A Tutorial for the Risk Analysis Screening Tool (RAST)

Purdue Process Safety and Assurance Center (P2SAC)
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Dr. Bruce K. Vaughen, PE, CCPSC
CCPS
• Process Safety
• The Process Hazards Analysis (PHA)
• The Risk Analysis Screening Tool (RAST)
• Some RAST Features for the Fearless
• Summary and Questions?
• Process Safety
  • The Process Hazards Analysis (PHA)
  • The Risk Analysis Screening Tool (RAST)
  • Some RAST Features for the Fearless
  • Summary and Questions?
Process Safety

- Mission
- Types of process hazards
- Potential consequences and impact
- Evaluation of risk
- Prioritization of risk reduction efforts
To reduce process safety risks:

- Harm to people
- Environmental damage, and
- Asset or business losses

Focusing on incidents that can cause:

- Runaway reactions
- Toxic releases
- Fires, and
- Explosions
Incidents occur with loss of:

- Containment of hazardous materials and energies
- Control of hazardous chemical reactions and interactions
- Control of hazardous processing conditions (i.e., energies)

Leading to:

- Runaway reactions
- Toxic releases
- Fires, and
- Explosions
## Potential Consequences and Impact

<table>
<thead>
<tr>
<th>Consequences</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harm to people</td>
<td>Fatalities, injuries</td>
</tr>
<tr>
<td>Environmental damage</td>
<td>Treatment and Clean up (land, water)</td>
</tr>
<tr>
<td>Asset or business losses</td>
<td>Property damage, market share losses</td>
</tr>
</tbody>
</table>

**Qualitative**

**Quantitative**
Tutorial Outline

• Process Safety

• The Process Hazards Analysis (PHA)

• The Risk Analysis Screening Tool (RAST)

• Some RAST Features for the Fearless

• Summary and Questions?
The Process Hazards Analysis (PHA)

PHAs are part of an effective process safety program:

• Used to identify and evaluate hazards and risks associated with processes and operations

• Can use qualitative techniques to identify and assess the process hazards

• Process safety risks are reduced with PHA recommendations

• Can use quantitative techniques to help prioritize the risk reduction efforts
One of many PHA technique often follows a Hazards Identification and Risk Analysis (HIRA) method:

1. What are the hazards?
2. What can go wrong?
3. What are the potential consequences?
4. How likely is it to happen?
5. Is the risk tolerable?
The PHA Team

There must be members on the PHA Team who can address the HIRA questions:

1. Process engineer (familiar with area chemistries, process and engineering designs)
2. Area operator (familiar with operating the process)
3. Area maintenance (i.e., mechanic, electrician, familiar with inspections, tests, and preventive maintenance)
4. Area supervisor (for consistency among shift operators)
5. Other personnel (e.g., rotating equipment expert, control systems expert, as needed)
These PHA Team member(s) develop the scenarios:

1. Process safety, in particular
   a. The potential process hazards, chemistries, unit operations, equipment and process design parameters (including P&IDs)
   b. How to run a PHA and how to document the risk evaluations
   c. And answer: *What can go wrong?*
These PHA Team member(s) also help develop scenarios: *What can go wrong?*

1. From process operations (an operator)
   a. Operating conditions
   b. How to respond safely to out-of-specification conditions

2. From process maintenance (a mechanic *and* an electrician)
   a. Equipment maintenance schedules (i.e., preventive maintenance)
   b. Specifications for equipment testing and inspections
   c. How to manage responses to failed inspections
Some PHA techniques:

1. What if/Checklist
2. Hazard and Operability Studies (HAZOP)
3. Failure Mode and Effect Analysis (FMEA)
4. Others...
HAZOP (See Glossary Handout):

A Structured approach using guidewords to evaluate potential deviations from normal (expected) operating design conditions, for example:

Flow: No Flow (i.e., when flow is expected), High Flow

Pressure: Vacuum, Low Pressure, High Pressure

(More Detailed: Handout 1)
Incidents occur with loss of:
- Containment of hazardous materials and energies
- Control of hazardous chemical reactions and interactions
- Control of hazardous processing conditions (i.e., energies)

Leading to:
- Runaway reactions
- Toxic releases
- Fires, and
- Explosions

Harm to people
Environmental damage
Asset or business losses

**1. What are the hazards?**

**2. What can go wrong?**

**3. What are Consequences?**

Remember Incidents Slide earlier?
Using a HIRA: PHA Team Develops PHA Scenarios

What are the hazards?
What can go wrong?

What are the potential consequences?
How likely is it to happen?

What are the material and process hazards?
Qualitative Frequency
Qualitative Consequence
Qualitative Risk
Develop Scenarios
P&ID (Piping and Instrumentation Diagram)

Scenarios
Consequences
Frequencies
Risks
Is the Risk Tolerable?

Recommendations
Documenting the HAZOP Discussion

The PHA Team documents their scenarios with a HAZOP table:

1. What are the hazards?
2. What can go wrong?
3. What are the potential consequences?
4. How likely is it to happen?

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<tbody>
<tr>
<td>Guideword: High Flow</td>
<td>More</td>
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</table>

(See: Handout 2;

Note defined as a “structured” PHA technique due to Guidewords in Handout 1)
Risk is a function of the Consequence (impact) and the Frequency (likelihood) of the event

\[ \text{Risk} = F \times C \]

Frequency \hspace{1cm} Consequence

Reduce F with preventive controls (prevent the incident from occurring)

Reduce C with inherently safer design and then additional mitigative controls (reduce incident magnitude)

Goal: To reduce Risk
A Qualitative Risk Matrix

Risk = F x C
A Qualitative Risk Matrix

Risk = F x C

- Unacceptable
- Undesirable
- Marginal
- Acceptable

Frequency

Consequence

High
Med
Low

Low
Medium
High
PHA Team example scenario development:

1. Hazard? Flammable material
2. Wrong? Valve opens unexpectedly (the scenario or event)
3. Consequence? Medium; Small release to atmosphere
4. Frequency? Low likelihood that this event will occur
5. Risk? Evaluate on a qualitative risk matrix
A Qualitative Risk Matrix

Scenario/Event

Low Frequency

Medium Consequence

Consequence

Marginal Risk

PHA Team discussion continues: are there safeguards to reduce Consequence or Frequency?

Is the Risk Tolerable?

Recommendations
The PHA Team documents their scenarios with a HAZOP table:

1. What are the hazards?
2. What can go wrong?
3. What are the potential consequences?
4. How likely is it to happen?
5. Is the risk tolerable?

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(See: Handout 2)
Exercise:

Feed Flow
No High

(Fill out Handout 2)
Tutorial Outline

• Process Safety
  • The Process Hazards Analysis (PHA)
  • The Risk Analysis Screening Tool (RAST)
  • Some RAST Features for the Fearless
• Summary and Questions?
The Risk Analysis Screening Tool (RAST)

• What is RAST?
• How RAST Supports the PHA Team
• A Brief RAST Overview
RAST is the “Risk Analysis Screening Tool”

Recognize that RAST is

1) Tool to help PHA Teams assess process hazards and risk
2) Screening Tool using linearized theoretical equations
3) Risk Analysis used to help Screen between scenario risks
   (Helps PHA Teams prioritize PHA Recommendation)
4) Tool which helps a company with different divisions assess risk using a common risk framework and matrix
RAST is software and manual that was

- Donated by Dow Chemical for *your personal computer/laptop*
- Donated with CHEF software and manual, the Chemical Hazards Engineering Fundamentals (Tool/Aid)
- Again: RAST is risk *screening* software that
  - Uses the linearized theoretical equations from CHEF
  - Uses the Hazard Identification and Risk Analysis (HIRA) method
  - Provides both qualitative and semi-quantitative risk evaluations
The RAST and CHEF Website

Software downloadable *at no cost* from CCPS Website


(See Handout 3)

RAST  Download software

RAST  User’s Manual (with example)

CHEF  User’s Manual

Theory from Crowl and Louvar
And data from literature

CHEF Calculation Aid (Excel workbook)
Case Studies

- Vapor Cloud Explosion (BP Texas City)
- Outdoor Toxic Release (Chlorine, DPC Enterprises)
- Confined Space Explosion (CAI and Arnel)
- Runaway Reaction and Physical Explosion (T2 Laboratories)

Based on US Chemical Hazards and Safety Board (US CSB) Incident Investigation reports

(See Handout 3)
Both the PHA and RAST

- Use the “Hazard Identification and Risk Analysis (HIRA)” method

- To identify hazards and evaluate risk
  1) to help make certain that risks to employees, the public, or the environment are *consistently controlled*
  2) within the organization's *risk tolerance*
Scenario Development: PHAs and RAST

What are the hazards? What can go wrong?

Identify Equipment or Activity to be Analyzed

Identify Chemical and Process Hazards

Develop Scenarios

Analyze Consequences

Estimate Frequency

Analyze Risk

Implement Additional Safeguards as Needed

Sustain Safeguards for Life Cycle of Facility

P&ID

Scenarios

RAST validates scenario development
Analyzing Risk: PHAs and RAST

What are the potential consequences? How likely is it to happen?

RAST/CHEF helps quantify Consequence, Frequency and Risk.
Minimal data entry (input) is *required* for screening calculations.
Minimal data entry (input) is required for screening calculations.

"Min Complete" box white

Orange boxes are "Min Input" data

Note: Critical Errors 😞

Piping and Instrument Diagrams
Identify Chemical and Physical Hazards

- Identify Chemical and Process Hazards
- Estimate Frequency
- Analyze Consequences
- Analyze Risk
- Implement Additional Safeguards as Needed
- Develop Scenarios
- Identify Equipment or Activity to be Analyzed
- Chemicals Handled
- Operating Conditions
- Plant Layout
- Equipment Specs

P&ID

Sustain Safeguards for Life Cycle of Facility
Using RAST in a PHA

1. What are the hazards?
   a. Already identified by PHA Team
   b. Entered into the RAST software:
      Chemical and physical hazards
      Information from P&IDs, chemical reactivity, equipment files, etc.
      The more information input, the more “refined” the estimates and screening analysis
RAST has internal “chemical reactivity” modeling and >250 chemicals in a pre-populated list (User can enter new chemicals)

Screen from the RAST Main Menu

Chemical Data
Equipment Parameters
Process Conditions
Plant Layout

Reactivity Inputs (if part of HIRA)
Once Minimum Inputs completed, then RAST can proceed to develop scenarios.
Continuing with using RAST in a PHA

2. What can go wrong?
   a. Already identified by PHA Team
   b. *RAST can be used to help identify causes*
      - *Add Historical Incidents (causes)*
      - *Add Equipment integrity issues (causes)*
      - *Validate PHA Team-generated scenarios*
      - *Suggest other potential scenarios*
RAST for Validating Scenarios

Process Hazards Analysis (PHA), Hazards and Operability Study (HAZOP)

1. Identify Equipment or Activity to be Analyzed
2. Identify Chemical and Process Hazards
3. Develop Scenarios
4. Analyze Consequences
5. Estimate Frequency
6. Analyze Risk
7. Implement Additional Safeguards as Needed
8. Sustain Safeguards for Life Cycle of Facility

Scenario development:
Based on materials, processing conditions, area and industry incident history and potential types of equipment failure
Continuing with using RAST in a PHA

3. What are the potential consequences?
   a. Already identified qualitatively by PHA Team
   b. RAST can be used to help evaluate consequences
      • What is the scenario’s impact to people, environment, business?
RAST - Analyze Consequence and Impact

- Identify Chemical and Process Hazards
- Develop Scenarios
- Analyze Consequences
- Estimate Frequency
- Analyze Risk
- Implement Additional Safeguards as Needed
- Source and Dispersion Modeling Impact Assessments

- Weather
- Population
- Congestion & Confinement
- Vulnerability

Added earlier

Plant Layout
RAST - Analyze Consequences - continued

RAST uses different source models for modeling vapor and liquid releases.

Source Modeling
Details are in the CHEF User’s Manual
Selecting a source (discharge) model to determine the release rate

**Hole Size**
Modeling the discharge from a hole of specified diameter, process pressure, and fluid density

**Overflow or Specified Rate**
Modeled by the feed rate or other specified release rate

**Excessive Heat**
By dividing the heat input by the heat of vaporization

**Rupture**
By the sudden release of the entire contents
Different source parameters influence the different source models

Estimates of **Vapor** Release Rate
- Based on Hole Size
- Based on Vaporization of Liquid

Estimates of **Liquid** Release Rate
- Based on Hole Size
- Based on Catastrophic Failure
- Based on Flashing Liquid Flow
  - Evaluates Flash Fraction
  - Tests for Two-Phase Flow
Source modeling also

Evaluates Aerosol Evaporation Fraction

Estimates of Evaporation from a Liquid Pool
Selecting a dispersion model to determine “downwind” concentrations

**Vapor dispersion rates**
- Continuous versus instantaneous release from the source

**Atmospheric dispersion modeling**
- Release elevation
- Released material’s momentum and buoyancy
- Wind direction
- Atmospheric stability
- Surface (terrain) roughness and wind speed
- Plume concentrations (“averaging time”)

Weather parameters entered in RAST at this point
For example, in neutrally buoyant models, the atmospheric stability relates to vertical mixing of the released material the air.

Are the atmospheric conditions
Stable?
   RAST selects “Class D” Neutral Conditions
Unstable?
   RAST selects “Class F” Moderately Stable Conditions
For toxic releases:
  Are there toxic concentrations downwind?

For flammable releases:
  Are there flammable or explosive concentrations downwind?
If explosive, what are the potential blast overpressures?

RAST provides simplified modeling capabilities:
  • Vapor Cloud Explosions (VCE)
Parameters include

• Congestion

Congestion parameters entered in RAST at this point
Once the consequences have been understood, then RAST evaluates the *impact* to people and property: *How bad could it be?*

- **Flash (or Jet) Fire**: Function of flammable cloud and fire
- **Vapor Cloud Explosion**: Function of flammable cloud and release rate
- **Building Explosion**: Function of flammable cloud indoors
- **Physical Explosion**: Function of blast overpressure and distance
- **Toxic Vapor Release**: Function of exposure to toxic concentrations

Addresses probability of people being exposed

Vulnerability parameters entered in RAST at this point
Summary – Analyze Consequences and Impact

- Identify Equipment or Activity to be Analyzed
- Identify Chemical and Process Hazards
- Develop Scenarios
- Analyze Consequences
- Estimate Frequency
- Analyze Risk
- Implement Additional Safeguards as Needed
- Sustain Safeguards for Life Cycle of Facility

RAST can be used to quantify the impact of the scenario's consequences.
Using RAST to Support a PHA Team

Continuing with using RAST in a PHA

4. How likely is it to happen?
   a. Already identified qualitatively by PHA Team
   b. RAST can be used to help estimate frequency of the event
      • What is the event rate? (e.g., how many events/year?)
RAST – Estimates of Frequency

Identify Equipment or Activity to be Analyzed → Identify Chemical and Process Hazards → Develop Scenarios → Analyze Consequences → Estimate Frequency → Analyze Risk

- Ignition Source
- Protection Layers
- Human Reliability
- Equipment Failure Rate

Identify Chemical and Process Hazards
Estimate Frequency
Analyze Consequences
Analyze Risk

Implement Additional Safeguards as Needed
Sustain Safeguards for Life Cycle of Facility

Develop Scenarios
Identify Equipment or Activity to be Analyzed

Sustain
Safeguards
for
Life Cycle of
Facility
RAST - Estimate Frequency

Identify Chemical and Process Hazards
Estimate Frequency
Analyze Consequences
Analyze Risk

Human Reliability
Equipment Failure Rate
Protection Layers
Ignition Source

Identify Equipment or Activity to be Analyzed
Develop Scenarios

Sustain Safeguards for Life Cycle of Facility
RAST – Estimate Frequency

How often does the cause happen? (see HAZOP table in Handout 2)

1. What are the hazards?
2. What can go wrong?
3. What are the potential consequences?
4. How likely is it to happen?

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<td>More</td>
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</table>

Addresses probability of people being exposed

Vulnerability parameters entered in RAST at this point
Before assessing Risk, address modeling expertise.
Difference in PHA Team Members

<table>
<thead>
<tr>
<th></th>
<th>Qualitative</th>
<th>RAST (Quantified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Engineer</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Operator</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Mechanic and Electrician</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Equipment specialist(s) failure modes</td>
<td>(√)</td>
<td></td>
</tr>
<tr>
<td>Source and dispersion modeling specialists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consequence Analysis specialist</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Risk Analysis specialists</td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

*(See Handout 4 – Next Slide)*
<table>
<thead>
<tr>
<th>Default Industry Guidance</th>
<th>Options for the User-defined Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a Specific to equipment or equipment group under review (User defined)</td>
<td>Yes User enters equipment types, chemicals handled, processing conditions, and equipment layout</td>
</tr>
<tr>
<td>Yes Provides guidance on hazard severity sufficient to warrant a hazard evaluation</td>
<td>Yes Option for Users to enter new chemicals, reactivity data, and mixture properties</td>
</tr>
<tr>
<td></td>
<td>Yes Option for Users to enter facility-specific equipment design parameters and detailed processing conditions</td>
</tr>
</tbody>
</table>

*(See Handout 4)*
### Default and User-defined Options within the Risk Analysis Screening Tool (RAST)

<table>
<thead>
<tr>
<th>Default Industry Guidance</th>
<th>Options for the User-defined Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes Provides a comparative list of possible scenarios for analysis</td>
<td>Yes Option for Users to enter facility-specific scenarios based on experience</td>
</tr>
<tr>
<td>Yes Evaluates the loss event using standard, but simplified, release and dispersion models</td>
<td>Yes Option for Users to enter detailed release and dispersion modeling results, if available (Note 4)</td>
</tr>
<tr>
<td>Yes Estimates incident outcome, impact zone, and worst-case consequence</td>
<td>Yes Option for Users to enter specific consequence based on other qualitative or detailed quantitative analysis</td>
</tr>
</tbody>
</table>

(See Handout 4)
## Difference Between Qualitative and RAST

### Default and User-defined Options within the Risk Analysis Screening Tool (RAST)

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<th>Default Industry Guidance</th>
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</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Provides possible initiating event frequencies and enabling conditions or modifiers</td>
<td>Option for Users to enter specific initiating event frequencies and specific enabling conditions or modifiers</td>
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<tr>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Estimates individual and cumulative scenario risk and compares to a tolerable risk criteria to help identify gaps</td>
<td>Option for Users to enter specific risk tolerance levels (i.e., a different risk matrix)</td>
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</tbody>
</table>

(See Handout 4)
RAST - Analyze Risk – Quantitative Screening

1. Identify Chemicals Handled
   - Plant Layout
   - Equipment Specifications

2. Operating Conditions
   - Historical Incidents

3. PHA, HAZOP
   - Equipment Integrity Failures

4. Weather
   - Congestion & Confinement

5. Population
   - Human Reliability

6. Ignition Source
   - Vulnerability

7. Protection Layers
   - Equipment Failure Rate

Risk Equation

Identify Chemicals and Process Hazards
Estimate Frequency
Analyze Consequences
Analyze Risk

Identify Equipment or Activity to be Analyzed
Develop Scenarios
Sustain Safeguards for Life Cycle of Facility
Implement Additional Safeguards as Needed

Scenarios
Continuing with using RAST in a PHA

5. Is the risk tolerable?
   a. Already identified qualitatively by PHA Team
   b. *RAST can be used to help estimate a quantified Risk for screening between PHA Recommendations or further study*

\[
\text{Risk} = F \times C
\]
Using RAST in a PHA

The RAST Risk Matrix

- **Order of magnitude levels**
- “Quantitative” screening

<table>
<thead>
<tr>
<th>Consequence (Severity Level)</th>
<th>Frequency (10^-x/year)</th>
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<tbody>
<tr>
<td>Low</td>
<td>7 6 5 4 3 2</td>
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<tr>
<td>Low</td>
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<tr>
<td>High</td>
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<td>5</td>
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<tr>
<td>High</td>
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Legend

- Acceptable
- Tolerable - Offsite
- Tolerable - Onsite
- Unacceptable
Using RAST in a PHA

Same Goal as Qualitative
- *Reduce Consequence*
- *Reduce Frequency*
- *Reduce Risk*

\[
\text{Risk} = F \times C
\]
Another PHA Team scenario, with RAST quantifying Risk:

1. Hazard? Flammable material
2. Wrong? Pump fails unexpectedly (the scenario or event)
3. Consequence? High; Large release (loss of containment); “5”
4. Frequency? Medium likelihood that this event will occur; “4”
5. Risk? Evaluate on a quantitative risk matrix
Example on the Quantitative Risk Matrix

Scenario/Event
Medium (4) Frequency
High (5) Consequence

Frequency (10^x/year)

Legend
Acceptable - Green
Tolerable - Offsite - Yellow
Tolerable - Onsite - Orange
Unacceptable - Red

Unacceptable Risk
Requires PHA
Recommendation(s)
Examples on the Quantitative Risk Matrix

Prioritize PHA Recommendation(s)

RAST Risk Screening Result #1

RAST Risk Screening Result #2

Consequence (Severity Level)

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<th></th>
<th>Low</th>
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<th>2</th>
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Frequency
(10^-x/year)
Tutorial Outline

- Process Safety
- The Process Hazards Analysis (PHA)
- The Risk Analysis Screening Tool (RAST)
  - Some RAST Features for the Fearless
- Summary and Questions?
Additional RAST Features

Being “Fearless”

Be aware of the hazards, but not afraid of them!
Moving on beyond the PHA/RAST efforts...

Is the Risk Acceptable?
Yes – Manage the Risk

Sustaining safeguards is a part of the overall Process Safety and Risk Management program.
RAST helps identify additional safeguards

Is the Risk Acceptable?
No - Add Protection Layers

LOPA, QRA

RAST provides option for a Layer of Protection Analysis (LOPA)
RAST allows entries from a Quantitative Risk Analysis (QRA)
### Default and User-defined Options within the Risk Analysis Screening Tool (RAST)

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Users can stop here for a qualitative hazards review or they can continue with S7 to perform a LOPA, if needed.

| Yes Provides capability to perform a Layer of Protection Analysis (LOPA) on selected scenarios | Yes Option for Users to 1) Perform a LOPA on selected scenarios, and 2) Enter QRA results, if available (Note 4). |

*(See Handout 4)*
Focus on Frequency

- **Reduce Consequence**
- **Reduce Frequency**
- **Reduce Risk**

Risk = \( F \times C \)

By adding Independent Protection Layers (IPLs)
RAST uses a Bow Tie method to help screen for and identify potential safeguards or barriers.
RAST Documentation ("Reports") include:

- Assumptions and limits based on
  - industry guidance (default values)
  - company-specific guidance (overrides defaults)

- Scenarios used to establish tolerable risk
  (provides list of possible scenarios)

- Safeguards and protection layers needed to sustain tolerable risk
  (can use the Layer of Protection Analysis - LOPA)
If RAST’s LOPA is used to determine Independent Protection Layers (IPLs) needed to sustain tolerable risk,

- Report can list the Independent Protection Layers (IPL)
- IPLs are the basis and are used for developing asset integrity programs
  - Inspections and tests
  - Preventive maintenance programs

Manage risk by maintaining protection layers
Exercise:

Feed Flow

No High

(Fill out Handout 2)
Case Studies

Vapor Cloud Explosion (BP Texas City)
Outdoor Toxic Release (Chlorine, DPC Enterprises)
Confined Space Explosion (CAI and Arnel)
Runaway Reaction and Physical Explosion (T2 Laboratories)

Based on US Chemical Hazards and Safety Board (US CSB) Incident Investigation reports

(See Handout 3)
### Case Study – Quantitative Assessment

<table>
<thead>
<tr>
<th>Scenario I.D.</th>
<th>Scenario Type</th>
<th>Cross Ref.</th>
<th>Scenario General Description</th>
<th>Initiating Event</th>
<th>Loss Event</th>
<th>Outcome</th>
<th>Outcome Descriptors</th>
<th>Consequence</th>
<th>Tolerable Frequency Factor</th>
<th>Gap in Layers of Protection</th>
<th>Worst Case Scenario for Further Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.01</td>
<td>Overflow/flooding or plugging</td>
<td>BPCS Instrument Loop Failure</td>
<td>Equipment rupture at Operating Temperature</td>
<td>Flash fire or fireball</td>
<td>Modeled as instantaneous release at a distance to Severe Flammable Impact (0 SLFL, BLEVE, or Dust Fireball) of 1100m</td>
<td>Severity Level-5</td>
<td>6</td>
<td>5</td>
<td>High TF &amp; IPL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.01</td>
<td>Overflow/flooding or plugging</td>
<td>BPCS Instrument Loop Failure</td>
<td>Equipment rupture at Operating Temperature</td>
<td>Vapor cloud explosion</td>
<td>Modeled as instantaneous release impacting on site personnel at an explosion distance of 1 psi overpressure of 553 m including explosion overpressure at low strength Occupied Bldg (1 psi) of 3.2</td>
<td>Severity Level-5</td>
<td>6</td>
<td>5</td>
<td>High TF &amp; IPL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.02</td>
<td>Overflow/flooding or plugging</td>
<td>Mechanical Failure</td>
<td>Equipment rupture at Operating Temperature</td>
<td>Flash fire or fireball</td>
<td>Modeled as instantaneous release at a distance to Severe Flammable Impact (0 SLFL, BLEVE, or Dust Fireball) of 1060m</td>
<td>Severity Level-5</td>
<td>6</td>
<td>5</td>
<td>High TF &amp; IPL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.02</td>
<td>Overflow/flooding or plugging</td>
<td>Mechanical Failure</td>
<td>Equipment rupture at Operating Temperature</td>
<td>Vapor cloud explosion</td>
<td>Modeled as instantaneous release impacting on site personnel at an explosion distance of 1 psi overpressure of 553 m including explosion overpressure at low strength Occupied Bldg (1 psi) of 3.2</td>
<td>Severity Level-5</td>
<td>6</td>
<td>5</td>
<td>High TF &amp; IPL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.01</td>
<td>Overflow/flooding or plugging</td>
<td>BPCS Instrument Loop Failure</td>
<td>Overfill release</td>
<td>Vapor cloud explosion</td>
<td>Impacting on site personnel at an explosion distance of 1 psi overpressure of 231 m including explosion overpressure at low strength Occupied Bldg (1 psi) of 19</td>
<td>Severity Level-5</td>
<td>6</td>
<td>5</td>
<td>High TF &amp; IPL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One of the RAST suggested scenarios
## Explosion Summary:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCE or Building Explosion Energy, kcal</td>
<td>2.4E+07</td>
</tr>
<tr>
<td>VCE or Building Explosion Distance to 1 psi Overpressure, m</td>
<td>238.5</td>
</tr>
<tr>
<td>Maximum Distance to LFL Concentration, m</td>
<td>202.1</td>
</tr>
<tr>
<td>Blast Overpressure at Center of Occupied Building 1, psi</td>
<td>3.2</td>
</tr>
<tr>
<td>Blast Overpressure at Center of Occupied Building 2, psi</td>
<td>0.0</td>
</tr>
<tr>
<td>Distance to Severe Thermal Radiation Impact, m</td>
<td></td>
</tr>
<tr>
<td>Rupture Explosion Energy, kcal</td>
<td></td>
</tr>
<tr>
<td>Distance to Direct Blast Impact (10 psi), m</td>
<td></td>
</tr>
<tr>
<td>Maximum Fragment Range, m</td>
<td></td>
</tr>
<tr>
<td>Rupture Distance to 1 psi Overpressure, m</td>
<td>0.0</td>
</tr>
<tr>
<td>Rupture Overpressure at Center of Occupied Building 1, psi</td>
<td>0.0</td>
</tr>
<tr>
<td>Rupture Overpressure at Center of Occupied Building 2, psi</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Probability of Ignition (POI):**

- **Potential Explosion Impact to Occupied Building**

Trailers won’t survive this overpressure.
Case Study – Quantitative Assessment

Incident Outcome and Consequence Summary:
Impact Assessment with Personnel routinely in the immediate area

*Offsite Toxic Impact based on Toxic Integration Method and 1000 m to Fence Line*

*Onsite Toxic Impact based on Distance to LC-50 Concentration of 43 m*

*Outdoor Toxic Exposure Duration 600 sec*

*Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 286 m*

*Chemical Exposure based on Dermal or Thermal Hazards and Spray Distance of 0 m*

*Onsite Direct Blast Impact based on Distance to 10 psi of 0 m*

*Onsite Thermal Radiation Impact based on Distance from Fireball of 0 m*

<table>
<thead>
<tr>
<th>LOPA Tolerable Frequency Factors Based Estimated Number of People Impacted</th>
<th>Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impacted</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Step 4 (Worst Case Outcome)

“Conservative” number of fatalities
Tutorial Outline

- Process Safety
- The Process Hazards Analysis (PHA)
- The Risk Analysis Screening Tool (RAST)
- Some RAST Features for the Fearless
- Summary and Questions
• Process Safety – Mission
• The Process Hazards Analysis (PHA) – Qualitative
• The Risk Analysis Screening Tool (RAST) – Quantitative
• Some RAST Features for the Fearless – LOPA
Our goal is to reduce process safety risks

The result is preventing incidents
  Less harm to people, the environment, and property

Fewer – and less severe - incidents!
HIRA and RAST Summary

(See Handout 5)

(Corresponds to Table 3 in Handout 4)
PHA (Qualitative) supported by RAST (Quantitative)

Qualitative PHA
- Identify Equipment or Activity to be Analyzed
- What are the hazards?
- What can go wrong?
- How bad could it be?
- How often might it happen?
- Is the risk tolerable?
- Recommend Additional Safeguards as Needed
- Sustain Safeguards for Life Cycle of Facility

Semi-quantitative RAST
- Compare to PHA Team Discussions
- Impact from Leak Rates Dispersion Profiles
- Failure Rates (Equipment, Human)
- Screen for Unacceptable Risk

Scope of RAST Tutorial
- Identify Equipment or Activity to be Analyzed
- Identify Chemical and Process Hazards
- Develop Scenarios
- Analyze Consequences
- Estimate Frequency
- Analyze Risk
- Implement Additional Safeguards as Needed
- Sustain Safeguards for Life Cycle of Facility

See Handout 6
RAST-specific Expertise for Results Analysis

Using RAST in a PHA Team

**Identify Equipment or Activity to be Analyzed**
- Chemical reactivity

**Identify Chemical and Process Hazards**
- Source modeling (leaks; ruptures) and Dispersion modeling (plumes; distances; etc.)

**Develop Scenarios**
- Consequence Analysis (Impact from toxic release, fire pools, Vapor Cloud Explosions [VCE], etc.)

**Analyze Consequences**
- Equipment Failure Rates (Probability of Failure on Demand [PFD])

**Estimate Frequency**
- Risk Analysis (Societal risks)

**Analyze Risk**
- Layer of Protection Analysis (LOPA) (Independent Protection Layers [IPLs])

**Implement Additional Safeguards as Needed**
- Bow Ties (Barriers)

**Sustain Safeguards for Life Cycle of Facility**

(See Handout 7)
### When is RAST used?

<table>
<thead>
<tr>
<th>Increasing Process Risk Analysis</th>
<th>Detail Level</th>
<th>Type of Risk Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative</td>
<td></td>
<td>Process Safety Review</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Checklist Analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hazards and Operability Study (HAZOP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safeguard or protection layers (in HAZOP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Barrier Analysis (e.g. Bow Tie)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Risk Analysis Screening Tool (RAST)</strong></td>
</tr>
<tr>
<td>Simplified (semi-quantitative)</td>
<td></td>
<td>Layers of Protection Analysis (LOPA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Risk Analysis Screening Tool (RAST)</strong></td>
</tr>
<tr>
<td>Quantitative Risk Analysis (QRA)</td>
<td></td>
<td>Fault Tree Analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detailed Dispersion Modeling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detailed Explosion Modeling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Human Vulnerability Analysis</td>
</tr>
</tbody>
</table>
Identify Chemical and Process Hazards

Estimate Frequency
Analyze Consequences
Analyze Risk
Implement Additional Safeguards as Needed
Sustain Safeguards for Life Cycle of Facility

Risk = F \times C

Questions?

Consequence
Frequency
Risk