Learning from QRA for pipelines – A case study approach

22nd September 2014

8th CCPS Asia Pacific Regional meeting on process safety
Overview

- Introduction
- Scope & Objective
- QRA methodology
- Sensitivity analysis
- Observations
- Mitigation Measures
- Learning
- Areas requiring Attention
Introduction

- Pipelines are a safe and efficient means of transporting large quantities of crude oil
  - Require significantly less energy to operate
  - A much lower carbon footprint
June 27th India (Andhra Pradesh): Natural Gas pipeline explosion

July 31st Taiwan: propylene pipeline explosion
Introduction: The case studied is for a Pipeline Corridor-Gravity lines

- 3.85 Km long crude oil pipeline from tank farm to refinery pump house is considered for the study.
- Risk associated with the pipeline is estimated.
- Sensitivity analysis is carried out to understand the criticality by varying inventory, failure frequency and population. Trends are observed.
The objective of the study is to use Sensitivity Analysis to help identify mitigation measures which can have major impact on risk reduction.

To share the learning which at times goes beyond the technical aspects
Pipeline Layout
QRA methodology

- Determines the potential for damage or injury from specific incidents.
- A single release (e.g. Leak of gasoline pipeline) could result in different possible outcomes e.g.
  - Jet fire
  - Pool fire
  - Flash Fire
  - Toxic dispersion
## Jet Fire

### Consequence analysis

- **Failure frequency calculation**
- **Risk estimation**
- **Risk presentation**
- **ALARP demonstration**

### Jet fire: Distance to radiation levels (m)

<table>
<thead>
<tr>
<th>Leak size (mm)</th>
<th>1.5F Weather condition</th>
<th>5D Weather condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.0 Kw/m²</td>
<td>12.5 Kw/m²</td>
</tr>
<tr>
<td>70</td>
<td>78.9</td>
<td>52.9</td>
</tr>
<tr>
<td>FBR</td>
<td>330.7</td>
<td>239.0</td>
</tr>
</tbody>
</table>
### QRA methodology

**Pool fire:**

<table>
<thead>
<tr>
<th>Leak size (m)</th>
<th>Pool fire: Distance to radiation levels (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5F Weather condition</td>
</tr>
<tr>
<td></td>
<td>6.0 Kw/m²</td>
</tr>
<tr>
<td>70</td>
<td>423.3</td>
</tr>
<tr>
<td>FBR</td>
<td>708.4</td>
</tr>
</tbody>
</table>

**Consequence analysis**

- Failure frequency calculation
- Risk estimation
- Risk presentation
- ALARP demonstration
QRA methodology

### Parts count

<table>
<thead>
<tr>
<th>Type</th>
<th>Diameter (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline</td>
<td>36</td>
</tr>
<tr>
<td>Flange</td>
<td>36</td>
</tr>
<tr>
<td>Actuated valves</td>
<td>36</td>
</tr>
<tr>
<td>Instrument connections</td>
<td>2</td>
</tr>
</tbody>
</table>

### Release Diameter (mm) vs. Failure frequency

<table>
<thead>
<tr>
<th>Release Diameter (mm)</th>
<th>Failure frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>5.14E-05</td>
</tr>
<tr>
<td>&gt;150</td>
<td>5.18E-05</td>
</tr>
</tbody>
</table>

Ref: OGP – Risk assessment data directory, March 2010
QRA methodology

- This combines the consequences and likelihood of all incident outcomes from all selected incidents to provide a measure of risk.

\[ \text{Risk} = \text{Likelihood} \times \text{Severity} \]

- Risk depends on:
  - Consequence,
  - Base event frequency
  - Ignition probability
  - Population density in the area
  - Weather conditions etc.
QRA methodology

- Individual risk
- Societal risk

Risk associated with pipeline (per average year)

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Risk Per Annum</td>
<td>4.64E-03</td>
</tr>
<tr>
<td>Societal Risk</td>
<td>1.78E-03</td>
</tr>
</tbody>
</table>

Consequence analysis → Failure frequency calculation → Risk estimation → Risk presentation → ALARP demonstration
Case – 1: Increase / decrease in Failure Frequency

- Considering the excavation, nature of pipeline, properties of chemical flowing (corrosive nature) from the pipeline, failure frequency may vary.

<table>
<thead>
<tr>
<th>Risk</th>
<th>20% Increase in FF</th>
<th>20% Decrease in FF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Risk Per Annum</td>
<td>5.58E-03</td>
<td>3.72E-03</td>
</tr>
<tr>
<td>Societal Risk</td>
<td>2.14E-03</td>
<td>1.43E-03</td>
</tr>
</tbody>
</table>

Note: All units are in “ per Average Year”
Sensitivity analysis

20% Increase in failure frequency

20% Decrease in failure frequency

Inference: Risk values directly varies with failure frequency.
Case – 2: Increase / decrease of Population

- Considering the renovation of the society in the vicinity of the pipeline or limit the people in the vicinity of pipeline Risk will differ.

<table>
<thead>
<tr>
<th>Risk</th>
<th>100% Increase Population</th>
<th>50% Decrease in Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Risk Per Annum</td>
<td>7.61E-03</td>
<td>2.70E-03</td>
</tr>
<tr>
<td>Societal Risk</td>
<td>2.98E-03</td>
<td>1.62E-03</td>
</tr>
</tbody>
</table>

Note: All units are in “per Average Year”
Sensitivity analysis

**100% Increase in Population**

- IR: 4.64E-03
- SR: 2.98E-03

**50% Decrease in Population**

- IR: 4.64E-03
- SR: 2.70E-03

**Inference:** Risk values directly varies with Population
Observations

- Risk increase or decrease is directly proportional to Failure Frequency.
- Same is true for Population.
- Hence, ‘Rate of Change’ or slope of this line shall suggest which parameter shall play a major role in risk reduction.
- Consequence shall change based on other factors such as release inventory, wind speed, easy availability of source of ignition etc.
- Hence, mitigation measures which bring reduction in inventory shall impact the risk in a major way.
Mitigation Measures

- Target should be to choose a mitigation measure that will have maximum impact on the risk.

- Bund Wall along the pipeline in critical sections with sump / catch pit in safe areas which can contain the major leak.

- Evaluation of addition of Sectionalising valves interlocked with Leak Detection system can help in quick isolation and reduction in leaked quantity.

- Other soft measures such as High Security Fencing, Access Control helping in reducing failure frequency due to third party damage or Corrosion Monitoring and control or reducing population in designated areas.
• Considering the operation, Interlocking leak/fire detection system with isolation valves as generally thought to be effective was not recommended. As per operations group, they close the upstream valve only, allowing the liquid to flow to Pump house which brings in the desired reduction in released inventory.

• Require special focus on mitigation measures in Populated areas / Road crossings etc.
Areas requiring Attention

• Mutual Risk Management --
  – Additional Risk due to upcoming process facilities of other service providers
  – Increasing risk due to population increase and compromise on safe distance from risk source

• Solution –
  – Regulations / Guidelines to include ‘Mutual Risk’ aspect?
  – Stricter monitoring of Violations – encroachments?
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