Prioritizing Integrity & Public Safety Decisions Using Risk-based Approaches

The integration of pipeline integrity with emergency management will allow industry to establish goals and prioritize business decisions and activities in a structured, supportable and cost effective manner.

Overview

A. Basic risk concepts and consideration of the standards applied to public safety decisions;
B. Comment on public safety risk assessments applied in Alberta; and
C. Consider the use of public safety, risk-based approaches, linked with pipeline integrity approaches to support prioritized decisions.
BASIC RISK CONCEPTS
What is Risk?  
Definition of Risk

Steps Involved in Hazard and Risk Assessment

Steps
• Identify the hazards and endpoints of concern
• Define the system and characterize the source
• Conduct dispersion modeling
• Estimate the consequences
• Compare the consequences to public health and safety criteria
• Review options for eliminating, reducing and mitigating the hazards
• Calculate the risk
  – Examine failure frequency and probability data
  – Combine probability and frequency data with estimates of the consequences
• Compare calculated risk to accepted risk criteria
• Review the options for managing and reducing the risks

Description
Hazard Analysis
Hazard Assessment
Hazard Management
Risk Analysis
Risk Assessment
Risk Management

See Comment: Use of Hazard and Risk Analysis Results
Calculate the Risk: Combine Frequency & Consequence Data

**What failure rates should be associated with the operation of a pipeline system?**

- Examine Frequency Information
  - Historical
    - Example: Pipeline Failure Statistics 2012
    - Example: Pipeline Fault Tree Data
  - Integrity
    - Example: Adjust failure frequencies to reflect integrity of individual pipeline segments
- Combine Consequence and Frequency Data
  - Equation for Calculating Individual Risk for a Pipeline
  - Determine Societal Risk
  - Assumptions used in Risk Calculations
  - Example: Determining Failure Frequencies

Note: Societal risk considers the frequency of individual accidents (leaks through ruptures) and the number of fatalities associated with each accident. The calculation of societal risk requires a consideration of individual risk and population density.

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Compare Results to Risk Acceptability Criteria

**How do the risks associated with this industrial activity compare with risks associated with other similar activities?**

- Risk acceptability (individual and societal risk) may be judged by:
  - Comparing the results known statistics
    - Individual Risk – American Mortality Experience
    - Individual Risk - Common Risks Experienced in Alberta
  - Comparing risk to associated with historical experience
    - Societal Risk
  - Example Risk Calculation Results
    - Individual Risk Adjacent to a Sour Gas Pipeline
    - Relationship between Emergency Response Times & Risk
  - Risk Guidelines
    - Canada (CSChe, AER Setback Provisions)
    - Netherlands
    - HSE Societal Risk
  - Comparison of Results to Guidelines
    - Application of CSChe Guidelines to Sour Gas Pipeline Results

Note: Industrial risks are imposed rather than naturally occurring or voluntary. It is recommended that industrial risks are **not compared** to voluntary or naturally occurring risks.
Public Safety Risk Assessments

Management (EM) systems applied internationally include rule-based, goal-oriented, and goal-based approaches.

Canadian EM systems are typically prescriptive/deterministic. They:
- Provide detailed instructions on “what to do” and “how to do it”; and
- Assume that “good processes” and “good data” will result in a “good outcomes”.

Our understanding and ability to evaluate hazards and risks, to evaluate benefits, and to establish priorities has advanced significantly. A move to more goal-based systems is now desirable & achievable.

A move to goal-based systems, rather than a one-size-fits-all approach, provides the opportunity to prioritize programs, activities and costs.

The ability to assess and integrate risk associated with all aspects of your operations (i.e., the design, operations, inspections, maintenance and emergency management) is essential to developing and supporting goal-based EM systems.

Spectrum of Regulation

Comment

• Currently the only regulation using pipeline-risk assessment applies to sour gas pipelines
  – Existing AER setback requirements for sour gas pipelines are based on a rudimentary risk assessment done in the early 1970’s
• The majority of data used for integrity management, emergency management, and for conducting hazard and risk assessments overlap: i.e.,
  – Pipeline information (e.g., segment lengths, diameter, location, substance(s) transported, connectivity, operating pressure, etc)
• Specific data required for risk assessment may exist independently: i.e.,
  – Resident information and location
• The ability to assess and integrate risk associated with all aspects of your operations (i.e., the design, operations, inspections, maintenance and emergency management) is essential to developing and supporting goal-based EM systems.

Comments on Selected Recommendations from the Alberta Pipeline Safety Review ...

Selected Recommendation

1. Institute the risk ranking of all pipelines based on standardized methodology to be developed by Canadian regulators and stakeholders.

Comments

• Current hazard and risk assessment practices applied in Canada, and as advanced to the AER, are rigorous and supportable but typically use historical failure frequency data
• To be effective, the use of standardized risk methods that consider both individual and societal risk should:
  – Be applied at ‘screening-level’, recognizing that this would provide a starting point for
    • identifying high-risk areas and
    • prioritizing integrity programs but would exaggerate the risk presented
  – Allow for adjustments in historically frequencies to better represent the current condition of pipelines
Comments on Selected Recommendations from the Alberta Pipeline Safety Review ...

**Selected Recommendations**

3. Set minimum requirements for comprehensive inspection and testing programs for pipelines to establish the current condition of pipelines in assessed high-risk areas as identified in recommendation 1 above.

**Comments**

- Requirements could include recommendations for incorporating this type of data into more detailed, comprehensive risk assessments to better reflect the risk.

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**Selected Recommendations from the Alberta Pipeline Safety Review ...

**Selected Recommendation**

10. Third party encroachment and pipeline interference is still a major concern to licensees. Additional education of industry and the public as to the risk and regulatory requirements of working near pipelines could be promoted.

**Comments**

- Current AER setbacks for H₂S should be reviewed and extended to other hazardous products.
- Additional and reciprocal regulation should be applied on both sides of the fence (i.e., pipelines and land development).
footnote 1

- Must be standardized so that all stakeholders are using the same basis for comparison and have a common level of understanding and definition of risk.

footnote 2

- Potentially a near impossible task in Alberta
- Consideration should be given to accepting self- or third-party audits from licensees complimented by random and risk assessed requirements for ERCB led audits (could vary in intensity or focus as required)
footnote 4

- Leak detection, depth of cover, inline inspection, direct assessment of right of way surveillance
- Used with recommendation 5 will allow licensees with solid performance records to meet these requirements

EXAMPLES
Example: Define the System

How much gas is released, how fast and for how long?

Example: Characterize the Source

Determine the thermodynamic properties of the fluid during a pipeline blowdown

Determine the mass release rate with time for a range of failure scenarios
Example: Dispersion Modeling

H₂S concentrations following a pipeline rupture

00:00:30

Example: Determining Failure Frequencies

- Historical
  - Sour Gas Pipeline Failure Statistics 2012
  - Fault Tree Analysis
  - Bayesian models

- Tools
  - Coupons
  - Inspections (visual, UT, MPI, etc.)
  - Close interval surveys (coating evaluation)
  - In-line inspection (defect measurement)

- Predictive methods
  - Prediction of corrosion rates from corrosion models
  - Crack growth rate predictions

- Adjustments to Failure Rates
  - Based on above

Notes
- The current regulatory view of risk is based on the use of historical failure statistics.
- A move to goal-based systems will require that regulators accept adjustments (+/-) to historical values based on integrity programs and predictive models
Example: Pipeline Failure Statistics 2012


(Leak and rupture frequencies have been approximated; additional work is required)

Example: Pipeline Fault Tree Data


(Leak and rupture frequencies have been approximated; additional work is required)
Example: Integrity Data

- Cathodic Protection
  - Soil to Pipeline Measured As a Function of Distance From Facility

- In-Line Inspection
  - Pit Depth As a Function of Distance From Facility

- Coating Anomalies
  - As a Function of Distance From Facility

Example: Individual Risk for a Pipeline

\[ R_j(x,y) = P_R P_O \sum_{ijkl} F_{ij} P_{NI} P_{E_1} P_{E_2} P_{M_1} \int_{\theta} P_{\theta}(x,y) P_{E_{ijkl}}(x,y) dL d\theta \]

- Probability of a meteorological condition
- Probability of a release geometry
- Probability of non-ignition
- Frequency of failure
- Probability of wind angle
- Position of the receptor
- "Pipeline Interaction Length"
- Probability of being outdoors
- Probability of receptor at location
- Probability of fatality
- Probability of an emission rate

Note: Each scenario represented will have a singular frequency and fatality profile. The total number of people affected is a function of the population density.
Individual Risk of Mortality by Age (all causes)

Example: Setting a Standard - Societal Risk
Example: Individual Risk Common Risks in Alberta

<table>
<thead>
<tr>
<th>Cause</th>
<th>Individual Risk (Chances in a million of death per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Accidents</td>
<td>680</td>
</tr>
<tr>
<td>Motor Vehicle Accidents</td>
<td>250</td>
</tr>
<tr>
<td>Falls</td>
<td>66</td>
</tr>
<tr>
<td>Fires</td>
<td>21</td>
</tr>
<tr>
<td>Drowning</td>
<td>17</td>
</tr>
<tr>
<td>Poisoning</td>
<td>15</td>
</tr>
<tr>
<td>Struck by Falling Object</td>
<td>6</td>
</tr>
<tr>
<td>Excessive Cold</td>
<td>4</td>
</tr>
<tr>
<td>Railway Accident</td>
<td>2</td>
</tr>
<tr>
<td>Cataclysmic Storm</td>
<td>1</td>
</tr>
<tr>
<td>Lightning</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Example: Assumptions used in Risk Calculations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1. Base Case Screening-Level Data</th>
<th>2. Screening-level Data - Example ERCB Precedence</th>
<th>3. Site-specific Data - Example Site Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probability</td>
<td>Failure Frequency</td>
<td>Probability</td>
</tr>
<tr>
<td>Oil Emulsion Pipelines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaks (5 mm hole) (1000 km × yr)</td>
<td>0.88</td>
<td>7.15</td>
<td>0.93</td>
</tr>
<tr>
<td>Ruptures (1000 km × yr)</td>
<td>0.12</td>
<td>0.99</td>
<td>0.07</td>
</tr>
<tr>
<td>Small (AE/AP &gt; 50%)</td>
<td>0.40</td>
<td>0.39</td>
<td>0.40</td>
</tr>
<tr>
<td>Medium (AE/AP &gt; 50%)</td>
<td>0.30</td>
<td>0.29</td>
<td>0.30</td>
</tr>
<tr>
<td>Large (AE/AP &gt; 50%)</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Largest (AE/AP &gt; 100%)</td>
<td>0.15</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>Saltwater Pipeline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaks (100% of flow)</td>
<td>0.88</td>
<td>12.9</td>
<td>0.93</td>
</tr>
<tr>
<td>Ruptures (100% of flow)</td>
<td>0.12</td>
<td>1.8</td>
<td>0.07</td>
</tr>
<tr>
<td>Release Trajectory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal Jet</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Vertical Jet</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Probability: Ignition/Non-Ignition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ignition (pipes/wells)</td>
<td>0/0.5 min</td>
<td>0.1/0.5 min</td>
<td>Supported by Study of similar accidents</td>
</tr>
<tr>
<td>Non-Ignition (pipes/wells)</td>
<td>1</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Probability: Present @ Location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Outside (rural/urban)</td>
<td>1</td>
<td>1.0</td>
<td>0.44/0.32</td>
</tr>
<tr>
<td>Indoors (rural/urban)</td>
<td>0</td>
<td>0.4/0.6</td>
<td>0.32/0.48</td>
</tr>
</tbody>
</table>
Example: Event Tree for a Propane Release

Immediate Ignition | Delayed Ignition | VCE | Final Event | Probability of Final Event
--- | --- | --- | --- | ---
Initial Release | YES | 0.2 | Fireball | 0.2
NO | 0.8 | 0.12 | UVCE | 0.0096
| 0.88 | 0.9 | Flash Fire | 0.086
| | | Unignited Release | 0.704

VCE = Vapour cloud explosion

Example: Guidelines for Acceptable Land Use in the Vicinity of Industrial Facilities CSChE

Annual Individual Risk
Chance of fatality per year

<table>
<thead>
<tr>
<th>Risk Source</th>
<th>Individual Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing, warehousing, open space (e.g., ballparks, golf courses, etc.)</td>
<td>1 in a million (10^-6)</td>
</tr>
<tr>
<td>Low-density residential (up to 10 units with ground floor access, per net heating) and commercial, including offices, retail centers, restaurants, entertainment centers, sporting complexes</td>
<td>1 in a million (10^-6)</td>
</tr>
<tr>
<td>High-density residential and commercial, including places of continuous occupancy such as hotels and tourist resorts</td>
<td>0.3 in a million (0.3 x 10^-6)</td>
</tr>
<tr>
<td>Sensible developments (e.g., hospitals, child care facilities and aged care housing developments)</td>
<td>150 in a million (150 x 10^-6)</td>
</tr>
</tbody>
</table>

Allowable Land Uses
### Example: AER Setback Requirements for Sour Gas Pipelines

<table>
<thead>
<tr>
<th>Level of Sour Gas Facility</th>
<th>Potential H₂S Release</th>
<th>Minimum Distance to Various Developments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sour Well release rate (m³/s)</td>
<td>Other Facility, release volume (m³)</td>
</tr>
<tr>
<td>1</td>
<td>&lt; 0.3</td>
<td>&lt; 300</td>
</tr>
<tr>
<td></td>
<td>For wells 0.1 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No minimum</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.3 – 2.0</td>
<td>300 - 2000</td>
</tr>
<tr>
<td></td>
<td>0.1 km to individual permanent dwelling and unrestricted country residential</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5 km to urban centre</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.0 – 6.0</td>
<td>2000 - 6000</td>
</tr>
<tr>
<td></td>
<td>0.1 to individual permanent dwellings up to 8 dwellings per quarter section</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5 to unrestricted country residential</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.5 km to an urban centre</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&gt; 6.0</td>
<td>&gt; 6000</td>
</tr>
<tr>
<td></td>
<td>As specified by the regulator but not less than Level 3</td>
<td></td>
</tr>
</tbody>
</table>

### Example: Societal Risk (UK)

![Graph showing societal risk](image)
Example: Individual Risk Adjacent to a Sour Gas Pipeline

- 1.5 km of 16% H₂S Pipeline
- 168.3 mm (6.6")
- MOP = 6500 kPa
- ESD Trigger pressure = 4000 kPa

Note: For a person located 1000 m from the pipeline, a risk of 2 in a million represents a chance of an event resulting in fatality once every 500,000 years.

Example: Relationship between Emergency Response Times & Risk

- No evacuation
- Evacuation within 1-hour
Example: Relationship between Emergency Response Times & Risk

Evacuation within 15-minutes

- Generally, ruptures result in larger impact zones and longer event durations than leaks. Conversely, leaks have smaller impact zones but longer event durations.
- Emergency response times (time required for boots-on-the-ground) that are greater than the event time will be less effective than response times which are less.
- In cases where the public are at risk and the response time may exceed the event time, the public should be made aware of the nature of the hazard, its location relative to them and be provided with information regarding public protection actions such as shelter-in-place.

Example: Application of CSChE Guidelines to Sour Gas Pipeline Results

- Annual Chance of Fatality (Chances in 1 million)
- Distance from Pipeline (m)
- Exclusion Zone (no other land use) NA
- High-density residential, and commercial, including places of continuous occupation (hotels, resorts)
- Low-density residential & commercial, including offices, retail, restaurants, entertainment & sporting
- Manufacturing, warehouses, open spaces (parkland, golf courses, etc)
- Sensitive developments such as hospitals, aged & child care
- No Rainout
- Rainout
- >= 100 chances / million
- Manufacturing, warehouses, open spaces (parkland, golf courses, etc)
- 10
- 100
- 1000
- 1500
- 2000
- NA
- Manufacturing, warehouses, open spaces (parkland, golf courses, etc)
Comment: Use of Hazard- & Risk-based Information

- Hazard-based information considers "What could go wrong?"
  - Identifies the nature and extent of a release
  - Historically the worst-case hazard has been used to define Emergency Planning Zones (EPZs)
  - Current AER method for determining EPZs uses meteorologically averaged distances
  - Can be used to evaluate the effectiveness of the design and control measures as well as public the protection measures being considered

- Risk-based information considers "What is expected to go wrong!"
  - Looks at the likelihood that a specific event or range of events will occur and produce a defined level of harm
  - Considers impacts to individuals and society as a whole
  - Used to establish setbacks and acceptable land-use activities adjacent to a hazardous facility
  - (e.g., CSChE and AER setback provisions)
  - The level of risk can be reduced if an effective ERP is in place

DEFINITIONS
**Definition: Risk**

- Risk is a measure of the potential to cause harm. This includes consideration of the:
  - Likelihood that a range of individual release events (e.g., leaks through ruptures) can occur, and the
  - Magnitude of harm associated with each event.
- In simple terms risk is:
  \[ \text{Risk} = \text{Frequency} \times \text{Consequence} \]
- Risk may be considered from the perspective of:
  - An individual, and
  - Society as a whole

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**Thank you for your participation!**

**THE END**