description

Equipment Parameters

Equipment Volume =	18000	gal
MAWP (gauge) =	375	psi
Full Vacuum Rated?		
Estimated High Temperature Failure =		C
Estimated Embrittlement Temperature =		C
Nozzle or Pipe Size =	1	in
Number of Flanges or Nozzles =		
Material of Construction		
Estimated Equip Mass based on C. Steel	*45473*	*kg*
Equipment Mass =		kg
Internal Corrosive or Stress Cracking Potential?		
Susceptible to Vibration Fatigue?		
Motor Power =		Kwatt
Insulation		
Insulation Heat Reduction Factor =		
Tracing ?		
Estimated Equipment Max Wetted Area =	*78*	*sq m*
User Equipment Max. Wetted Area =		sq m
Equipment Elevation to Surface =		m
Drain Valve Size		mm

Piping Parameters

Pipe Length =		m
Piping Vulnerable to Damage?		
Apply Screwed Connection Penalty?		

Pump / Agitator Parameters

Pump Type =		
Seal or Containment Type =		
Remote Start Pump?		
Pump Automated Suction or Discharge?		
	Estimated	*User Entry*
Pump Volume (including piping to block valves), liter	*0.3*	
Pump Surface (including piping to block valves), m^2	*0.06*	

Transportation Equipment or Piping Parameters

Equipment or Piping Connection =	Hose

Other Equipment Parameters

Replacement Cost & Business Loss		
Drum Oven Volume =		cu m
High Speed Rotating Equipment?		
Bellows or Expansion Joint Used?		
Sight Glass Used?		

Vessel/Tank Parameters

Vessel/Tank Geometry?	
Low Pressure Tank with Weak Seam Roof?	
Vessel/Tank Considered as "Storage"?	
Conductive Dip Pipe or Bottom Fill?	

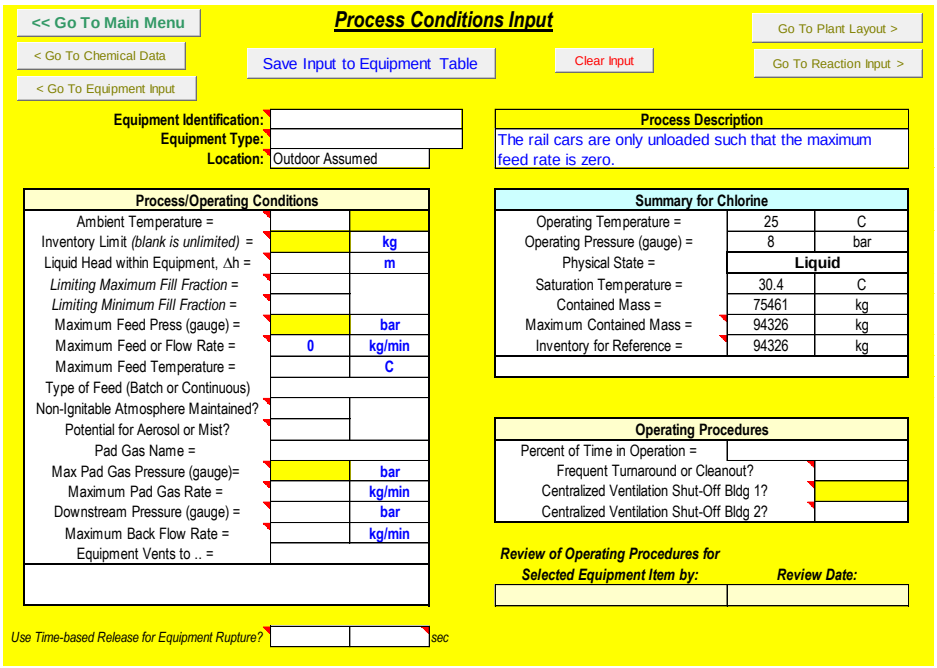
Heat Transfer Parameters

Heating Transfer Area =		sq m
Heating Overall U =		Kwatt /sq m C
Heating Fluid Temperature =		C
Heat Transfer Fluid Pressure (gauge) =		bar
Tube Failure Release to Atmosphere?		
Heat Transfer Fluid Name =		
Heat Transfer Fluid State =		
Quantity Hot Oil Handled (for F&E) =		
Tube (or Leak) Diameter =		mm
Number of Tubes =		
Cooling Transfer Area =		sq m
Cooling Overall U =		Kwatt /sq m C
Coolant Temperature =		C

Relief Device Parameters

Relief Device Identification		
Relief Type =		
Relief Discharges to:		
Relief Set Pressure (gauge) =		bar
Relief Size (equiv. diameter) =		mm
Relief Design Actual Flow Rate =		kg/min
Release Pipe Diameter =		mm
Release Elevation		m
Closest Distance From Relief to Elevated Work Area =		m
Furthest Distance from Relief to Elevated Work Area =		m
Elevation of Nearest Work Area =		m
Enter Distances from Relief Location ONLY if Different from Equipment Location		
Relief Distance to Property Limit or Fence Line =		m
Relief Distance to Occupied Bldg 1 or Area =		m
Relief Distance to Center of Occ Bldg 1 =		m
Occ Bldg 2 in Same Wind Direction for Relief?		
Relief Distance to Occupied Bldg 2 =		m
Relief Distance to Center of Occ Bldg 2 =		m

Since the rail cars are used for unloading only, the feed rate is entered as zero. If it were possible to back flow from the process into the rail car, a backflow rate would be entered to evaluate an overfill situation.



Process Conditions Input

<< Go To Main Menu | < Go To Chemical Data | < Go To Equipment Input | Save Input to Equipment Table | Clear Input | Go To Plant Layout > | Go To Reaction Input >

Equipment Identification:
Equipment Type:
Location: Outdoor Assumed

Process Description
The rail cars are only unloaded such that the maximum feed rate is zero.

Process/Operating Conditions

Ambient Temperature =		
Inventory Limit *(blank is unlimited)* =		kg
Liquid Head within Equipment, Δh =		m
Limiting Maximum Fill Fraction =		
Limiting Minimum Fill Fraction =		
Maximum Feed Press (gauge) =		bar
Maximum Feed or Flow Rate =	0	kg/min
Maximum Feed Temperature =		C
Type of Feed (Batch or Continuous)		
Non-Ignitable Atmosphere Maintained?		
Potential for Aerosol or Mist?		
Pad Gas Name =		
Max Pad Gas Pressure (gauge)=		bar
Maximum Pad Gas Rate =		kg/min
Downstream Pressure (gauge) =		bar
Maximum Back Flow Rate =		kg/min
Equipment Vents to .. =		

Use Time-based Release for Equipment Rupture? sec

Summary for Chlorine

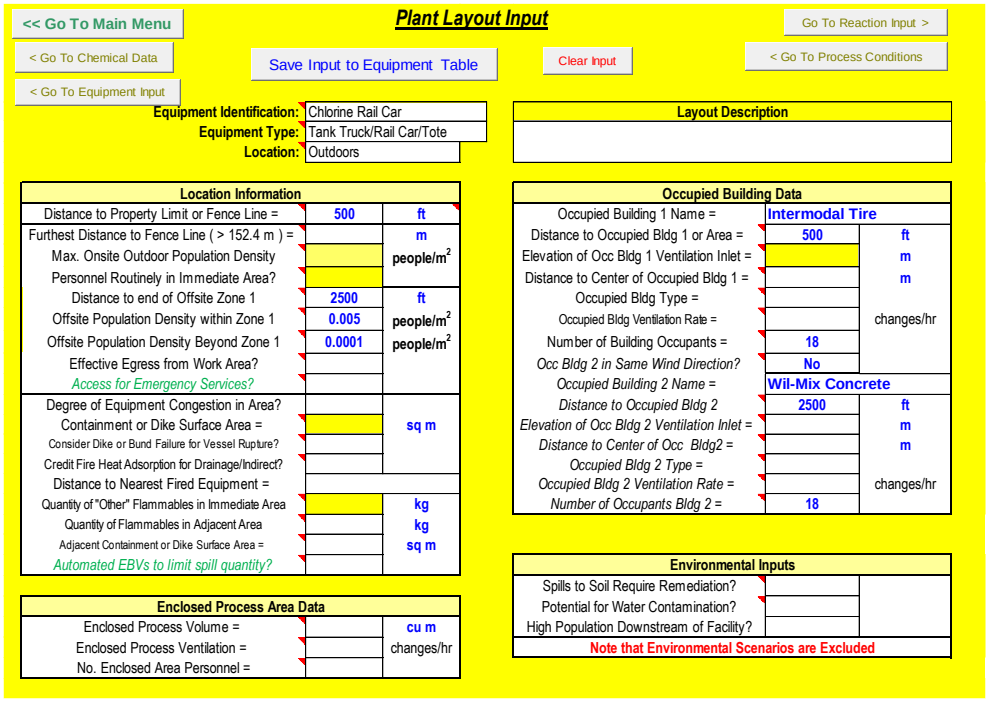
Operating Temperature =	25	C
Operating Pressure (gauge) =	8	bar
Physical State =	Liquid	
Saturation Temperature =	30.4	C
Contained Mass =	75461	kg
Maximum Contained Mass =	94326	kg
Inventory for Reference =	94326	kg

Operating Procedures

Percent of Time in Operation =	
Frequent Turnaround or Cleanout?	
Centralized Ventilation Shut-Off Bldg 1?	
Centralized Ventilation Shut-Off Bldg 2?	

Review of Operating Procedures for Selected Equipment Item by: ***Review Date:***

Plant and Site Layout information is entered on the Plant Layout worksheet. For this example, we have entered two offsite population regions with the mobile home park between 500 and 2500 ft. from the rail car unloading with a population of 200 people across roughly 10 acres (40000 m^2) or 0.005 people/m^2 (densely populated). The area beyond the mobile home park is farmland assumed 0.0001 people/m^2. The airport is north at more than 5000 ft. away.



Plant Layout Input

<< Go To Main Menu | < Go To Chemical Data | < Go To Equipment Input | Save Input to Equipment Table | Clear Input | Go To Reaction Input > | < Go To Process Conditions

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Location: Outdoors

Layout Description

Location Information

Distance to Property Limit or Fence Line =	500	ft
Furthest Distance to Fence Line (> 152.4 m) =		m
Max. Onsite Outdoor Population Density		people/m^2
Personnel Routinely in Immediate Area?		
Distance to end of Offsite Zone 1	2500	ft
Offsite Population Density within Zone 1	0.005	people/m^2
Offsite Population Density Beyond Zone 1	0.0001	people/m^2
Effective Egress from Work Area?		
Access for Emergency Services?		
Degree of Equipment Congestion in Area?		
Containment or Dike Surface Area =		sq m
Consider Dike or Bund Failure for Vessel Rupture?		
Credit Fire Heat Adsorption for Drainage/Indirect?		
Distance to Nearest Fired Equipment =		
Quantity of "Other" Flammables in Immediate Area		kg
Quantity of Flammables in Adjacent Area		kg
Adjacent Containment or Dike Surface Area =		sq m
Automated EBVs to limit spill quantity?		

Enclosed Process Area Data

Enclosed Process Volume =		cu m
Enclosed Process Ventilation =		changes/hr
No. Enclosed Area Personnel =		

Occupied Building Data

Occupied Building 1 Name =	Intermodal Tire	
Distance to Occupied Bldg 1 or Area =	500	ft
Elevation of Occ Bldg 1 Ventilation Inlet =		m
Distance to Center of Occupied Bldg 1 =		m
Occupied Bldg Type =		
Occupied Bldg Ventilation Rate =		changes/hr
Number of Building Occupants =	18	
Occ Bldg 2 in Same Wind Direction?	No	
Occupied Building 2 Name =	Wil-Mix Concrete	
Distance to Occupied Bldg 2	2500	ft
Elevation of Occ Bldg 2 Ventilation Inlet =		m
Distance to Center of Occ Bldg2 =		m
Occupied Bldg 2 Type =		
Occupied Bldg 2 Ventilation Rate =		changes/hr
Number of Occupants Bldg 2 =	18	

Environmental Inputs

Spills to Soil Require Remediation?	
Potential for Water Contamination?	
High Population Downstream of Facility?	

Note that Environmental Scenarios are Excluded

There is no reaction data input for this example.

Reports

Following entry of the input information, several reports may be run to summarize hazards and risks. A good report to start with is the **Hazard Summary**. Based on the input information, RAST suggests considering toxic hazards. A Process Hazard is also noted due to the low normal boiling point where frostbite may be a concern.

HAZARD SUMMARY

RAST Version 1.1 *Date:*

Summary of Chemical Information **for Process Unit: Tank Truck/Rail Car/Tote; Chlorine Rail Car**

Physical State at Operating Conditions for Chlorine = Liquid and Feed of:

Weight Fraction Chlorine	*1*
Normal Boiling Point, C	-34.0
Flash Point, C	
Lower Flammable Limit at Initial Composition, vol %	0.0
Combustible Dust?	No
ERPG-2 at Initial Composition, ppm	3.0
ERPG-3 at Initial Composition, ppm	**20.0**
Dermal Toxicity Classification *(or Corrosive to Human Tissue)*	
Aquatic Toxicity Classification	
Considered Toxic by a Regulatory Agency?	No
Heat of Reaction, kJoule/kg	
Highly Volatile or Gaseous Products Generated?	No
Potential for Mixing Incompatible Materials?	No
Considered Condensed Phase Detonable?	No

Hazard Screening

Note Chemical Information in Bold

Toxicity Hazard Sufficient for Further Consideration

Process Equipment is Considered in Hazardous Service

Summary of Equipment and Process Conditions

Equipment or Vessel Volume 18000 gal

	Temperature C	Pressure bar gauge	*Pressure Exceeds Maximum Allowable Working or Relief Set Pressure?*
Normal Operating Conditions	**25**	**8.00**	
Maximum Allowable Working or Relief Set Pressure	79.5	**25.86**	
Catastrophic Failure/Burst Pressure	119.4	**51.71**	
Full Vacuum Rated? Not Entered			
Catastrophic Failure High Temperature	**600.0**		
Temperature where Low Temp Embrittlement may Occur? Not Entered			
Maximum Feed Pressure		Not Entered	
Maximum Gas Pad Pressure		Not Entered	
Maximum Downstream Equipment Pressure		Not Entered	
Maximum from Liquid Displacement *(based on 9 X compression or feed pressure)*		5.82	**No**
Estimated Maximum Headspace Deflagration Pressure			**No**
Maximum Pressure from Hydraulic Surge (Piping Only)			
Maximum Ambient Conditions	25	8.00	**No**
Maximum Feed Temperature			
Minimum Coolant Temperature			
Normal Boiling Point of Equipment Contents	-34.0		
Maximum from Heating Media Temperature			
Estimated time to Relief Set Pressure or MAWP from Heat Transfer at Low Level, min			
Estimated time to Relief Set Pressure or MAWP from Heat Transfer at High Level, min			
Heating Media Source Pressure		0.00	**No**
Max from Mechanical Energy at Low Level: Non-Insulated			
Estimated time to Relief Set or MAWP from Mechanical Energy at Low Level, min			
Max from Mechanical Energy at High Level: Non-Insulated			
Estimated time to Relief Set or MAWP from Mechanical Energy at High Level, min			

Max. Temperature Exceeds High Temperature Failure

Maximum Temperature , C **25.0** **No**

Min Temperature less than Embrittlement Temperature

Minimum Temperature, C **25** **No**

Potential for Uncontrolled Reaction **No**

Reaction Temperature of No Return is Greater than the Boiling Point at Relief Set Pressure or MAWP or non-Reactive

Exothermic Reaction Temperature of No Return			Pressure Exceeds Maximum Allowable Working or Relief Set Pressure?
	Temperature, C	*Pressure, barg*	
Maximum Reaction based on Adiabatic and Initial Temperature as Operating Temperature	25.0	8.90	

Max Reaction Temp Exceeds High Temperature Failure?

Potential for Pool Fire No

Quantity Flammable Available based on Flammable in Area	0.0	kg
Maximum Pool Fire Duration based on Direct Fire		minutes
Fire Heat Input per API 521 for Process Vessel or Equipment	0.0	Kwatt

Another very useful report is the **Scenario List.** Deviations of common Parameters for unloading operations that could lead to an unintended loss of hazardous material or energy along with the most common causes are listed. The list also contains comments why the scenario was selected. Scenarios in gray were not selected. The comments may explain why which may indicate a missing input. This table provides a "starting point" for identifying scenarios to consider for Risk Analysis. Note that "Piping or Equipment Leak" caused by Unloading Hose Failure is one of the scenarios suggested for consideration.

<< Go To Main Menu | Update | ***Suggested Scenarios from the RAST Library*** | Go To Scenario Results >

Create User Scenario

HAZOP Node:
Plant Section =
Equipment Type = Tank Truck/Rail Car/Tote
Equipment Tag = Chlorine Rail Car

HAZOP Design Intent
Chlorine Rail Car is a Tank Truck/Rail Car/Tote containing Chlorine that operates at 25 C and 8 bar. The volume is 18000 gal with a design pressure of 375 psi. The maximum feed or flow rate is 0 kg/min.

Scenarios in gray were considered but are excluded for reason noted

LOPA Menu Filters:

Scenarios with NO IPL's Required will NOT be reported.

Scenario Type	Scenario Comments	Parameters and Deviation	Initiating Event (Cause)	Initiating Event Description	Incident	Outcome
Damage from Movement	Spill caused by Truck or car movement while transfer is in progress	Flow-Loss of Containment	3rd Party Intervention	Driver inadvertantly moves truck or car	Full Bore Hole Size Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Drain or Vent Valve Open	Drain or Vent Valve left open following loading/unloading or batch transfer	Flow-Loss of Containment	Human Failure Action more than once per quarter	Operator leaves Drain or Vent Open following unloading or clean-out	Drain or Vent Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Hose or Loading Arm Connection	Spill associated with improper connection of hose or loading arm	Flow-Loss of Containment	Human Failure Action more than once per quarter	Operator fails to ensure a proper connection before starting material transfer	Gasket Failure	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Mechanical Integrity Failure - Extremely Large	Largest Pipe or Nozzle Size less than Extremely Large Hole Size	Flow-Loss of Containment	IEF=4 as determined by Process Safety	Failure from corrosion, fatigue, etc.	Extremely Large Hole Size Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Mechanical Integrity Failure - Medium	Mechanical Integrity Loss of Containment for Medium Hole Size	Flow-Loss of Containment	IEF=4 as determined by Process Safety	Failure from corrosion, fatigue, etc.	Medium Hole Size Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Mechanical Integrity Failure - Very Large	Largest Pipe or Nozzle Size less than Very Large Hole Size	Flow-Loss of Containment	IEF=4 as determined by Process Safety	Failure from corrosion, fatigue, etc.	Very Large Hole Size Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Mechanical Integrity Failure - Very Small	Mechanical Integrity Loss of Containment for Very Small Hole Size	Flow-Loss of Containment	IEF=3 as determined by Process Safety	Failure from corrosion, fatigue, etc.	Very Small Hole Size Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Piping or Equipment Leak - Full Bore	Loss of Containment for Full Bore Pipe or Equipment Nozzle Hole Size	Flow-Loss of Containment	Unloading/Loading Hose Failure	Failure of Hose from fatigue,etc.	Full Bore Hole Size Leak	Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration
Excessive Heat Input - Heat Transfer	No Heating Media Temperature was noted	Pressure-High	BPCS Instrument Loop Failure	Failure of Flow Control	Criteria for Triggering Incidents Not Met	
Excessive Pad Gas Pressure	Maximum Pad Gas Pressure Does Not Exceed the Maximum Allowable Working Pressure or Relief Set Pressure	Flow-High	Regulator Failure	Regulator Fails causing high flow or pressure	Criteria for Triggering Incidents Not Met	
Overfill, Overflow, or Backflow	Overfill or Backflow of liquid with spill rate equal to the feed rate to a maximum quantity of the available inventory minus contained mass	Level-High or Flow-Backflow	BPCS Instrument Loop Failure	Failure of Level Indication with continued addition of material	Criteria for Triggering Incidents Not Met	
Pad Gas Compression	Maximum Feed or Downstream Pressure does not exceed the Maximum Allowable Working Pressure or Relief Set Pressure	Pressure-High	BPCS Instrument Loop Failure	Failure of Pressure Control	Criteria for Triggering Incidents Not Met	
Vacuum Damage	Equipment is rated for Full Vacuum	Pressure-Low	Human Failure Action more than once per quarter	Operator leaves valves closed allowing vacuum during emptying of equipment	Criteria for Triggering Incidents Not Met	

RAST also performs **Consequence Analysis** on each of the scenarios suggested (in addition to any scenarios the User adds). A summary of this analysis is found on the Consequence Summary worksheet. For example, the Incident Type suggested for the Uncontrolled Reaction scenario listed above is Rupture at Saturation Temperature.

CONSEQUENCE SUMMARY

RAST Version 1.1 *Date:*

Incident Type for: Tank Truck/Rail Car/Tote; Chlorine Rail Car Containing Chlorine : Full Bore Pipe or Nozzle Leak

Release Location	Outdoors
Airborne Quantity Summary:	
Release Temperature, C	25.0
Release Pressure, barg	8.000
Physical State at Release Conditions	Liquid
Heat Input, Kcal/min	
Equivalent Hole Size, cm	2.540
Release Rate, Kg/sec	5.75
Release Duration, min	60.00
Spray Distance, m	14.0
Flash + Aerosol Evaporation Fraction	0.784
Estimated Aerosol Droplet Diameter, *micron*	99
Pool Area, sq m	55.9
Estimated Pool Temperature, C	-34.4
Maximum Pool Evaporation Rate, kg/sec	1.9973
Total Airborne Rate, kg/sec	6.50
Total Airborne Quantity, Kg	19821.4

Prob of Exposure (proximity based) with Personnel Not in Immediate Area

	Factor	Probability
On-Site Toxic POE		
Flash Fire POE		
Chemical Exposure POE		
Physical Explosion POE		

Airborne Quantity Composition:

Mole Fraction Chlorine	1.000
Mole Fraction Pad Gas (at Mw = 29)	
ERPG-2 for Vapor Composition, ppm by volume	3.2
ERPG-3 for Vapor Composition, ppm by volume	21.2
LFL for Vapor Composition, % by volume	

Fence Line Concentration Exceeds ERPG-2

Ground or Work Area Exceeds 1/2 LFL or Multiple of ERPG-3

Dispersion Summary:

Max Distance to Time-Scaled ERPG-2, m	3428.0
Max Distance to Time-Scaled ERPG-3, m	1327.6
Max Distance to 1% Lethality for 1.5 F weather, m	2134.8
Max Distance to ERPG-3 multiple, m	494.0
Max Distance to 1/2 LFL, m	
Maximum Ground Elevation Concentration, ppm	1000000.0
Concentration at Distance to Fence Line, ppm	1610.1
Concentration at Distance to Unrestricted Work Area, ppm	1000000.0
Concentration at Distance to Occupied Bldg 1, ppm	1610.1
Concentration at Distance to Occupied Bldg 2, ppm	64.5
Concentration within Enclosed Process Area, ppm	
Conc within Enclosed Process Area w/Ventilation, ppm	

Potential Toxic Impact to Occupied Building (Conc > ERPG-3)

Explosion Summary:

VCE or Building Explosion Distance to 1 psi Overpressure, m	
Overpressure at Distance to Occupied Building, psi	
Overpressure at Center of Occupied Building, psi	
Distance to Severe Thermal Radiation Impact, m	
Distance to Direct Blast Impact (10 psi), m	
Maximum Fragment Range, m	
Rupture Distance to 1 psi Overpressure, m	
Rupture Overpressure at Distance to Occupied Building, psi	
Ruture Overpressure at Center of Occupied Building, psi	

Probability of Ignition (POI)

Probability of Explosion (POX)

Consequences:

Impact Assessment with Personnel routinely in the immediate area	Exceeds Threshold Criteria	**LOPA Tolerable Frequency Factors**
Offsite Toxic Impact based on 152.4 m to Fence Line	Yes	**7**
Onsite Toxic Impact with 200 people/sq km outdoors	Yes	**5**
Outdoor Toxic Exposure Duration 3047 sec		
Onsite Flammable Impact with 200 people/sq km outdoors		**NA**
Onsite Chemical Exposure with 200 people/sq km outdoors		**NA**
Onsite Direct Blast Impact with 200 people/sq km outdoors		
Onsite Therm Rad Impact with 200 people/sq km outdoors		
Occupied Building Toxic Impacts	Yes	**6**
Number of Potential Serious Impacts for Building 1: 13.4 people		
Number of Potential Serious Impacts for Building 2: 0 people		
Occupied Building Explosion Impacts		**NA**
Number of Potential Serious Impacts for Building 1: 0 people		
Number of Potential Serious Impacts for Building 2: 0 people		
Occupied Building Physical Explosion Impacts		
Number of Potential Serious Impacts for Building 1: 0 people		
Number of Potential Serious Impacts for Building 2: 0 people		
Environmental Impact:		**NA**

RAST estimated 54 people could be seriously impacted for 3 D weather conditions with wind direction directly toward the mobile home park.

The analysis provides tolerable frequency for the various incident outcome based on the company's risk criteria. In this example, Offsite toxic represents a very high consequence scenario.

Unfortunately, this incident (release of chlorine caused by unloading hose failure) occurred at 9:20 am on August 14, 2002 at the DPC Enterprises repacking facility near Festus, MO. Fortunately, there were no fatalities but 66 people sought medical help. The hose failure was due to installation of an improper stainless steel rather than the required Hasteloy C hose.

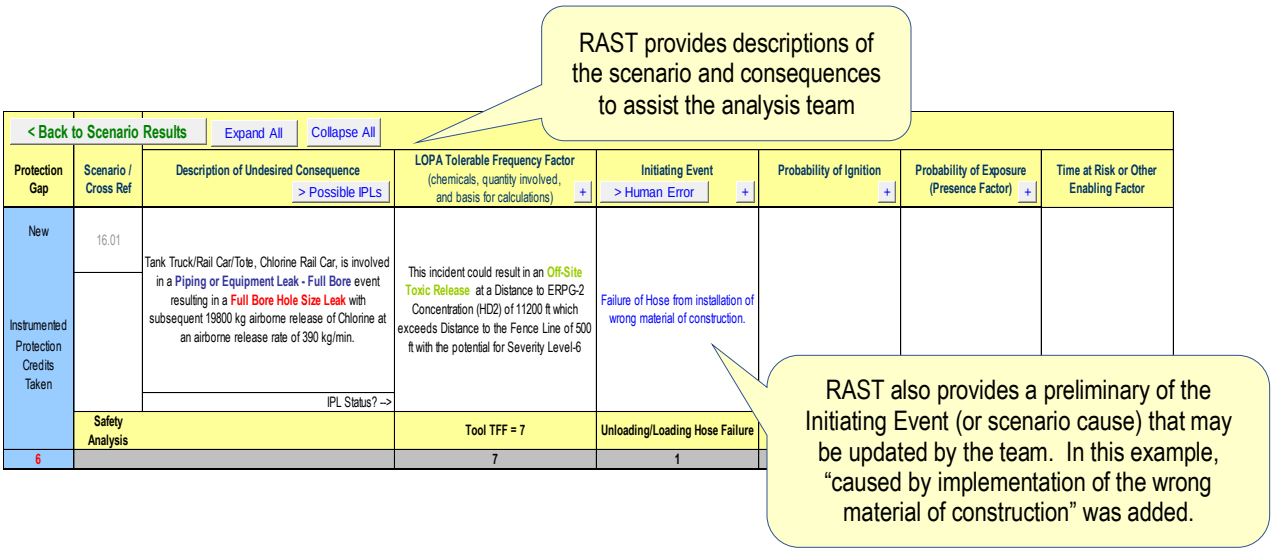
CSB Final Report – CHLORINE RELEASE, DPC Enterprises. Figure 14 - Chlorine release at tank car station #3

KTVI-TV, St. Louis, Missouri

CSB estimated that a concentration of 3 ppm could have extended as far as 3.7 mile on the morning of the release where the wind speed was in the range of 1.5 to 2.5 m/sec. RAST estimated a distance of 2.1 miles to 3 ppm at a wind speed of 3 m/sec and 3.0 miles at a wind speed of 1.5 m/sec with Class D atmospheric stability (which is in good agreement). Fortunately, wind was in the opposite direction of the mobile home part toward the Intermodal Tire facility where employees were able to successfully evacuate.

Finally, RAST provides a list of possible cause-consequence scenario cases that may be selected as a starting point for **Layers of Protection Analysis (LOPA)**. In addition to the scenario that occurred at DPC Enterprises, RAST provided an additional 23 cause-consequence pair cases. These cases (in addition to cases the study team identifies) may be evaluated by LOPA to ensure compliance with a company's risk criteria. RAST allows a Technical Administrator to enter a company risk matrix or table of tolerable frequencies for severe consequences. In this example, a tolerable frequency of 10^{-7} / year was entered into RAST for a scenario with the potential to result in multiple offsite fatalities.

RAST contains Initiating Event frequencies and Probability of Failure upon Demand factors for common causes and protective layers used in LOPA analysis. RAST provides a LOPA format that helps to document process risk and the protective layers needed. A description of the scenario and tolerable frequency with key information from the Consequence Analysis is provided.



Information regarding Protective Layers such as instrumented interlocks, pressure relief systems, and other safety related protection systems may be captured by the analysis team in addition to the safety integrity level or probability of failure on demand. Once the mitigated scenario frequency meets the tolerable frequency, the scenario is considered adequately managed.

	Not Allowed							
BPCS Control or Human Response to Alarm	BPCS Control or Human Response to Alarm	SIS Function A	SIS Function B	Pressure Relief Device	SRPS 1	SRPS 2	SRPS 3	Notes / Comments

Reference:

United States Chemical Safety and Hazard Investigation Board (CSB), Investigation Report, "Chlorine Release, DPC Enterprises, L.P., Festus, Missouri," Report No. 2002-04-I-MO, May 2003.