

AnACHE Technology Alliance
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Center for Chemical Process Safety

Risk Analysis Screening Tools (RAST) Overview / Demonstration

Risk Analysis Screening Tools (RAST) Case Study – BP Texas City



REFINERY EXPLOSION AND FIRE
Texas City, Texas
March 23, 2005

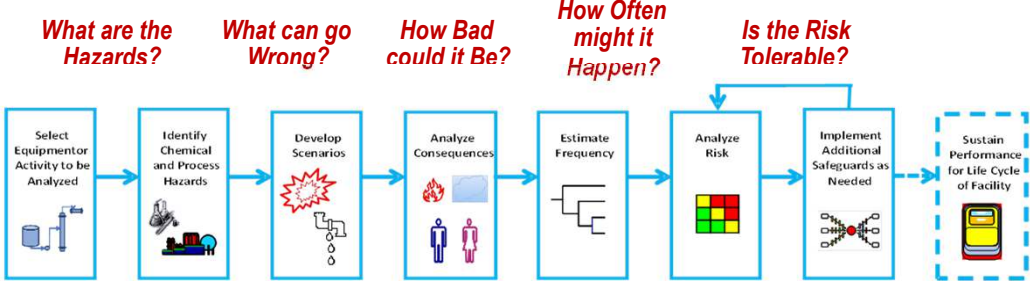
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Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – BP Texas City Hazard Identification and Risk Analysis (HIRA) Study

What are the Hazards? *What can go Wrong?* *How Bad could it Be?* *How Often might it Happen?* *Is the Risk Tolerable?*



We begin the study by **Identifying the Equipment or Activity** for which we intend to perform an analysis. RAST uses the operation of a specific equipment item containing a specific chemical or chemical mixture to define the activity. For example, the operation of a storage tank, a reactor, a piping network, etc. Inputs are chemical data, equipment design information, operating conditions, and plant layout.

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Case Study – BP Texas City

Process Description

We have been asked to perform a HIRA study of the ISOM unit of the BP Texas City refinery. The ISOM unit provides higher octane components for unleaded gasoline, consists of four sections: an Ultrafiner14 desulfurizer, a Penex15 reactor, a vapor recovery / liquid recycle unit, and a raffinate splitter. At the BP Texas City refinery, the ISOM unit converted straight-chain normal pentane and hexane into branched-chain isopentane and isohexane for gasoline blending and chemical feedstocks.

We will start with the raffinate splitter section where a hydrocarbon mixture is separated into light and heavy components. About 40 percent of the raffinate feed was recovered as light raffinate (primarily pentane/hexane). The remaining raffinate feed was recovered as heavy raffinate.. The raffinate splitter section could process up to 45,000 barrels per day (approximately 1300 gallons/minute) of raffinate feed.

This is an illustrative example and does not reflect a thorough or complete study.

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Case Study – BP Texas City

Process Description

The process equipment in the raffinate splitter section consisted of a feed surge drum; a distillation tower; a furnace with two heating sections, one used as a reboiler for heating the bottoms of the tower and the other preheating the feed; air-cooled fin fan condensers and an overhead reflux drum; various pumps; and heat exchangers.

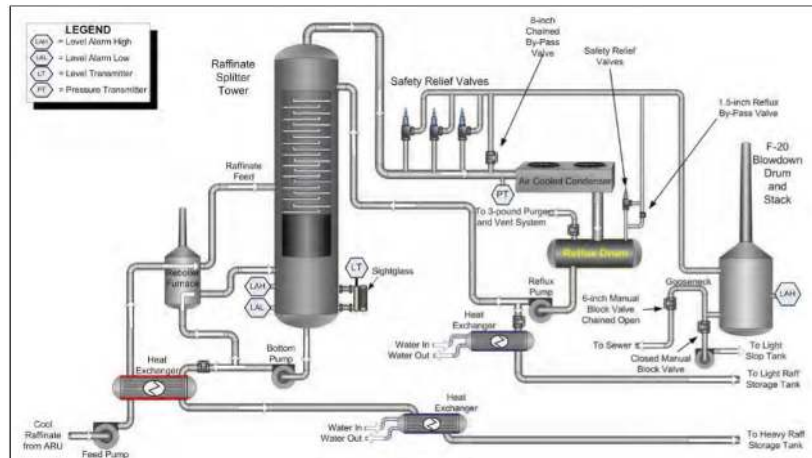


Figure 1: Raffinate Splitter Tower System of the ISOM Unit

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Case Study – BP Texas City

Process Description

Liquid raffinate feed was pumped into the raffinate splitter tower near the tower's midpoint. An automatic flow control valve adjusted the feed rate. The feed was pre-heated by a heat exchanger using heavy raffinate product and again in the preheat section of the reboiler furnace, which used refinery fuel gas. Heavy raffinate was pumped from the bottom of the raffinate splitter tower and circulated through the reboiler furnace, where it was heated and then returned below the bottom tray. Heavy raffinate product was also taken off as a side stream at the discharge of the circulation pump and sent to storage. The flow of this side stream was controlled by a level control.

Light raffinate vapors flows overhead, is condensed by air-cooled fin fan condensers, and then deposited into a reflux drum. Liquid from the reflux drum, was then pumped back into the raffinate splitter tower above the top tray.


Risk Analysis Screening Tools (RAST)

Case Study – BP Texas City

We will start by entering information for the raffinate column and reboiler. These items were selected as higher hazard equipment. At some point, we may decide to include other equipment in the study.

One the Main Menu, enter the equipment identification as the **Raffinate Splitter**, equipment type as **Distillation** and location as **Outdoors**.

Chemical Data – RAST requires a chemical or chemical mixture that is representative of the hazards. RAST does not perform time-dependent or location-dependent composition changes (such as within a reactor or distillation column). Where hazards may be significantly different between reactor feed and products, or distillation overheads versus bottoms; evaluation of the equipment may be repeated using different composition (such as Reactor A with feed composition and Reactor B with products composition).

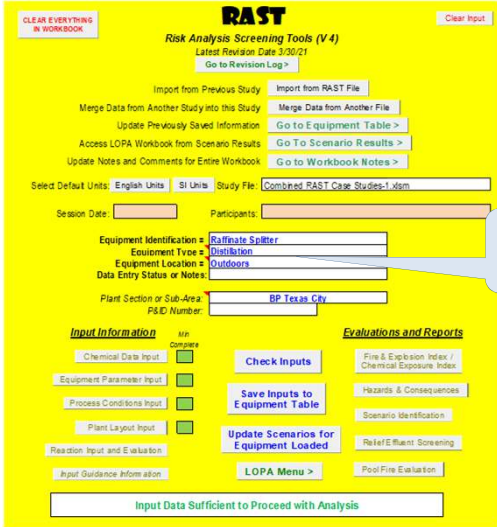


Risk Analysis Screening Tools (RAST) Overview / Demonstration

Risk Analysis Screening Tools (RAST)

Case Study – BP Texas City

Begin by entering information on the Main Menu worksheet. Start with the Raffinate Splitter.



Enter Equipment Identification, Equipment Type and Location

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Case Study – BP Texas City

Raffinate Composition

Table G- 1. Raffinate splitter column simplified composition model (Fisher, 2006)

Compound	Weight Fraction
n-pentane	0.0383
2-methyl butane	0.0263
n-hexane	0.1519
2-methyl pentane	0.2950
n-heptane	0.3072
n-octane	0.1300
n-nonane	0.0409
Heavies as n-decane	0.0104
Total	1.0000

}

For entry into RAST, the mixture is simplified to:

- 0.06 n-pentane (including isopentane)
- 0.15 n-hexane
- 0.30 isohexane (2-methyl pentane)
- 0.31 n-heptane
- 0.18 n-octane

Typical Raffinate composition *per Refinery Explosion and Fire*, CSB Report No. 2005-04-I-TX page 259

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Risk Analysis Screening Tools (RAST)

Case Study – BP Texas City

2-methyl pentane or isohexane is one major component of the feed but not listed in the RAST chemical data table, so we will enter this as a new chemical. Many companies have access to large chemical property databases that contain the information we will need. In other cases, vendor Safety Data Sheets, Cameo Chemicals (US National Oceanic and Atmospheric Administration), or literature references may be used. It is good to look for agreement among multiple sources.

CAMEO Chemicals

Chemical Datasheet

ISOHEXANE

Chemical Identifiers | Hazards | Response Recommendations | Physical Properties | Regulatory Information | Alternates

Chemical Identifiers

What is this information?

CAS Number: 107-83-5
UN/NA Number: 1208
DOT Hazard Label: Flammable Liquid

NIOSH Pocket Guide: none
International Chem Safety Card: 2-METHYLPENTANE

NFPA 704

Diamond	Hazard	Value	Description
3 3 0	Health	1	Can cause significant irritation.
	Flammability	3	Can be ignited under almost all ambient temperature conditions.
	Instability	0	Normally stable, even under fire conditions.

Case Study – BP Texas City

Chemical Data

Select “Add New Chemical” from the Chemical Data worksheet to access the “New Chemical” worksheet.

Since the information available from common sources is very limited, we will start with data from hexane and update with what little we know.

RAST uses relatively simple correlations for chemical properties that require only one or two data points.

Chemical Properties	Starting Chemical That is Similar	User Supplied Values	Properties of User Chemical to be Saved
Chemical Name *	hexane	100483-5	Some info
CAS Number *	110-54-3	100483-5	107-83-5
Chemical Source		Properties online - hexane, vapor pressure - PubChem	
Mol Weight *	86.2	86.2	86.2
Melting Point, °C (CL) *	-95.4	-95.4	-95.4
Boil Point, °C (CL) *	68.7	68.2	68.2
Vap Press A, kPa *	9.739	9.269	9.269
Vap Press B, kPa *	278.81	284.02	284.02
Vap Press C, kPa *	45.1	43.0	43.0
Dens A, g/cm3 *	0.659	0.674	0.674
Dens B, g/cm3 *	0.0033	0.0033	0.0033
Liq Heat C, kJ/kg *	0.812	0.812	0.812
Liq Heat V, kJ/kg *	0.0029	0.0029	0.0029
Liq Heat W, kJ/kg *	91.6	91.6	91.6
Liq Heat E, kJ/kg *	0.144	0.144	0.144
Liq Heat S, kJ/kg *	0.0009	0.0009	0.0009
Flash Pt (CL), °C *	-20	-20	-20
LP, Oxy % *	1.1	1.2	1.2
LP, Hyd % *	7.7	7.7	7.7
Autotemp, Temperature (CL) *		307	307
Exp of Vap (CL) *	Normal		
Exp Reactivity *	Medium		Medium
Liquid Conductivity	Non-Conductive		Non-Conductive
Solid Conductivity	Non-Conductive		Non-Conductive
Solubility in Organic Solv. (m g/g)			
Solubility in Water (m g/g)			
Solubility in Other (m g/g)			
ERPG-1 of 100 ppm (15 min) *	2000	11000	11000
ERPG-2 of 100 ppm (15 min) *	8000	40000	40000
ERPG-3 of 100 ppm (15 min) *	2	1	1
NFPA Health *	2	1	1
NFPA Reactivity *	2	0	0
NFPA Instability *	0	0	0
Chem. Toxicity *		Toxic	Toxic
Respiratory Corrosivity *			
Good Warning Precedent?			

Case Study – BP Texas City

Chemical Data

A composition (weight fraction):

- 0.06 n-pentane
- 0.15 n-hexane
- 0.3 isohexane
- 0.31 n-heptane
- 0.18 n-octane

was used as representative.

The operating pressure was entered as 25 psig and the operating temperature was selected as the saturation temperature such that the physical state is "liquid" (essentially a boiling liquid).

The operating pressure entered as an "average" within the column

Saturation temperature entered as Operating Temperature with physical state as "liquid"

RAST allows up to 5 components.

Chemical details may be shown or hidden

Case Study – BP Texas City

Equipment Input

The raffinate splitter is a 12.5 ft diameter column 170 ft tall. It has a total volume of roughly 155,000 gallons and a maximum allowable working pressure near 40 psig.

The column relief system discharges to a blowdown tank with elevated stack located 120 m northeast of the unit.

Only minimal data will be entered at this time.

The equipment volume and maximum allowable working pressure

A largest "working" nozzle of 12 inches is also entered

Case Study – BP Texas City Process Conditions

The maximum flowrate to the column is approximately 1500 gal/min. under normal operations.

Ambient temperature of 30 C has been assumed.

Process Conditions Input

Equipment Identification: Raffinate Splitter
Equipment Type: Distillation
Location: Outdoors

Process/Operating Conditions		
Ambient Temperature =	30	C
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 =	1500	gal/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 ... =		

Summary for Pentane (n-)		
Operating Temperature =	104.9	C
Operating Pressure (gauge) =	25	psi
Physical State =	Liquid	
Saturation Temperature =	107.9	C
Contained Mass =	58506	kg
Maximum Contained Mass =	342528	kg
Inventory for Reference =	541415	kg

Operating Procedures

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

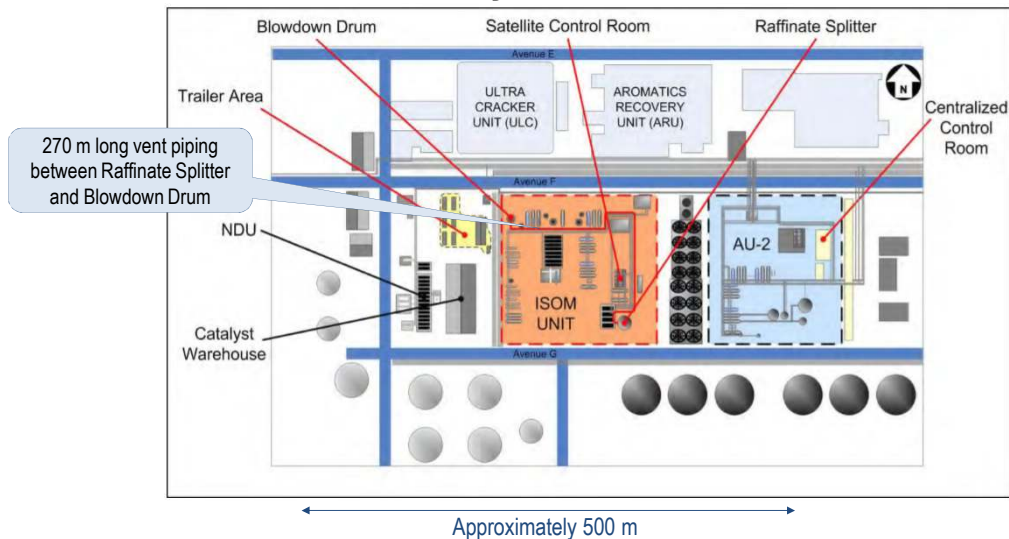
Review of Operating Procedures for Selected Equipment Item by: _____ Review Date: _____

Use Time-based Release for Equipment Rupture? _____ sec

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Case Study – BP Texas City Site Layout



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Site Layout

Congestion or Obstacle Density Categories

RAST is limited to consideration of the entire cloud volume as a single Potential Explosion Site (PES) at an overall or average category of process equipment congestion. RAST does not account for small localized areas of higher congestion where blast overpressure will be higher.



Low – Only 1-2 layers of obstacles. One can easily walk through the area relatively unimpeded.

Medium – 2-4 layers of obstacles. One can walk through an area, but it is cumbersome to do so. Medium Congestion is assumed in RAST if a category is not entered by the user.

High – Many layers of repeated obstacles. One could not possibly walk through the area and little light penetrates the congestion .

Case Study – BP Texas City

Site Layout

The distance to the property limit for the 1200 acre site is greater than 1000 m. Several wooden trailers are located approximately 200 m from the raffinate splitter housing 20 people. The trailers are “low strength” construction. In addition, the process area appears to be relatively “low” equipment congestion.

The blowdown tank which receives the discharge from the raffinate splitter relief devices is located 50 m from the wooden trailers and vents at an elevation of 36 m. *This location information is entered on the Equipment Input worksheet.*

Plant Layout Input

<< Go To Main Menu Save Input to Equipment Table Clear Input Go To Reaction Input >

< Go To Chemical Data > Go To Process Conditions

< Go To Equipment Input

Equipment Identification	Raffinate Splitter	Layout Description	
Equipment Type	Distillation		
Location	Outdoors		

Location Information	
Distance to Property Limit or Fence Line =	1000 m
Furthest Distance to Fence Line (> 1000 m) =	
Max. Onsite Outdoor Population Density Personnel Routinely in Immediate Area?	
Distance to end of Offsite Zone 1	
Offsite Population Density within Zone 1	
Offsite Population Density Beyond Zone 1	
Effective Egress from Work Area?	
Access for Emergency Services?	
Degree of Equipment Congestion in Area?	Low
Containment or Dike Surface Area =	
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	
Quantity of Flammables in Adjacent Area	
Adjacent Containment or Dike Surface Area =	
Automated EBVs to limit spill quantity?	

Occupied Building Data	
Occupied Building 1 Name =	
Distance to Occupied Bldg 1 or Area =	200 m
Elevation of Occ Bldg 1 Ventilation Inlet =	
Distance to Center of Occupied Bldg 1 =	
Occupied Bldg Type =	Low Strength
Occupied Bldg Ventilation Rate =	
Number of Building Occupants =	20
Occ Bldg 2 in Same Wind Direction?	
Occupied Building 2 Name =	
Distance to Occupied Bldg 2	
Elevation of Occ Bldg 2 Ventilation Inlet =	
Distance to Center of Occ. Bldg2 =	
Occupied Bldg 2 Type =	
Occupied Bldg 2 Ventilation Rate =	
Number of Occupants Bldg 2 =	

Enclosed Process Area Data	
Enclosed Process Volume =	
Enclosed Process Ventilation =	
No. Enclosed Area Personnel =	

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

Note that Environmental Scenarios are Excluded

Risk Analysis Screening Tools (RAST)

Case Study – BP Texas City

Select **Save Inputs to Equipment Table** (blue macro button). All Input Information will be stored in the Equipment Table in a single row identified by a unique Equipment Identification or Tag.

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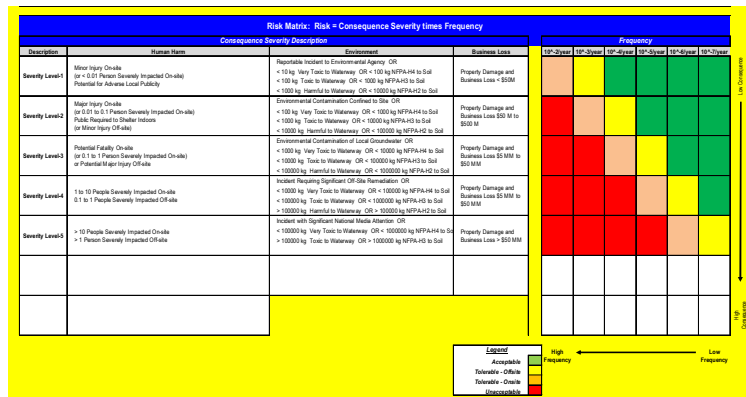
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Risk Analysis Screening Tools (RAST)

Risk Matrix


To understand the Consequence Severity and Tolerable Frequency, the values for key Study Parameters and a Risk Matrix may be viewed on the Workbook Notes worksheet. These values may be updated on hidden worksheets and should reflect the company's specific risk criteria.

For this case study, the Risk Matrix (right) has been used. The Human Harm criteria is based on an estimated number of people severely impacted (severe injury including fatality).



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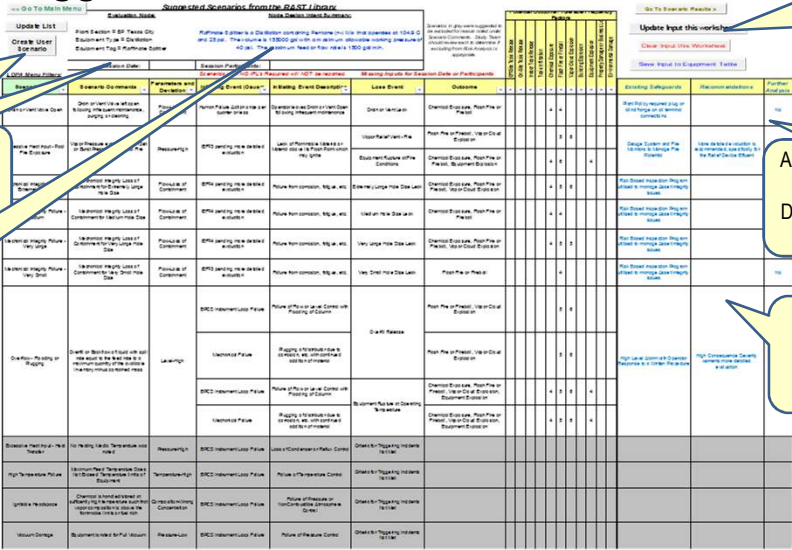
Case Study – BP Texas City

Suggested Scenarios for Raffinate Column

Additional Scenarios are Added using "Create User Scenario"

Evaluation Date(s) and Participant Names are entered on the Main Menu

Draft Design Intent Statement for updating by the Evaluation Team




Once Inputs are Entered use "Update Input this Worksheet" to Save

Analysis Team captures which Scenarios warrant more Detailed Evaluation (Layers of Protection Analysis)

Analysis Team captures Existing Safeguards and Recommendations for Scenarios Identified

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Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – BP Texas City

Suggested Scenarios for Raffinate Column

WORKING WITH YOUR EVALUATION TEAM:

- Review the suggested list of scenarios. Do these represent what you would expect for a distillation column?
- Are there scenarios that have been "screened out" (shown in gray) that should be considered?
- Are there scenarios missing? (Possibly similar scenarios with different Initiating Events)
- Do you agree with the "worst" Consequence (Tolerable Frequency Factor) for the scenario listed?

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Case Study – BP Texas City

Suggested Scenarios for Raffinate Column

WORKING WITH YOUR EVALUATION TEAM:

- ❑ Utilize an Appropriate Hazard Evaluation Technique (HAZOP, What If, etc.) to capture additional scenarios.
- ❑ Capture existing Safeguards and Recommendations for each Scenario. Note the Dates and Names of participants in the Study.
- ❑ Select which Scenarios warrant more detailed Risk Evaluation (such as Layers of Protection Analysis).

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Risk Analysis Screening Tools (RAST)

Case Study – BP Texas City

*Enter information for additional equipment associated with the Raffinate Splitter. Enter the Reboiler. As a gas-fired unit, the reboiler will consist of two equipment items, a **fired process heater** and a combustion unit.*

Enter:

- Equipment Identification: **Reboiler – Fired Heater**
- Equipment Type: select, **Fired Equipment – Process Heater**
- Location: **Outdoors**

Since the chemical inputs and location are essentially the same as the Raffinate Splitter, we will not clear data but update entries as needed.

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Case Study – BP Texas City

Equipment Input and Process Conditions- Reboiler

For illustration, assume the fired heater consists primarily of 4 inch tubes with a total volume of 8000 gal. Use 100 psig for the MAWP, 400 C as the combustion gas temperature, and 10,000 gal/min circulation rate. Limit the total inventory to liquid in the reboiler, piping and bottom of the Raffinate Splitter, roughly 20,000 gal.

Select **Save Inputs to Equipment Table** (blue macro button)..

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Case Study – BP Texas City

Suggested Scenarios for Reboiler – Fired Heater

Scenario Type	Scenario Comments	Parameters and Description	Initiating Event (Cause)	Initiating Event Description	Loss Event	Outcome	Existing Safeguards	Recommendations	Further Analysis
Blockage with Thermal Expansion	Thermal Expansion of hydrocarbon full equipment leading to excessive pressure	Pressure-High	BPCC instrument Loop Failure	Failure of Temperature Control	Equipment Damage	Process Damage or Business Loss			Yes
Drain or Vent Valve Open	Drain or Vent Valve not closed following maintenance, leading to overpressure	Pressure-High	BPCC instrument Loop Failure	Failure of Temperature Control	Equipment Damage or Fire Conditions	Chemical Exposure, Plant Fire or Release			No
Excessive Heat Input - Heat Transfer	Vapor Pressure plus and overpressure instrument working pressure or Relief Set Pressure adjustment or missing Media Temp ensure	Pressure-High	BPCC instrument Loop Failure	Failure of Temperature Control	Equipment Damage or Fire Conditions	Chemical Exposure, Plant Fire or Release, Equipment Emission		Additional Evaluation for the Equipment Failure	Yes
Loss of Feed Level - Feed Equipment	Control loop and recycle loop not working upon reboiler feed into hot dry unit	Pressure-Low	BPCC instrument Loop Failure	Failure of Pressure Control	Equipment Damage or Fire Conditions	Chemical Exposure, Plant Fire or Release, Equipment Emission			Yes
Control or Backflow	Backflow to Drums or Heat Tank resulting in Over or Overpressure Failure	Pressure-High	BPCC instrument Loop Failure	Failure of Temperature Control	Equipment Damage or Fire Conditions	Chemical Exposure, Plant Fire or Release, Vapor Cloud Emission, Equipment Emission			Yes
Vacuum Damage	Equipment is used for Full Vacuum	Pressure-Low	BPCC instrument Loop Failure	Failure of Pressure Control	Cracks or Tripping Incidents Not				

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Risk Analysis Screening Tools (RAST) Case Study – BP Texas City

Enter information for additional equipment associated with the Raffinate Splitter. Enter the Reboiler. As a gas-fired unit, the reboiler will consist of two equipment items, a fired process heater and a combustion unit.

- Enter:
- Equipment Identification: **Reboiler – Combustion Unit**
 - Equipment Type: select, **Fired Equipment – Combustion Unit**
 - Location: **Outdoors**

Again, the chemical inputs and location are essentially the same as the Raffinate Splitter, we will not clear data but update entries as needed.

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Case Study – BP Texas City Equipment Input and Process Conditions- Reboiler

For illustration, assume the combustion unit is approximately 10,000 ft³ and operates under slight vacuum. Use a MAWP of 1 psig and a maximum of 1000 standard ft³/min fuel as natural gas.

Select **Save Inputs to Equipment Table** (blue macro button)..

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Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – BP Texas City

Suggested Scenarios for Reboiler – Combustion Unit

<< Go To Main Menu

Update List

Create User Scenario

Suggested Scenarios from the RAST Library

Evaluation Node: **Node Design Intent Summary**

Plant Section = BP Texas City
Equipment Type = Fired Equipment -
Equipment Tag = Reboiler - Combustion Unit

Reboiler - Combustion Unit is a Fired Equipment - Combustion Unit containing Methane that operates at 20 C and 3 psig. The volume is 10000 gal with a maximum allowable working pressure of 1 psig. The maximum level or flow rate is 1000 gal/min.

Scenario in gray (not suggested) to be excluded for HAZOP or HAZID under 20 hours. Scenario in blue (not suggested) to be excluded for HAZOP or HAZID under 20 hours.

Potential Outcome / Evaluate Frequency

Death	0
Major Injury	0
Minor Injury	0
Property Damage	0
Environmental Damage	0

Go To Scenario Results >


Update Input this worksheet

Clear Input this Worksheet

Save Input to Equipment Table

Scenario Type	Scenario Comments	Parameters and Deviation	Initiating Event (Cause)	Initiating Event Description	Loss Event	Outcome	Existing Safeguards	Recommendations	Further Analysis
Fuel Accumulation during Light Off	Accumulation of unburned fuel may cause an unburned fuel or explosion. The safety devices should be in place during light off.	Flow High	EFCD Instrument Loop Failure	Failure of Pressure Fuel Flow control system in conjunction with gas burner for manual ignition. (See section for manual ignition.)	Equipment Failure - Detonation	Risk: Fire or Explosion		Review and manage to the fire burner management program. Such that the fuel analysis is not needed.	No
Fuel Accumulation during Operation	Accumulation of unburned fuel in a hot combustion chamber where components may be above the auto-ignition temperature.	Flow High	EFCD Instrument Loop Failure	Failure of Combustion Air Flow with Continued Addition of Fuel	Equipment Failure - Detonation	Risk: Fire or Explosion			No
Fuel Accumulation when Down	Accumulation of unburned fuel in a cold combustion chamber may cause an unburned fuel or explosion.	Flow High	EFCD Instrument Loop Failure	Failure of Fuel or Air Flow with Low level on air	Equipment Failure - Detonation	Risk: Fire or Explosion			Yes
High Fuel Flow or Spray Current	Feeding more fuel than expected may result in equipment damage if conditions are uncontrolled for an extended period of time.	Flow High	EFCD Instrument Loop Failure	High Pressure Fuel or Control Flow causing overflowing and damage to the combustion chamber	Equipment Damage	Property Damage or Business Loss			No

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Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – BP Texas City

Suggested Scenarios for Reboiler

WORKING WITH YOUR EVALUATION TEAM:

- Review the suggested list of scenarios. Do these represent what you would expect for a fired reboiler?
- Are there scenarios that have been “screened out” (shown in gray) that should be considered?
- Are there scenarios that do not apply? (Overflow of the deaerator may not apply as this unit is not a steam boiler. If so, this scenario would be recommended to be omitted from further evaluation.)
- Are there scenarios missing? (Possibly similar scenarios with different Initiating Events)

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Case Study – BP Texas City Suggested Scenarios for Reboiler

WORKING WITH YOUR EVALUATION TEAM:

- Do you agree with the “worst” Consequence (Tolerable Frequency Factor) for the scenario listed?
- Utilize an Appropriate Hazard Evaluation Technique (HAZOP, What If, etc.) to capture additional scenarios.
- Capture existing Safeguards and Recommendations for each Scenario. Note the Dates and Names of participants in the Study.
- Select which Scenarios warrant more detailed Risk Evaluation (such as Layers of Protection Analysis).

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Case Study – BP Texas City Consequence Analysis

For the Raffinate Splitter, select **Overfill Release** as the Loss Event. This represented a “worst” Consequence for the unit with a Tolerable Frequency Factor of 5. Note that a Vapor Cloud Explosion was listed as a potential Incident Outcome.

The distance to 1 psi overpressure is estimated at 273 m and overpressure at the distance to the wooden trailers is estimated at 3.2 psi.

CONSEQUENCE SUMMARY		RAST Version 4.1		Date:
Loss Event for: Distillation, Raffinate Splitter Containing Pentane (n-)				
Release Location: <input type="checkbox"/> Outdoors <input checked="" type="checkbox"/> Inside <input type="checkbox"/> Inside with Personnel Present				
Airborne Quantity Summary:				
Release Temperature, C	104.0	Auto	Probability	
Release Pressure, barg	1.24	On-Flow	Event PDE	
Physical State at Release Conditions	Liquid	Flash	Fire PDE	
Heat Input, kcal/min	3.703	Chemical	Exposure PDE	
Equivalent Hole Size, cm	55.25	Physical	Exposure PDE	
Release Rate, Kg/sec	60.00			
Release Duration, min	0.0			
Total Release Quantity, kg	0.0			
Spill Distance, m	0.0			
Plume + Aerosol Evaporation Fraction	0.000			
Estimated Aerosol Droplet Diameter, micron	185			
Pool Area, sq m	6580.0			
Estimated Pool Temperature, C	23.1			
Maximum Pool Evaporation Rate, kg/sec	15.1031			
Total Airborne Rate, kg/sec	0.0			
Total Airborne Quantity, Kg	100226.4			
Airborne Quantity Concentration:				
Mole Fraction Pentane (n)	0.096			
Mole Fraction Hexane	0.186			
Mole Fraction Isobutane	0.295			
Mole Fraction Hydrogen	0.295			
Mole Fraction Carbon (n)	0.077			
Mass Fraction Pool Gas (at Max T = 20)				
ERPG-2 for Vapor Composition, ppm by volume	1718.0			
ERPG-3 for Vapor Composition, ppm by volume	11316.0			
LC-50 Concentration, ppm by volume	2053.0			
One-hour ERPG-3 for Vapor Composition, ppm by volume	10443.0			
One-hour LC-1 Concentration, ppm by volume	22887.0			
LFL for Vapor Composition, % by volume	1.15			
Dispersion Summary (Atmospheric Stability Class D with 3 m/sec wind except as noted):				
Max Distance to Time-Scaled ERPG-2, m	830.0			
Max Distance to Time-Scaled ERPG-3, m	2053.0			
Max Distance to 1% Lethality for 15' worker, m	1384.0			
Max Distance to Estimated LC-50 Concentration, m	319.0			
Max Distance to Flash Fire Impact or 0.5 LFL, m	1000000.0			
Maximum Ground Elevation Concentration, ppm	781.0			
Concentration at Distance to Release Line, ppm	1000000.0			
Concentration at Distance to Unrestricted Work Area, ppm	2450.0			
Concentration within Occupied Bldg 1, ppm				
Concentration within Occupied Bldg 2, ppm				
Concentration within Unbounded Process Area, ppm				
Conc within Enclosed Process Area w/ventilation, ppm				
Explosion Summary:				
VCE or Building Explosion Energy, kcal	2.4E+07			Probability of Ignition (POI)
VCE or Building Explosion Distance to 1 psi Overpressure, m	283.4			<input type="checkbox"/>
Maximum Distance to LFL Concentration, m	203.9			Potential Explosion Impact to Occupied Building
Blat Overpressure at Center of Occupied Building 1, psi	3.2			<input type="checkbox"/>
Blat Overpressure at Center of Occupied Building 2, psi	0.0			<input type="checkbox"/>
Distance to Severe Thermal Radiation Impact, m				Probability of Explosion (POX)
Rupture Explosion Energy, kcal				<input type="checkbox"/>
Distance to Direct Blast Impact (10 psi), m				<input type="checkbox"/>
Maximum Fragment Range, m				<input type="checkbox"/>
Rupture Distance to 1 psi Overpressure, m				<input type="checkbox"/>
Rupture Overpressure at Center of Occupied Building 1, psi	0.0			<input type="checkbox"/>
Rupture Overpressure at Center of Occupied Building 2, psi	0.0			<input type="checkbox"/>
Incident Outcome and Consequence Summary:				
Impact Assessment with Equipment at a Remote Location and no Personnel routinely nearby	Exceeds Threshold Criteria			LOPA Tolerable Frequency Factors Based On Estimated Number of People Impacted
Offsite Toxic Release based on Toxic Inhalation Method and 1000 m to Facility Line with potential for 0 people seriously impacted	No			NA
Onsite Toxic Exposure Duration 600 sec	No			NA
Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 211 m	5			5
Chemical Exposure based on Thermal Hazards and Spray Distance of 0 m	NA			NA
Equipment/Rupture Direct Blast Impact based on Distance to 10 psi	NA			NA
Onsite Thermal Radiation Impact based on Distance from Fireball	NA			NA
Number of Potential Serious Toxic Impacts Outside 0.8 people	NA			NA
Number of Potential Serious Flash Fire/Facetal Impacts Outside 0.8 people	NA			NA
Occupied Building Toxic Impact	No			NA
Number of Potential Serious Impacts for Building 1	0 people			0
Number of Potential Serious Impacts for Building 2	0 people			0
Occupied Building Impact from Vapor Cloud Explosion	Yes			6
Number of Potential Serious Impacts for Bldg 1	17.1 people and 0 offsite			17.1
Number of Potential Serious Impacts for Bldg 2	0 people and 0 offsite			0
Occupied Building Physical Explosion	No			NA
Number of Potential Serious Impacts for Building 1	0 people and 0 offsite			0
Number of Potential Serious Impacts for Building 2	0 people and 0 offsite			0
Environmental Impact	NA			NA

The number of people severely impacted (likely fatalities) within the wooden trailers is estimated at 18 of the 20 occupants plus 6 people outdoors.

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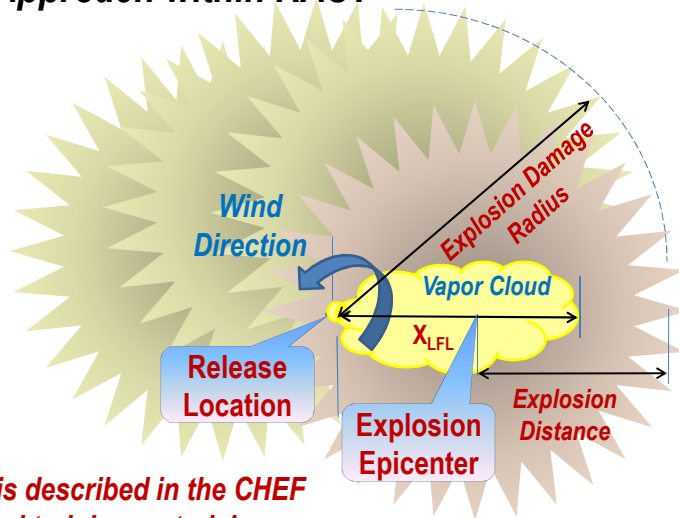
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Vapor Cloud Explosion Simple Modeling Approach within RAST

The entire vapor cloud is considered a single Potential Explosion Site with epicenter at the center of the flammable cloud ($0.5 X_{LFL}$).

An single overall level of congestion and confinement for the entire cloud is used.

Wind direction is assumed toward greatest population or building with highest occupancy.



Methodology is described in the CHEF Manual and training materials

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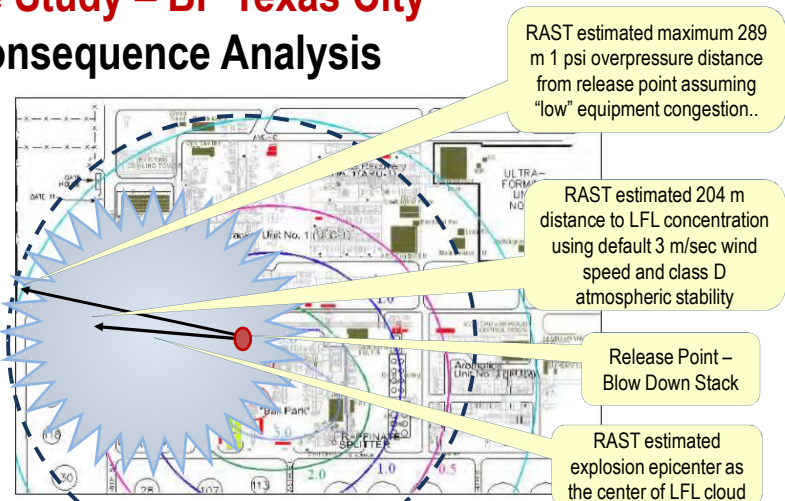
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Case Study – BP Texas City Consequence Analysis

A simplification in RAST is wind direction toward the highest population. This is quite reasonable in Risk Analysis where the wind direction is unknown.

In the actual incident, the wind direction was toward the southeast rather than west toward the wooden trailers.

Wind Direction represents a key difference between estimates for Risk Analysis versus Incident Investigation. *Blast overpressure at the wooden trailers would likely have been higher if wind direction was toward the trailers.*



REPORT NO. 2005-04-I-TX , US Chemical Safety Board,
 Figure H-2.Blast-Overpressure Map

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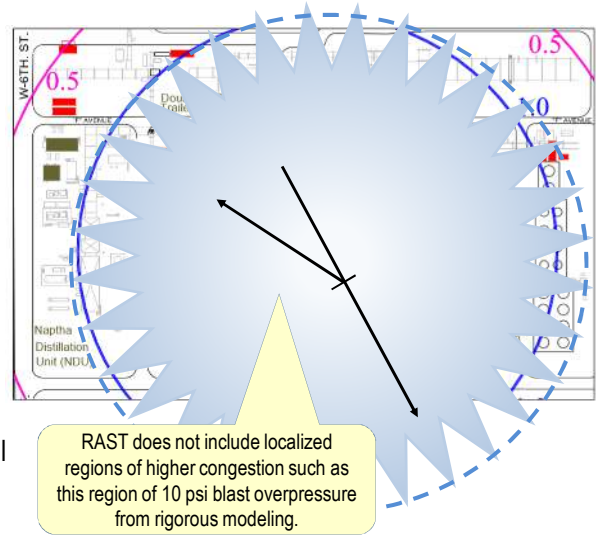
Case Study – BP Texas City

Consequence Analysis

If we account for wind direction, the trailers would be roughly 115 m from the RAST estimated explosion epicenter versus an epicenter nearly 50 m beyond the trailers. The estimated overpressure at the trailers would be 1.6 psi (versus 2.5 psi estimated by CSB) and number of occupants severely impacted (fatalities) would be approximately 12.

Adjusting for wind direction, the 1 psi overpressure contour from RAST (dashed blue line) closely approximates the detailed modeling in the CSP report (the solid blue line). However **RAST does not consider localized regions of higher congestion** leading to regions of higher blast overpressure. The CSB report also noted that flow from the safety valves may have been 8500 gal/min for 6 minutes until the valves closed versus the 1500 gal/min feed rate which would increase the distance to 1 psi blast overpressure.

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Case Study – BP Texas City

Risk Analysis / Layers of Protection Analysis (LOPA)

Version: 1.2

Equipment Loaded: Receiver - Combustion Unit

LOPA Worksheet

Clear Results

Scenario / Cross Ref	Description of Undesired Consequence	LOPA Tolerable Frequency Factor (chemicals, quantity involved, and basis for calculations)	Initiating Event	Probability of Ignition	Revised Probability of Ignition	Probability of Exposure (Presence Factor)	Time to Evacuate	Notes
8.01	Distillation, Refinate Splitter, is involved in an Overfill - Flooding or Plugging event resulting in an Overfill Release with subsequent 142000 kg airborne release of a Pentane (n) Mixture at an airborne release rate of 6690 Lb./min. Estimated time to relief set pressure is 5 min.	6.0	Failure of Flow/Level Control with Flooding of Column	0.0	0.0	5	4	Outdoor Release of 6690 Lb./min Flammable Material with Distance to LFL of 170 m. POX

Select Loss Event of **Overfill Release** with Incident Outcome of **Vapor Cloud Explosion** for analysis in LOPA ("Yes"), then select LOPA Worksheet

The initial Initiating Event description notes flooding of the column where this case may be better described simply as overfill. The study team would update descriptions for clarity.

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Case Study – BP Texas City

Risk Analysis / Layers of Protection Analysis (LOPA)

< Back to Scenario		Results	Expand All	Collapse All	Scenario Definition		
Protection Gap	Scenario / Cross Ref	Description of Undesired Consequence → Possible	LOPA Tolerable Frequency Factor (the initials, quantity involved, and basis for calculations)	Initiating Event → Human Error	Probability of Ignition →	Probability of Exposure (Presence Factor) →	Time at Risk or Other Enabling Condition / Conditional Modifier
Revised	8.01	Distillation, Raffinate Splitter, is involved in an Overflow - Flooding or Plugging event resulting in an Overflow Release with subsequent 155000 kg airborne release of a Pentane (n-) Mixture at an airborne release rate of 6700 Lb/min. Estimated time to relief set pressure is min. IPL Status? →	This incident could result in a Vapor Cloud Explosion impacting on site personnel at a Explosion Distance to 1 psi Overpressure of 289 m including Explosion Overpressure at Low Strength Occupied Bldg 1 (psi) of 3.2 psi with the potential for Seventy Level-5	Failure of Flow or Level Control with Flooding of Column	Outdoor Release of 6700 Lb/min Flammable Material with Distance to LFL of 204 m-POX		
Instrumented Protection Credits Taken							
Safety Analysis			Tolerable Frequency Factor 6	BPCS Instrument Loop Failure	POI Probability Factor 8		
0.0			6.0	1.0	0.0	0.0	

The probability of ignition in RAST is estimated at greater than 0.1 due to the large size of the flammable cloud footprint. In addition, the probability of explosion (POX) is taken as the probability of ignition since the likelihood an ignited cloud will result in a vapor cloud explosion is not known. Hence, there is no risk reduction credit taken.

Case Study – BP Texas City

Risk Analysis / Layers of Protection Analysis (LOPA)

Not Allowed								Notes / Comments	Issues to Resolve
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		
PCV-5002 Pressure Control for Raffinate Reflux Drum	LHS-5020 Blowdown Drum High Level Alarm	LHS-5102 Raffinate Splitter High Level Alarm with automated action to stop feed			Residing personnel in locations adjacent to the unit during startup may adequately mitigate the consequence to meet LOPA criteria for IPL.				
BPCS Independent of Initiating Event	Human Response to Abnormal Condition Alarm > 14 hr to respond	SIS - SIL 1			Restricted Access to a Hazardous Area				
1	1	1			1				

The existing safeguards were close to sufficient for managing this scenario to a tolerable risk level had they been adequately maintained and some actions automated rather rely only on operator response to an alarm. In addition to those listed in the LOPA worksheet, several other alarms existed (such as high pressure) that may have contributed to reducing the overall scenario frequency if the potential for column overflow would have been recognized.

Risk Analysis Screening Tools (RAST) Case Study – BP Texas City

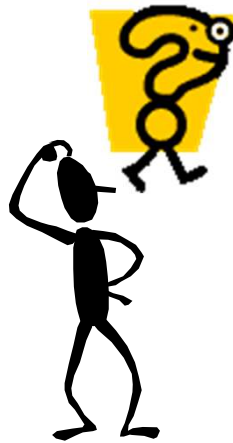
Risk Analysis and Incident Investigation often use similar methods to better understand the scenario. Risk Analysis “anticipates” what could go wrong and what the potential “worst” consequences may be. For Incident Investigation, the Incident Outcome and Consequences are known in addition to the actual weather conditions and wind direction.

For the Raffinate Splitter, RAST did suggest column overfill as one of many scenarios to consider. RAST also recognized that a Vapor Cloud Explosion could be a feasible Incident Outcome for an Overfill loss event. RAST was conservative in estimating blast damage as actual wind direction was not toward the wooden trailers. However, the “order of magnitude” estimate of consequences seems reasonable. The estimated number of people severely impacted in RAST was higher than the actual incident (24 versus 15 fatalities and 66 seriously injured).

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Questions?



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