Part 13: Pipeline Risk Assessment
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WARNING
GAS PIPELINE
BEFORE EXCAVATING OR IN EMERGENCY
CALL YOUR LOCAL CITY
NATURAL GAS SYSTEM
•
DAY OR NIGHT (000) 000-7777
Introduction

• The ability to predict pipeline failures—where and when the next is to occur—would obviously be a great advantage in reducing risk.
• This is not possible except in extreme cases
• Modern risk assessment methodologies provide a surrogate for such predictions.
• Risk efforts are NOT attempts to predict how many failures will occur or where the next failure will occur.
• Efforts are designed to capture and use information to make better decisions.


Formal versus Informal Risk Management

• Risk management has always been practiced by these pipeline operators
• Every time a decision is made to spend resources in a certain way, a risk management decision has been made
• An informal approach to risk management can have the further advantages of being simple, easy to comprehend and to communicate, and the product of expert engineering consensus built upon solid experience
Historical (Informal) Risk Management

Has pluses and minuses
- Simple/intuitive
- Consensus is often sought
- Utilizes experience and engineering judgment
- Somewhat successful, based upon pipeline safety record

Reasons to change:
- More at stake from mistakes
- Inefficiencies/subjectivities inherent in informal systems
- Lack of consistency and continuity in a changing workforce unless decision-support systems are in place
- Need to better consider complicated risk factors and their interactions
Beginning the Risk Modeling Process

Successful risk assessment modeling involves:

• Identifying an exhaustive list of contributing factors versus choosing the critical few to incorporate in a model (complex versus simple)

• "Hard" data and engineering judgment (how to incorporate widely held beliefs that do not have supporting statistical data)

• Uncertainty versus statistics (how much reliance to place on the predictive power of limited data)

• Flexibility versus situation-specific model (ability to use same model for a variety of products, geographical locations, facility types, etc.)
Definition

Risk = Probability x Consequence
    = Likelihood x Severity
Questions to Pipeline Operator

• What data do you have?
• What is your confidence in the predictive value of those data?
• What are the resource demands (and availability) in terms of costs, man-hours, and time to set up and maintain a risk model?
• What benefits do you expect to accrue, in terms of cost savings, reduced regulatory burdens, improved public support, and operational efficiency?
Choices in Risk Assessment Techniques

- The goal is to quantify the risks in either a relative or an absolute sense
- Risk assessment phase is the critical first step in practicing risk management
- No one can definitively state where or when an accidental pipeline failure will occur.
- More likely failure mechanisms, locations, and frequencies can be estimated in order to focus risk efforts.
- There is no universally accepted way to assess risks from a pipeline
- Three general categories of more formal pipeline risk assessment models can be found in use today
Three General Categories

1. Simple decision support: Matrix models
2. The rigorous approach: Probabilistic/mechanistic models
3. The hybrid approach: Indexing models
Simple Decision Support: Matrix Models

- Ranks risks according to the likelihood and potential consequences of an event by a simple scale, such as high, medium, and low.
- Events with both a high likelihood and a high consequence appear higher on the resulting prioritized list.
- This approach may be as simple as using an expert's opinion or as complicated as using quantitative data to rank risks.
Risk Matrix

- High risk: > 12 risk index
- Medium risk: 5 < risk index < 12
- Low risk: < 5 risk index
Probabilistic/Mechanistic Models

- The more rigorous and complex risk assessment is often called a Probabilistic Risk Assessment (PRA)
- Refers to a technique employed in the nuclear and aerospace industries
- Uses event trees and fault trees to model every aspect of a system
- Initiating events are flowcharted forward to all possible concluding events, with probabilities being assigned to each branch along the way
- Failures are backward flowcharted to all possible initiating events, again with probabilities assigned to all branches
- Relies on historical failure rate data. It yields absolute risk assessments for all possible failure events
Fault Tree

Loss of Spacecraft Control

- Mechanical Failure
- Operator Error

- Read Instrument Error
- Wrong Command

BE1  BE2  BE3

OR

On Space Station Trajectory?

n  

p1

y  1-p1

Approaching Station

Able to Stop before Station?

n  

p2

y  1-p2

Collision with Station

Main Damage to Station?

n  

1-p3

y  p3

LOSS OF MISSION

LOSS OF MISSION

Potential of Loss of Module

Module Recovery Effective?

n  

1-p4

y  p4

LOSS OF STATION ELEMENT

INTERUPTION OF STATION OPERATION
Event Tree

- Sprinkler System
  - Success: Call to Fire Dept. → Outcome: OK → Consequence: 1
  - Failure: Call to Fire Dept. → Outcome: Partial Damage → Consequence: 2
- Failure: Call to Fire Dept. → Outcome: Partial Damage → Consequence: 2
- Failure: Call to Fire Dept. → Outcome: System Destroyed → Consequence: 3
Fault Tree

- Loss of Asset
  - OR
  - Fire Propagation
    - AND
    - Fire
      - AND
      - Material having CV
      - Expired Extinguishers
    - Gas leakage
    - Thermal Flow
      - OR
      - Shock
      - Aging
      - Corrosion
      - Faulty component
  - OR
  - Continuation of Explosion
    - AND
    - Explosion
      - AND
      - Gas Bottle
        - AND
        - Heat Source
      - Thermal Flow
      - Fire
      - Fire Propagation
    - Expired Extinguishers
    - Material having CV
    - Gas leakage
Indexing Models

• Most popular pipeline risk assessment technique
• A relative weight is assigned to every important condition and activity on the pipeline
• This includes both risk-reducing and risk-increasing items
• This relative weight reflects the importance of the item in the risk assessment
• The risk component scores are subsequently summed for each pipeline section to obtain a relative risk ranking of all pipe sections
• The various pipe segments may then be ranked according to their relative risk scores in order to prioritize repairs and inspections
Indexing Models

• Among pipeline operators today, this technique is widely used and ranges from a very simple 5-20 factor model
• Models with hundreds of factors considering virtually every item that impacts risk
• When an indexing model is created from probabilistic approach-using scenarios, event/fault trees, and all available historical data-this approach is often a solution with the best cost-benefit ratio
Typical Pipeline Risk Model Structure

Relative Risk Score

Leak Impact Factor

Index Sum

Third Party Damage

Corrosion

Design

Incorrect Operations
Other Issues in Risk Modeling

- Absolute versus relative risk
- Quantitative versus qualitative models
- Subjectivity versus objectivity
- The use of unquantifiable evidence
- Uncertainty
Choosing a Risk-Assessment Technique

• Any or all of the previously described techniques might have a place in risk assessment/management.
• The choice may well be dependent on the situation.
• Understanding the strengths and weaknesses of the different risk assessment methodologies gives the user the basis for choosing one.
• A case can be made for using each in certain situations.
• For example, a simple matrix approach crystallizes thinking and is a step above informal risk assessment.
Pros and Cons (Matrix)

+ Improvement over informal techniques
+ Forces more logical examination of situation
+ Inexpensive approach
- Limited number of risk factors (not comprehensive)
- Subjective
Pros and Cons (PRA)

+ Rigorous, scientific approach
+ Accepted in other industries
+ Uses all available information
- Costly
- Difficult to do resource allocation
- Difficult to do overall risk management
- Might create the "illusion of knowledge"
- Intimidating to non-technical audience
Pros and Cons (Indexing)

+ Uses all available information + Intuitive
+ Flexible
- Possibly more subjective
- Must be well documented
- Often requires a subsequent linkage to absolute values
Application Choices (Matrix)

- Better quantify a belief
- Create a simple decision support tool
- Combine several beliefs into a single solution
- Document choices in resource allocation
Application Choices (PRA)

• Better quantify a belief
• Create a simple decision support tool
• Combine several beliefs into a single solution
• Document choices in resource allocation
Application Choices (Indexing)

- Obtain an inexpensive overall risk model
- Create a resource allocation model
- Model the interaction of many potential failure mechanisms
- Study or create an operating discipline
The Ideal Risk Assessment Model

Includes the following:

• Costs
• Learning ability
• Signal-to-noise ratio
• Managing Risks: The Cost Connection
Sample Risk Variable List

- Relative Risk = [Index Sum]/[Leak Impact Factor]
- Index Sum = [Third Party] + [Corrosion] + [Design] + [Incorrect Operation]
# Third Party Damage Potential

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Percentage</th>
<th>Points</th>
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<tbody>
<tr>
<td>A</td>
<td>Minimum depth cover</td>
<td>20%</td>
<td>0-20 pts</td>
</tr>
<tr>
<td>8</td>
<td>Activity level</td>
<td>20%</td>
<td>0-20 pts</td>
</tr>
<tr>
<td>C</td>
<td>Above-ground facilities</td>
<td>10%</td>
<td>0-10 pts</td>
</tr>
<tr>
<td>D</td>
<td>One-call system</td>
<td>15%</td>
<td>0-15 pts</td>
</tr>
<tr>
<td>E</td>
<td>Public education</td>
<td>15%</td>
<td>0-15 pts</td>
</tr>
<tr>
<td>F</td>
<td>Right-of-way condition</td>
<td>5%</td>
<td>0-5 pts</td>
</tr>
<tr>
<td>G</td>
<td>Patrol</td>
<td>15%</td>
<td>0-15 pts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100%</td>
<td>100 pts</td>
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## Corrosion Potential

### A. Atmospheric corrosion  0-10 pts

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<tr>
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<th>Atmospheric corrosion</th>
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<tbody>
<tr>
<td>A1</td>
<td>Atmospheric coating</td>
<td>0-3 pts</td>
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<tr>
<td>A2</td>
<td>Atmospheric type</td>
<td>0-2 pts</td>
</tr>
<tr>
<td>A3</td>
<td>Atmospheric coating</td>
<td>0-3 pts</td>
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</tbody>
</table>
## Corrosion Potential

### B. Internal corrosion 0-20 pts

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>B1</td>
<td>Product corrosively</td>
<td>0-10 pts</td>
</tr>
<tr>
<td>B2</td>
<td>Internal protection</td>
<td>0-10 pts</td>
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</table>
## Corrosion Potential

### C. Subsurface corrosion (0-70 pts)

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<thead>
<tr>
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<th>Subsurface environment</th>
<th>0-20 pts</th>
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<tbody>
<tr>
<td>C1</td>
<td>Soil corrosivity</td>
<td>0-15 pts</td>
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<tr>
<td></td>
<td>Mechanical</td>
<td>0-5 pts</td>
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<tr>
<td></td>
<td>corrosion</td>
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<table>
<thead>
<tr>
<th></th>
<th>Cathodic protection</th>
<th>0-25 pts</th>
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<tr>
<td>C2</td>
<td>Effectiveness</td>
<td>0-15 pts</td>
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<tr>
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<td>Interference potential</td>
<td>0-10 pts</td>
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<thead>
<tr>
<th></th>
<th>Coating</th>
<th>0-25 pts</th>
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<tbody>
<tr>
<td>C3</td>
<td>Fitness</td>
<td>0-10 pts</td>
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<tr>
<td></td>
<td>Condition</td>
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### Design Risk

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<tbody>
<tr>
<td>A</td>
<td>Safety factor</td>
<td>35%</td>
<td>0-35 pts</td>
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<tr>
<td>B</td>
<td>Fatigue</td>
<td>15%</td>
<td>0-15 pts</td>
</tr>
<tr>
<td>C</td>
<td>Surge potential</td>
<td>10%</td>
<td>0-10 pts</td>
</tr>
<tr>
<td>D</td>
<td>Integrity verification</td>
<td>25%</td>
<td>0-25 pts</td>
</tr>
<tr>
<td>E</td>
<td>Land movements</td>
<td>15%</td>
<td>0-15 pts</td>
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</table>

Total: 100%  
0-100 pts
# Design Risk

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<tr>
<th>A</th>
<th>Design</th>
<th>30%</th>
<th>0-30 pts</th>
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<tr>
<td></td>
<td>Hazard identification</td>
<td>0-4 pts</td>
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<td>MAOP potential</td>
<td>0-12 pts</td>
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<td></td>
<td>Safety systems</td>
<td>0-10 pts</td>
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<td></td>
<td>Material selection</td>
<td>0-2 pts</td>
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<tr>
<td></td>
<td>Checks</td>
<td>0-2 pts</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>B</th>
<th>Construction</th>
<th>20%</th>
<th>0-20 pts</th>
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<tbody>
<tr>
<td></td>
<td>Inspection</td>
<td>0-10 pts</td>
<td></td>
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<tr>
<td></td>
<td>Materials</td>
<td>0-2 pts</td>
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<tr>
<td></td>
<td>Joining</td>
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<tr>
<td></td>
<td>Backfill</td>
<td>0-2 pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handling</td>
<td>0-2 pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coating</td>
<td>0-2 pts</td>
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</tbody>
</table>
## Design Risk

<table>
<thead>
<tr>
<th></th>
<th>Operation</th>
<th>%</th>
<th>Pts</th>
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</thead>
<tbody>
<tr>
<td>C</td>
<td>Procedures</td>
<td>0</td>
<td>0-7 pts</td>
</tr>
<tr>
<td>SCADA/ communications</td>
<td>0</td>
<td>0-3 pts</td>
<td></td>
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<tr>
<td>Drug testing</td>
<td>0</td>
<td>0-2 pts</td>
<td></td>
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<tr>
<td>Safety programs</td>
<td>0</td>
<td>0-2 pts</td>
<td></td>
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<tr>
<td>Surveys/maps/ records</td>
<td>0</td>
<td>0-5 pts</td>
<td></td>
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<tr>
<td>Training</td>
<td>0</td>
<td>0-10 pts</td>
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<tr>
<td>Mechanical error preventers</td>
<td>0</td>
<td>0-6 pts</td>
<td></td>
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<tr>
<td><strong>D</strong></td>
<td>Maintenance</td>
<td>15</td>
<td>0-15 pts</td>
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<tr>
<td>Documentation</td>
<td>0</td>
<td>0-2 pts</td>
<td></td>
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<tr>
<td>Schedule</td>
<td>0</td>
<td>0-3 pts</td>
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<tr>
<td>Procedures</td>
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<td>0-10 pts</td>
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<tr>
<td><strong>Total</strong></td>
<td>100%</td>
<td>0-100 pts</td>
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</table>
Leak Impact Factor

• Leak Impact Factor = (Product Hazard) x (Receptors) x (Spill Size) x (Dispersion)
Leak Impact Factor

A: Product hazard
   I. (Acute + chronic hazards)
      Acute hazards
         a. Nf  0-4
         b. Nr  0-4
         c. Nh  0-4
      Total (Nh+Nr+Nf)  0-12
   2. Chronic hazard, RQ  0-1

B Receptors  0-1
   Population
   Environment
   High value areas

C Spill size  0-1
D Dispersion  0-1
Summary

• The move to more formal risk techniques is intended to increase operational consistency and credibility, especially when such techniques are offered for public viewing.

• Risk management has long been recognized as a valuable effort in pipeline operations.

• Risk assessment approaches are available to serve many needs.
References
