

## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum Company

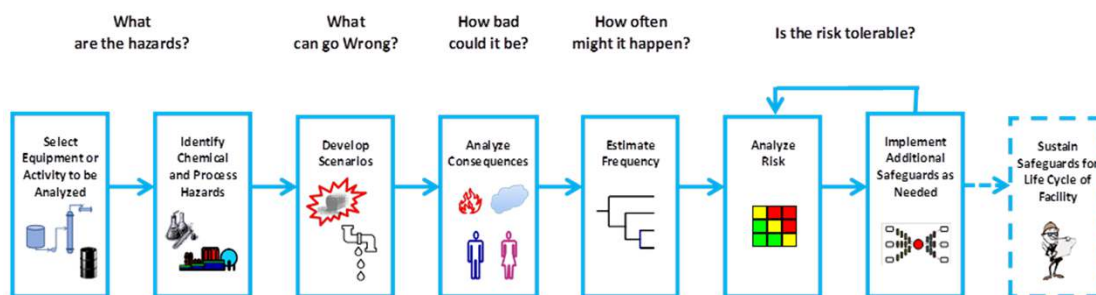


**Explosion and Fire  
 Pasadena, Texas  
 October 23, 1989**

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

Slide - 1

## Case Study – Phillips Petroleum Hazard Identification and Risk Analysis (HIRA) Study



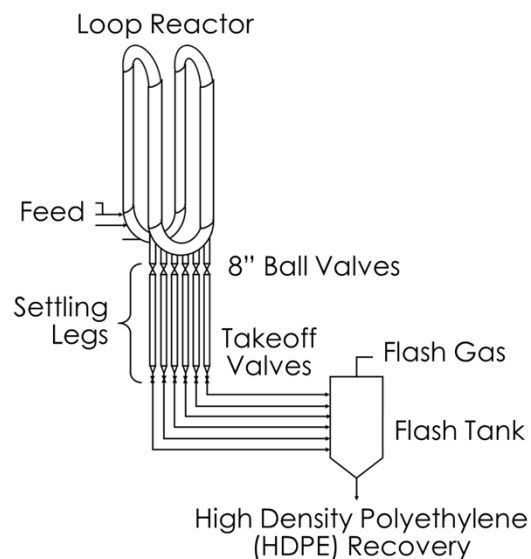
Begin by **Identifying the Equipment or Activity**. RAST uses the operation of a specific equipment item containing a specific chemical or chemical mixture to define the activity. Entries include chemical data, equipment design information, operating conditions, and plant layout.

Slide - 2



## Case Study – Phillips Petroleum Process Description

High-density polyethylene (HDPE) production occurred inside two process units at the site (Plant 4 and Plant 5). The process circulated through an arrangement of 30-inch diameter pipes mounted vertically in 150-foot tall, continuous, ring-like structures called “loop” reactors. Six loop reactors were operating in Plant 5. The loop reactors contained the catalytic reaction process that manufactured HDPE, starting with diluting ethylene in an isobutane solvent feed.

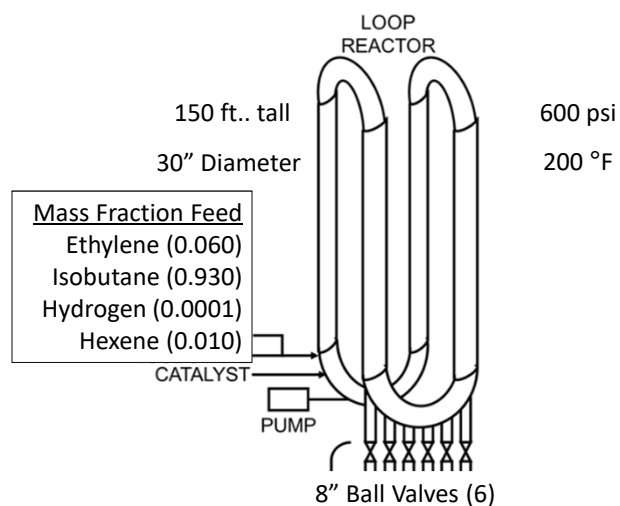


Slide - 3



## Case Study – Phillips Petroleum Process Description

Hydrogen and hexene were also added to adjust final product qualities for a specified product. Thus, the gas mixture in the loop reactor was flammable and easily ignitable, especially at the reaction's operating conditions: 600 psi (4,100 kPa) and 180°F–230°F (82°C–110°C). The catalyst accelerated the conversion rate of ethylene monomer polymerization into the larger and heavier HDPE molecules. As the reaction product gained mass in the loop reactor, it eventually became heavy enough to drop out of the circulating reaction mixture through settling legs at the bottom of one of the loops.



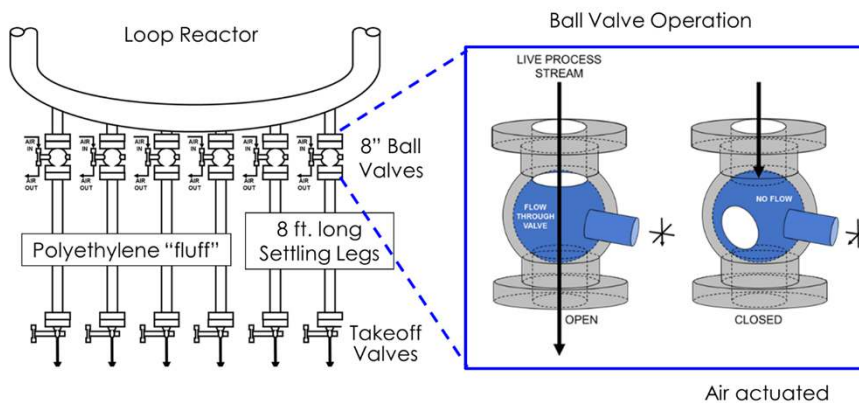
**The Process Conditions for the Loop Reactor**

Slide - 4

## Case Study – Phillips Petroleum Process Description

Six settling legs were attached to the bottom of each loop reactor. Each settling leg consisted of a flanged, 8-inch diameter pipe connected to an air-operated, tight-shutoff, 8-inch ball valve. Beyond this ball valve was an 8-foot length run of straight pipe where the reaction product called polyethylene “fluff,” collected. The 8-inch ball valves were to remain open during production. This configuration allowed polyethylene fluff to drop into the settling legs.

Below the settling leg was a takeoff valve where the fluff would pass on its way into the flash tank. The settling legs were the interface between the high-pressure (loop reactor) and low-pressure (flash tank) process sections. The intent of loop reactor operation was to deliver polyethylene fluff into the flash tank, where it was removed and later pelletized.



Slide - 5

## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

On the **Main Menu** worksheet, enter the equipment identification as the **Loop Reactor**, equipment type as **Reactor** and location as **Outdoors**.

**RAST**  
 Risk Analysis Screening Tools (V 3)  
 Latest Revision Date 3/19/20  
 Go to Revision Log >

Import from Previous Study    Import from RAST File  
 Merge Data from Another Study into this Study    Merge Data from Another File  
 Update Previously Saved Information    Go to Equipment Table >  
 Access LOPA Workbook from Scenario Results    Go To Scenario Results >  
 Update Notes and Comments for Entire Workbook    Go to Workbook Notes >

Select Default Units: English Units    SI Units    Study File: Risk Analysis Screening Tool V3 - Phillips 3.xlsm

Session Date: 3/20/2020    Participants: RAST Administrator

Equipment Identification = Loop Reactor  
 Equipment Type = Vessel/Tank  
 Equipment Location = Outdoors  
 Data Entry Status or Notes:

Enter Equipment Identification,  
 Equipment Type and Location

Select from pull-down menus

Slide - 6



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

On the **Main Menu** worksheet, select the Input Information buttons to add the minimum data for RAST to run its calculations.

Select from:  
**Chemical Data**  
**Equipment Parameters**  
**Process Conditions**  
**Plant Layout**

Incomplete minimum data entered (none at this point), RAST will not run

Slide - 7



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

On the **Chemical Data** worksheet, select **Ethylene** as “Key Chemical

Select Ethylene from pull-down list

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 %)
Ethylene					28.05	6600	40000	2.7
Sum =	0.00							

Slide - 8



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

On the **Chemical Data** worksheet, enter the chemical mixture that represents the hazards of the reactor's contents.

The representative composition used (weight fraction):

- 0.060 ethylene
- 0.930 isobutane
- 0.0001 hydrogen
- 0.0099 hexene

The operating pressure is 600 psig and the operating temperature is 200 F such that the physical state is "liquid" (essentially a boiling liquid inside the loop reactor).

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

Saturation temperature entered as Operating Temperature

Change units using Pull-down menus

Select other chemicals from pull-down list

Feed Wt. Fraction must sum to 1.0

**Chemical Data Input**

Equipment Identification: Loop Reactor  
 Equipment Type: Vessel/Tank  
 Location: Outdoors

Operating Temperature = 200 F  
 Operating Pressure (gauge) = 600 psi  
 Saturation Temperature = 206.5 F  
 Physical State = Liquid

Key Chemical: Ethylene  
 Reference:

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	ERP-2 (ppm)	ERP-3 (ppm)	LFL (vol %)
Ethylene	0.060		0.393	10.0830	28.05	6600	40000	2.7
isobutane	0.930		0.605	1.0000	58.1	800	4000	1.6
Hydrogen	0.000		0.001	16.1575	2.02	230000	400000	4.0
Hexene, 1-	0.010		0.001	0.1291	84.16	500	5000	1.2
Sum =	1.00							
Vapor Mixture Properties					40.1	1646.9	8444.9	2.1

Slide - 9



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

On the **Chemical Data** worksheet:

Save all input to Equipment Table

**Chemical Data Input**

Equipment Identification: Loop Reactor  
 Equipment Type: Vessel/Tank  
 Location: Outdoors

Operating Temperature = 200 F  
 Operating Pressure (gauge) = 600 psi  
 Saturation Temperature = 206.5 F  
 Physical State = Liquid

Key Chemical: Ethylene  
 Reference:

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	ERP-2 (ppm)	ERP-3 (ppm)	LFL (vol %)
Ethylene	0.060		0.393	10.0830	28.05	6600	40000	2.7
isobutane	0.930		0.605	1.0000	58.1	800	4000	1.6
Hydrogen	0.000		0.001	16.1575	2.02	230000	400000	4.0
Hexene, 1-	0.010		0.001	0.1291	84.16	500	5000	1.2
Sum =	1.00							
Vapor Mixture Properties					40.1	1646.9	8444.9	2.1

Slide - 10



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

Enter the equipment parameters on **Equipment Data** worksheet.

The Loop Reactor consists of four 30 in diameter loops 150 ft. tall. It has a total volume of roughly 3,240 cu. ft., a maximum allowable working pressure near 660 psig, pipe (“nozzle”) diameter of 8 in., an estimated wetted surface area of 2590 sq. ft., an estimated elevation from take-off valve to surface (ground) of 20 ft., and the “drain valve” diameter of 8 in (the take-off valve diameter).

Equipment Parameters		
Equipment Volume =	3240	cu ft
MAWP (gauge) =	660	psi
Full Vacuum Rated?		
Estimated High Temperature Failure =		C
Estimated Embrittlement Temperature =		C
Nozzle or Pipe Size =	8	in
Number of Flanges or Nozzles =		
Material of Construction		
Estimated Equip. Mass based on C. Steel	62202	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 =	1022	sq ft
User Equipment Max. Wetted Area =	2590	sq ft
Equipment Elevation to Surface =	20	ft
Drain Valve Size	8	in

The estimated equipment volume and estimated maximum allowable working pressure (MAWP)

Settling leg and ball valve diameter of 8 inches

Change units using Pull-down menus

Slide - 11



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

Enter the operating conditions on the **Process Conditions** worksheet.

Assume an ambient temperature of 70 F.

Since the contents of the loop reactor are at 600 psi, use the reported ~2 min release duration and a zero lb./min feed rate (deinventoried before more feed entered).

The percent of operating time is > 10% and there are frequent Cleanouts to remove settling leg logs.

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	Lb/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 Ethylene		
Operating Temperature =	200	F
Operating Pressure (gauge) =	600	psi
Physical State =		Liquid
Saturation Temperature =	206.5	F
Contained Mass =	31143	kg
Maximum Contained Mass =	38929	kg
Inventory for Reference =	38929	kg

Operating Procedures	
Percent of Time in Operation =	Greater than 10%
Frequent Turnaround or Cleanout?	Yes
Centralized Ventilation Shut-Off Bldg 1?	
Centralized Ventilation Shut-Off Bldg 2?	

Changed Inventory Limit to Lb units. Maximum Feed Rate of 0 Lb/min

Slide - 12



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

On the **Plant Layout** worksheet, data entered is based on ~300 ft. and population density of 0.0035 people/m<sup>2</sup> in the immediate, highly congested area at the time of the incident. The Development Reactor building, made of typical construction, is ~250 ft. away and contains 1 Person.

The administration building is one half mile (2,620 ft.) away and contains 40 People.

<b>Equipment Identification:</b> Loop Reactor					
<b>Equipment Type:</b> Vessel/Tank					
<b>Location:</b> Outdoors					
<b>Location Information</b>					
Distance to Property Limit or Fence Line =	300	ft			
Furthest Distance to Fence Line (> 91.44 m) =		m			
Max. Onsite Outdoor Population Density	0.0035	people/m <sup>2</sup>			
Personnel Routinely in Immediate Area?	Yes				
Distance to end of Offsite Zone 1		m			
Offsite Population Density within Zone 1		people/m <sup>2</sup>			
Offsite Population Density Beyond Zone 1		people/m <sup>2</sup>			
Effective Egress from Work Area?					
<i>Access for Emergency Services?</i>					
Degree of Equipment Congestion in Area?	High				
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			
<i>Automated EBVs to limit spill quantity?</i>					
<b>Occupied Building Data</b>					
Occupied Building 1 Name =	Reactor Develop Bldg.				
Distance to Occupied Bldg 1 or Area =	250	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 =	1				
Occ Bldg 2 in Same Wind Direction?	Yes				
Occupied Building 2 Name =	Administration Building				
Distance to Occupied Bldg 2	2620	ft			
Elevation of Occ Bldg 2 Ventilation Inlet =		m			
Distance to Center of Occ Bldg 2 =		m			
Occupied Bldg 2 Type =					
Occupied Bldg 2 Ventilation Rate =		changes/hr			
Number of Occupants Bldg 2 =	40				

Change units using Pull-down menus

Slide - 13




## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

Equipment Identification =	Loop Reactor	All Min. Inputs satisfied.
Equipment Type =	Vessel/Tank	
Equipment Location =	Outdoors	
Data Entry Status or Notes:		
Plant Section or Sub-Area:		
P&ID Number:		
<b>Input Information</b>		Input data sufficient to proceed with analysis
Chemical Data Input	<input checked="" type="checkbox"/>	
Equipment Parameter Input	<input checked="" type="checkbox"/>	
Process Conditions Input	<input checked="" type="checkbox"/>	
Plant Layout Input	<input checked="" type="checkbox"/>	
Reaction Input and Evaluation	<input type="checkbox"/>	
Input Guidance Information	<input type="checkbox"/>	
<b>Evaluation</b>		
Fire & Chem	<input type="checkbox"/>	
Hazards & Consequences	<input type="checkbox"/>	
Scenario Identification	<input type="checkbox"/>	
Effluent Screening	<input type="checkbox"/>	
Pool Fire Evaluation	<input type="checkbox"/>	
Input Data Sufficient to Proceed with Analysis		

At this point, every "Minimum Input" box on the **Main Menu** should be filled in ("green")

Slide - 14

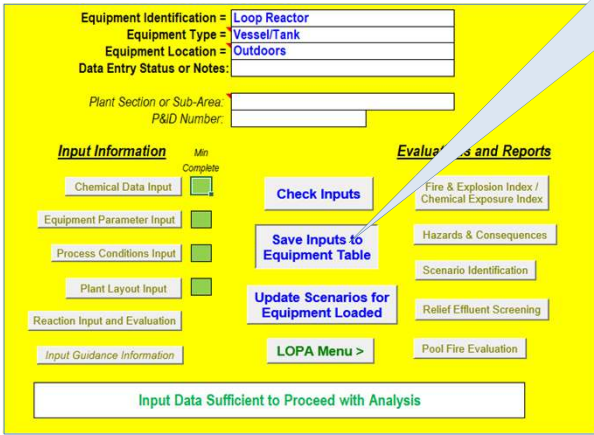


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## Risk Analysis Screening Tool (RAST)

### Case Study – Phillips Petroleum



The screenshot shows the RAST input form with the following details:

- Equipment Identification = Loop Reactor
- Equipment Type = Vessel/Tank
- Equipment Location = Outdoors
- Data Entry Status or Notes: (empty)
- Plant Section or Sub-Area: (empty)
- P&ID Number: (empty)

Buttons visible include: Check Inputs, Save Inputs to Equipment Table, Update Scenarios for Equipment Loaded, LOPA Menu >, and Input Data Sufficient to Proceed with Analysis.

Save Inputs to Equipment Table


Warning

Data already exists for this equipment tag in table. Are you sure you want to overwrite inputs? Click OK to overwrite data.

OK Cancel

For Loop Reactor, "OK"

Slide - 15

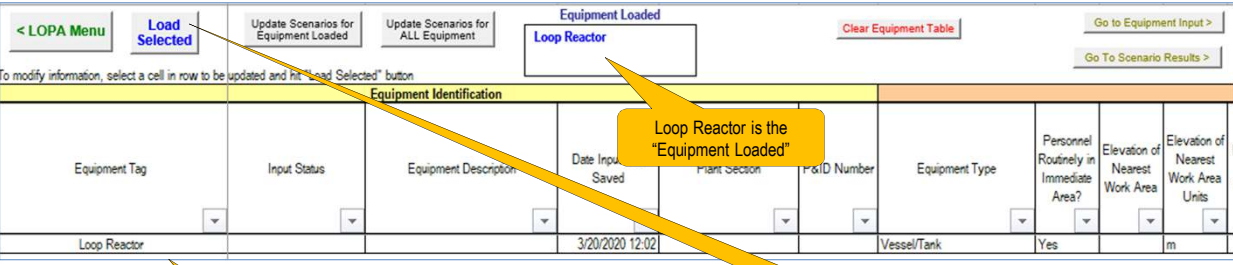


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## Risk Analysis Screening Tool (RAST)

### Case Study – Phillips Petroleum

The **Equipment** worksheet will open. All Input Information will be stored in the Equipment Table in a single row identified by a unique Equipment Identification or Tag.



The screenshot shows the Equipment Table interface with the following data row:


Equipment Tag	Input Status	Equipment Description	Date Input Saved	Plant Section	P&ID Number	Equipment Type	Personnel Routinely in Immediate Area?	Elevation of Nearest Work Area	Elevation of Nearest Work Area Units
Loop Reactor			3/20/2020 12:02			Vessel/Tank	Yes		m

Annotations in the screenshot:

- Yellow callout: "Loop Reactor is the 'Equipment Loaded'" pointing to the Equipment Loaded field.
- Yellow callout: "Click on 'Load Selected'" pointing to the Load Selected button.
- Yellow callout: "Input Data for an Equipment Item stored in one row by Equipment Tag" pointing to the first row of the table.

Slide - 16





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## Risk Analysis Screening Tool (RAST)

### Case Study – Phillips Petroleum

Screenshot of Scenario List suggested by the potential scenarios in the RAST Library. Focus on the "Loss Event" column "Drain or Vent Leak."

<< Go To Main Menu

Update List

Create User Scenario

**Suggested Scenarios from the RAST Library**

**Evaluation Node:** Chlorine Rail Car is a Tank Truck/Rail Car/Trailer containing Chlorine that operates at 25 C and 8 bar. The volume is 17300 gal with a maximum allowable working pressure of 375 psi. The maximum lead or flow rate is 0 kg/min.

**Node Design Intent Summary:**

*Scenarios in gray were suggested to be evaluated for reasons noted under Scenario Comments. Study Team should review each to determine if excluding from Risk Analysis is appropriate.*

Session Date: 3/20/2020    Session Participants: RAST Administrator

Go To Scenario Results >

Update Input this worksheet

Clear Input this Worksheet

Save Input to Equipment Table


Scenario Type	Scenario Comments	Parameters and Deviat	Initiating Event (Cau	Initiating Event Description	Loss Event	Outcome	Off-Site Toxic Release	On-Site Toxic Release	Indoor Toxic Release	Toxic Infiltration	Chemical Exposure	Flash Fire or Fireball	Vapor Cloud Explosion	Equipment Failure	Equipment Explosion	Property Damage or Blast	Environmental Damage	Existing Safeguards	Recommendations	Further Analysis
Drain or Vent Valve Open	Drain or Vent Valve left open following infrequent maintenance, purging or clearing	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	Chemical Exposure, Flash Fire or Fireball, Vapor Cloud Explosion						4	6							Yes
Excessive Heat Input / Pool Fire Exposure	Chemical complex vaporizes upon release, such that no liquid pool is formed	High	IEF=2, pending more detailed evaluation	Leak of Flammable Material or Material above its Flash Point which may ignite	Vapor Relief Vent - Fire	Flash Fire or Fireball, Vapor Cloud Explosion								6		6				

This suggested scenario applies to this case study

Select "Yes" for Further Analysis

Then "Save to Equipment Table"

Slide - 17



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## Risk Analysis Screening Tool (RAST)

### Case Study – Phillips Petroleum

Once saved to **Equipment Table**, return to **Main Menu** for results by selecting **Equipment Input**, then **Main Menu**.

< LOPA Menu

Load Selected

Update Scenarios for Equipment Loaded

Update Scenarios for ALL Equipment

Equipment Loaded: Loop Reactor

Clear Equipment Table

Go To Equipment Input >

Go To Scenario Results >

To modify information, select a cell in row to be updated and hit "Load Selected" button

Equipment Tag	Input Status	Equipment Description	Date Input Last Saved	Plant Section	P&ID Number	Equipment Type	Personnel Routinely in Immediate Area?	Elevation of Nearest Work Area	Elevation of Nearest Work Area Units
Loop Reactor						Vessel/Tank	Yes		ft

<< Go To Main Menu

< Go To Chem Data

Equipment Input

Save Input to Equipment Table

Equipment Identification: Loop Reactor

Equipment Type: Vessel/Tank

Location: Outdoors

Select Equipment Input

Select Main Menu

Slide - 18



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

From the **Main Menu** worksheet:

Equipment Identification = Loop Reactor  
 Equipment Type = Vessel/Tank  
 Equipment Location = Outdoors  
 Data Entry Status or Notes:   
 Plant Section or Sub-Area:   
 P&ID Number:   
**Input Information** Min Complete  
 Chemical Data Input   
 Equipment Parameter Input   
 Process Conditions Input   
 Plant Layout Input   
 Reaction Input and Evaluation   
 Input Guidance Information   
**Evaluations and Reports**  
 Fire & Explosion Index / Chemical Exposure Index  
 Hazards & Consequences  
 Scenario Identification  
 Relief Effluent Screening  
 Pool Fire Evaluation  
 LOPA Menu >  
 Check Inputs  
 Save Inputs to Equipment Table  
 Update Scenarios for Equipment Loaded  
 Input Data Sufficient to Proceed with Analysis

Evaluated Hazards and Consequences

Slide - 19



## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

From the **Consequence Summary** worksheet (scroll down).

For the Loop Reactor, select **Full Bore Pipe or Nozzle Leak** as the Loss Event drop down menu. Note that a Vapor Cloud Explosion was listed as a potential Incident Outcome with RAST's *maximum value* at  $2.4 \times 10^7$  kcal.

Explosion Summary:

With the release point at the bottom of the Loop Reactor, the distance to 1 psi overpressure is estimated at 2,215 ft. (675 m) and the distance >10 psi overpressure is within 250 ft. (the distance selected for Building 1).

**CONSEQUENCE SUMMARY**  
 RAST Version 3 Date: 3/20/2020  
 Loss Event for: Vessel/Tank: Loop Reactor Containing Ethylene: Full Bore Pipe or Nozzle Leak  
**Explosion Summary:**  

VCE or Building Explosion Energy, kcal	2.4E+07	Probability of Ignition (POI)	<input type="checkbox"/>
VCE or Building Explosion Distance to 1 psi Overpressure, m	674.2	Potential Explosion Impact to Occupied Building	
Maximum Distance to LFL Concentration, m	98.7		
Blast Overpressure at Center of Occupied Building 1, psi	> 10 psi	Probability of Explosion (POX)	<input type="checkbox"/>
Blast Overpressure at Center of Occupied Building 2, psi	0.8		
Distance to Severe Thermal Radiation Impact, m			
Rupture Explosion Energy, kcal			
Distance to Direct Blast Impact (10 psi), m			
Maximum Fragment Range, m			
Rupture Distance to 1 psi Overpressure, m			
Rupture Overpressure at Center of Occupied Building 1, psi	0.0		
Rupture Overpressure at Center of Occupied Building 2, psi	0.0		

Select Full Bore Pipe or Nozzle Leak

Slide - 20

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## Risk Analysis Screening Tool (RAST) Case Study – Phillips Petroleum

Scroll down the **Consequence Summary** worksheet.

Incident Outcome and Consequence Summary

Number of Serious Impacts Outside, >20

Number of Serious Impacts For Building 1, one occupant at time of explosion

CONSEQUENCE SUMMARY		
Loss Event for: Vessel/Tank: Loop Reactor Containing Ethylene :		Full Bore Pipe or Nozzle Leak
RAST Version 3		Date: 3/20/2020
<b>Incident Outcome and Consequence Summary:</b>		
Impact Assessment with Personnel routinely in the immediate area	Exceeds Threshold Criteria	<b>LOPA Tolerable Frequency Factors Based Estimated Number of People Impacted</b>
Offsite Toxic Impact based on Toxic Integration Method and 91.44 m to Fence Line	Yes	NA
Onsite Toxic Impact based on Distance to LC-50 Concentration of 0 m	No	NA
<i>Outdoor Toxic Exposure Duration 113 sec</i>		
Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 166 m		6
Chemical Exposure based on Dermal or Thermal Hazards and Spray Distance of 1 m		4
Equipment Rupture Direct Blast Impact based on Distance to 10 psi		
Onsite Thermal Radiation Impact based on Distance from Fireball		
<i>Number of Potential Serious Toxic Impacts Onsite: 0 people</i>		
<i>Number of Potential Serious Flash Fire/Fireball Impacts Onsite: &gt;20 people</i>		
<i>Occupied Buildings Noted as in the Same Wind Direction</i>		
Occupied Building Toxic Impact	No	NA
<i>Number of Potential Serious Impacts for Building 1: 0 people</i>		
<i>Number of Potential Serious Impacts for Building 2: 0 people</i>		
Occupied Building Impact from Vapor Cloud Explosion	Yes	6
<i>Number of Potential Serious Impacts for Building 1: 1 people</i>		
<i>Number of Potential Serious Impacts for Building 2: 0 people</i>		
<i>1 psi Blast Overpressure Distance exceeds the Fence Line, Consider additional Offsite Impacts</i>		
Occupied Building Physical Explosion Impact	No	
<i>Number of Potential Serious Impacts for Building 1: 0 people</i>		
<i>Number of Potential Serious Impacts for Building 2: 0 people</i>		
Environmental Impact:		NA


Slide - 21

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## RAST Results Comparison Case Study – Phillips Petroleum

**Incident Impact**

- 23 fatalities (22 within 250 ft.. of the loop reactor)
- > 300 injuries
- Estimated 85,000 lbs were released and ignited within 2 min
- Blast force was estimated at 2.4 tons of TNT (another study estimated 24 tons)
- Vapor Cloud Explosion (VCE) registered 3.5 magnitude on the Richter scale
- Significant property damage



Slide - 22



## RAST Results Comparison Case Study – Phillips Petroleum

### Incident Impact

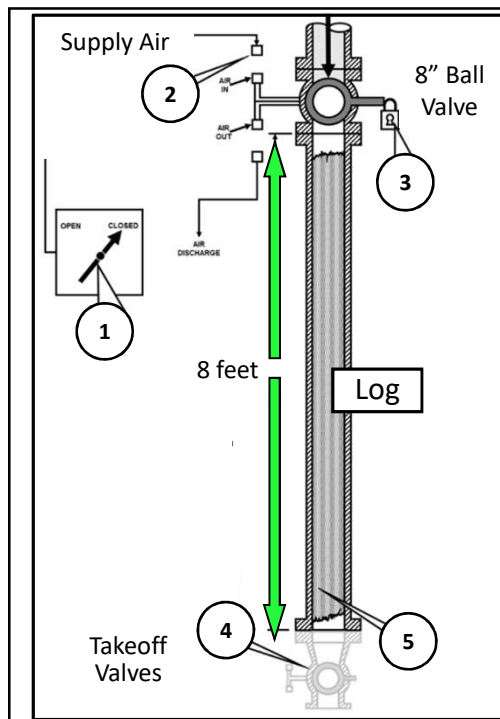
- 23 fatalities  
(22 within 250 ft.. of the loop reactor)
- 85,000 lbs were released
- Ignited within 2 min
- Blast force was estimated at 2.4 tons of TNT (*another study estimated 24 tons*)

### RAST Estimate

- > 20 Seriously Impacted
- 68,700 lbs Airborne Release
- Release Duration at 1.88 min
- Blast force was estimated at 2.4E7 kcal (maximum limit in RAST) which equals 24 tons of TNT

The following slides describe a feasible scenario for what may have happened that day.

Slide - 23



## RAST Results Comparison Case Study – Phillips Petroleum

Maintenance As Written

Steps when unplugging settling leg

- 1) Close the 8" Ball Valve (Indicator reads closed)
- 2) Disconnect the 8" Ball Valve actuator air supply and discharge hoses
- 3) Lock the 8" Valve stem in its closed position
- 4) Remove the takeoff valve
- 5) Manually pull the log out

Slide - 24

### RAST Results Comparison

#### Case Study – Phillips Petroleum

Maintenance Issue Day of Incident

Cannot reach Log fragment  
and then manually pull the log out

Slide - 25

### RAST Results Comparison

#### Case Study – Phillips Petroleum

Findings after the explosion

1. The 8" Ball Valve stem was ***unlocked***
2. The actuator air supply and discharge hose connections were ***reconnected in reverse***
3. The 8" Ball Valve will ***malfunction open*** if the air supply is ***connected in reverse***

*Note:* 3)'s data was obtained during the investigation afterwards.

Slide - 26

Reactor at 600 psi

Open 8" Valve

Plug

Takeoff valve removed (open to atmosphere)

### RAST Results Comparison

#### Case Study – Phillips Petroleum

Feasible conclusion due to findings

- Plug pushed out due to reactor pressure
- Nothing to stop flow from reactor
- Entire contents of reactor released outdoors

Slide - 27

### RAST Results Comparison

#### Case Study – Phillips Petroleum

Property Damage Table (NFPA)	
Overpressure (psi)	Building Damage
0.15	Typical pressure for glass failure
1-2	Failure of wood siding; partial demolition
> 10	Probable total destruction
> 30	Steel towers blown down

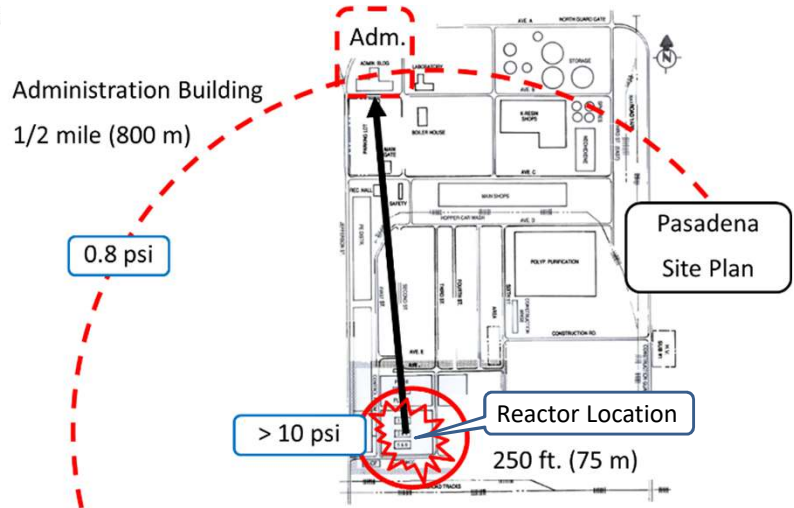
RAST Estimates for the Vapor Cloud Explosion (VCE)		
	Distance	Overpressure
Significant property damage within 250 ft..	1/2 Mile (800 m)	0.8 psi
	250 ft.. (75 m)	> 10 psi

Slide - 28



### RAST Results Comparison Case Study – Phillips Petroleum

Overpressures Estimated by RAST  
for Vapor Cloud Explosion

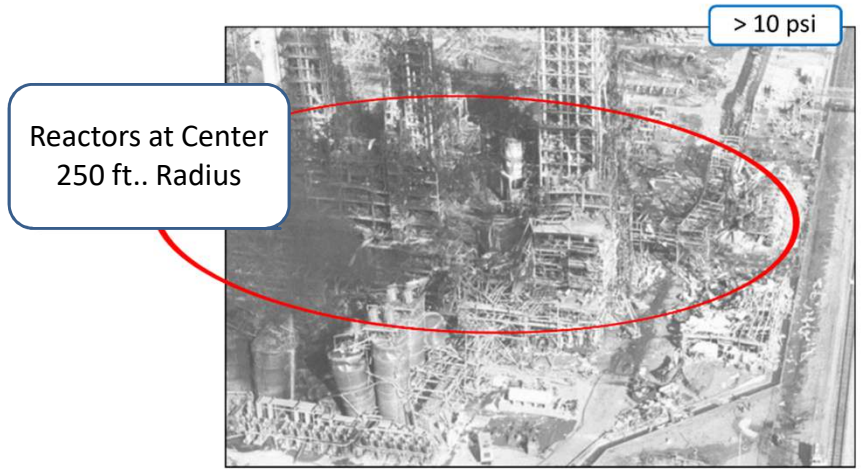


Slide - 29



### RAST Results Comparison Case Study – Phillips Petroleum

Physical Damage

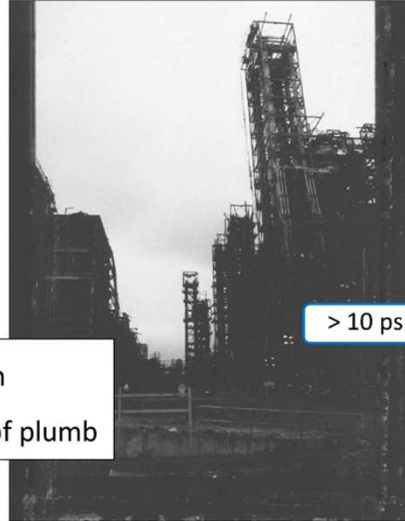


Slide - 30



### RAST Results Comparison Case Study – Phillips Petroleum

Physical Damage



> 10 psi

View from South to North  
Listing tower at 14 degrees out of plumb

Slide - 31



### RAST Results Comparison Case Study – Phillips Petroleum

Physical Damage



0.8 psi

Administration  
Building  
½ mile away

Slide - 32





## Risk Analysis Screening Tool (RAST) "Normal Operations" Study – Phillips Petroleum

What if the data had been entered to 0.0002 ("normal" operations) instead of 0.0035 people/m<sup>2</sup> (day of incident with many people in the area at the time of the release). The Development Reactor Building 1 still contains 1 Person and the Administration Building 2 still contains 40 People.

Maximum number of people outdoors at a specific time per total facility area during normal operation including operations, maintenance personnel, etc. Typical values would be in the range of 0.0001 to 0.001 people/m<sup>2</sup>

**Plant Layout Input**

Equipment Identification: Loop Reactor  
Equipment Type: Vessel/Tank  
Location: Outdoors

Location Information

Distance to Property Limit or Fence Line =	300	ft
Furthest Distance to Fence Line (> 91.44 m) =		m
Max. Onsite Outdoor Population Density	0.0002	people/m <sup>2</sup>
Personnel Routinely in Immediate Area?	Yes	
Distance to end of Offsite Zone 1		m
Offsite Population Density within Zone 1		people/m <sup>2</sup>
Offsite Population Density Beyond Zone 1		people/m <sup>2</sup>
Effective Egress from Work Area?		
Access for Emergency Services?		
Degree of Equipment Congestion in Area?	High	
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?		

Occupied Building Data

Occupied Building 1 Name =	Reactor Develop Bldg.	
Distance to Occupied Bldg 1 or Area =	250	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 =	1	
Occ Bldg 2 in Same Wind Direction?	Yes	
Occupied Building 2 Name =	Administration Building	
Distance to Occupied Bldg 2	2620	ft
Elevation of Occ Bldg 2 Ventilation Inlet =		m
Distance to Center of Occ. Bldg 2 =		m
Occupied Bldg 2 Type =		
Occupied Bldg 2 Ventilation Rate =		changes/hr
Number of Occupants Bldg 2 =	40	

Default is 0.0002

Slide - 33



## Risk Analysis Screening Tool (RAST) "Normal Operations" Study – Phillips Petroleum

On the **Consequence Summary** worksheet.

Incident Outcome and Consequence Summary

Number of Serious Impacts Outside drops to 2 people

Number of Serious Impacts For Building 1 stays same at 1 person

**CONSEQUENCE SUMMARY**

RAST Version 3 Date: 3/20/2020

Loss Event for: Vessel/Tank; Loop Reactor Containing Full Bore Pipe or Nozzle Leak

Ethylene:

Incident Outcome and Consequence Summary:	Exceeds Threshold Criteria	LOPA Tolerable Frequency Factors Based Estimated Number of People Impacted
Impact Assessment with Personnel routinely in the immediate area	Yes	NA
Offsite Toxic Impact based on Toxic Integration Method and 91.44 m to Fence Line	Yes	NA
Onsite Toxic Impact based on Distance to LC-50 Concentration of 0 m	No	NA
Outdoor Toxic Exposure Duration 113 sec		
Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 166 m		5
Chemical Exposure based on Dermal or Thermal Hazards and Spray Distance of 1 m		4
Equipment Rupture Direct Blast Impact based on Distance to 10 psi		
Onsite Thermal Radiation Impact based on Distance from Fireball		
Number of Potential Serious Toxic Impacts Onsite: 0 people		
Number of Potential Serious Flash Fire/Fireball Impacts Onsite: 2.3 people		
Occupied Buildings Noted as in the Same Wind Direction		
Occupied Building Toxic Impact	No	NA
Number of Potential Serious Impacts for Building 1: 0 people		
Number of Potential Serious Impacts for Building 2: 0 people		
Occupied Building Impact from Vapor Cloud Explosion	Yes	5
Number of Potential Serious Impacts for Building 1: 1 person		
Number of Potential Serious Impacts for Building 2: 0 people		
1 psi Blast Overpressure Distance exceeds the Fence Line, Consider additional Offsite Impacts		
Occupied Building Physical Explosion Impact	No	
Number of Potential Serious Impacts for Building 1: 0 people		
Number of Potential Serious Impacts for Building 2: 0 people		
Environmental Impact		NA

Slide - 34

## RAST Case Study – Phillips Petroleum

### Conclusion

#### RAST Estimate For Day of Incident

- > 20 Seriously Impacted
- 1 in Building 1 Seriously Impacted
- Tolerable Frequency Factor at 6

The Tolerable Frequency Factor (TFF) is the number of Independent Protection Layers (IPLs) needed to reduce the Risk to a tolerable level.

#### RAST Estimate For Normal Operations

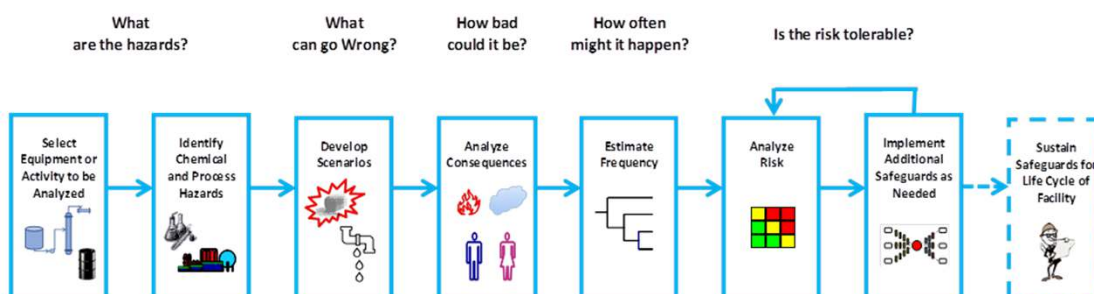
- > 2 Seriously Impacted
- 1 in Building 1 Seriously Impacted
- Tolerable Frequency Factor at 5

The TFF has been reduced by 1 (an order of magnitude reduction in Risk) with non-essential people removed from the area and with no changes to the administrative lock-out controls in place.

Slide - 35

## RAST Case Study – Phillips Petroleum

### Conclusion



Although RAST was not available in 1989, had a PHA Team compared the risk during normal operations (TFF = 5) and the risk associated with many people in the area as the maintenance was being performed (TFF = 6), *more protection layers would have probably been added with fewer people nearby during maintenance* to help reduce the likelihood and severity—the risk—of a release.

Slide - 36