Risk and Reliability Targets used by TransCanada

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Agenda

• Introduction

• Why do we need risk and reliability targets?

• Risk and Reliability Targets in System Wide Risk Assessment (SWRA)

• Reliability Targets in Corrosion Assessment

• Risk and Reliability Targets in Engineering Assessments (EAs)
TransCanada Corporation (TSX/NYSE: TRP)

One of North America’s Largest Natural Gas Pipeline Networks
- Operating 90,300 km (56,100 miles) of pipelines
- Transports 27 per cent of continental demand

North America’s Largest Natural Gas Storage Operator
- More than 664 Bcf of capacity

Canada’s Largest Private Sector Power Generator
- 17 power facilities, 10,700 MW
- Diversified portfolio, including wind, hydro, nuclear, solar and natural gas

Liquids Pipeline System
- Keystone Pipeline System: 4,300 km (2,700 miles), 545,000 bbl/d contracted capacity
- Safely delivered more than 1.3 billion barrels of Canadian oil to U.S. markets since 2010
Risk is the expected value of loss.

Risk = f(Probability of Failure - POF, Consequences of Failure)

Reliability = Probability of being safe = 1 - POF

POF is from the pipeline’s perspective

Risk is from the risk receptor’s perspective

Different risk measures – Individual risk, Societal risk

Definitions
Providing Safety levels

Engineered systems provide safety levels by:

- **Target Risk levels**
  - Qualitative methods cannot target consistent risk levels but has unknown varying levels of risk
  - Quantitative methods can achieve more consistent levels of risk
  - Risk targets are smeared which makes it more appropriate for segment risk

- **Target reliability levels**
  - Deterministic methods have implicit reliability targets
  - Reliability methods have explicit reliability targets
  - Reliability targets are more location specific and appropriate for site specific and defect specific management
Risk Targets

• From the **risk receptors and risk measure perspective**

• Can be **independent of infrastructure** if units match (transferable between industries)

**Generally based on:**

• Societal acceptance levels e.g., mortality rates of accepted lifestyles as in MIACC, HSE $10^{-4}$ /person/yr

• Safety levels implicit in code designs (back calculated and average considered acceptable) as in UK IGEM TD/1

• Safety levels based on statistics of different consequence categories as in PD-8010 based on both design considerations and real incidents – adopted by SWRA

• Due to units, varying risk aversion levels for occupations, acceptance definitions, and assessment methods it could vary considerably
RISK TARGETS IN SWRA
Three different measures and targets are used:

- Risk
  - Individual Risk
  - Societal Risk
- Reliability
  - LOF or POF
Individual Risk

- **Objective of IR**
  - To protect the individual that could potentially be there, and not the full time residents. It basically accounts for uncertainties in human activity.

- **Assumptions**
  - An individual is always present 24/7 at each interaction length (conservative)

- **Actual IR**
  - Calculated using the predicted failure frequencies and the predicted consequence

- **Acceptable IR**
  - Set through regulations and industry experience; actual IR must be below acceptable IR in order for the pipeline to be deemed safe
Significance of IR

• Constant Likelihood of Failure, different pipe OD

• Significantly different impact zones

![Graph showing annual risk of fatality vs. distance from the point of interest](image)

San Bruno rupture NPS 30

NPS 8

NPS 10

NPS 20
Individual Risk - Summary

- Annual probability that an individual will become a casualty due to hazards to which they are exposed

- Calculation algorithm assumes risk to an individual at certain location is due to all possible scenarios that would affect the individual

- IR tolerability criterion – established by examining risk posed by everyday activities
Individual Risk Criteria (fatalities/yr)

MIACC

**Annual Individual Risk**
- 100 in a million ($10^{-4}$)
- 10 in a million ($10^{-5}$)
- 1 in a million ($10^{-6}$)

**Risk source**
- No other land use
- Manufacturing, warehouses, open space (parkland, golf courses, etc.)
- Commercial, offices, low-density residential
- All other uses including institutions, high-density residential, etc.

**Allowable Land Uses**
- $1 \times 10^{-3}$ (worker)
- $1 \times 10^{-4}$ (public)
- $1 \times 10^{-6}$ (all)

**UK**
- $1 \times 10^{-5}$ (non-vulnerable)
- $1 \times 10^{-6}$ (vulnerable)

**Netherlands**
- TCPL
Societal Risk

- **Objectives of SR**
  - To capture the consequence of a pipeline failure to the residents that could potentially be affected by that failure.

- **Actual SR**
  - Calculated using the predicted failure frequencies and the predicted consequence

- **Acceptable SR**
  - Set through regulations and industry experience; actual SR must be below acceptable SR in order for the pipeline to be deemed safe

- **Risk aversion**
  - Captures lower tolerance to high consequence incidents
Societal Risk (SR)

- Risk to a group of people that are potentially affected by the risk source

- Generally expressed in terms of an FN curve over the evaluation length in terms of two variables:
  - $N$ – Expected Number of Fatalities
  - $F$ – Frequency of $N$ or More Fatalities

- Incorporates risk aversion
Societal Risk Criteria
SR - TransCanada Practical Cases

- Approximately 3.5km of pipe evaluated
- 24” pipeline, low POF of approximately $10^{-6}$ failures/km/yr
- High consequence
Reliability Targets

Reliability is infrastructure dependent (pipelines/km/yr)

Generally based on:

• Code calibration to design for consequence categories as in CSA Z662 Annex O calibrated to designs

• Historical statistics based – has to be inline with lower percentiles of historical failure rates

• Reliability levels implicit in safety factors as in structural codes and Carlo program

• Relative reliability levels as in Engineering assessments (site specific calibration to code acceptance)
Reliability in Deterministic vs Probabilistic methods

**Failure Pressure Ratio (FPR) = Rupture Pressure Ratio (RPR)**

\[ FPR = \frac{\text{Predicted Burst Pressure}}{\text{MOP}} \]

Remediation criterion: **FPR \leq SF (safety factor)**

Resistance to rupture at a given feature / load that causes the rupture

**Reliability = 1- Probability of Failure (POF)**

Remediation criterion:

- Reliability \leq Reliability Target, or
- POF \geq Max. Allowable POF
Conservatism in deterministic assessments

1. **Conservative constant inputs** (e.g., SMYS) – accounts for uncertainty in variables

2. Further conservatism with minimum **safety factors** (SF) – accounts for different consequences, human error, unaccounted uncertainties etc.

Each variable involved has uncertainty

For a given defect and pipeline using same equation a RPR (or SF) corresponds to a POF value.
Higher SF for higher classes

- For consistent safety/risk in higher consequence areas
  - Provide lower probability of failure by using higher SF
- Design principles are the same
Within class variation in Risk for deterministic code designs

Risk Levels Inherent in Compliant Pipelines [Nessim et al. 2004]

Deterministic compliance leads to highly variable risk levels
Why we need LOF criteria in addition to risk criteria,

- Risk and LOF are not equal concepts
  - A high LOF pipeline ≠ safety risk, if there is no risk receptor (i.e. no safety consequence)
- To reduce the number of incidents
  - Failures without safety risk but could cause significant business interruption
  - Negative impact to the company’s reputation, e.g.
    - NCC
    - Otterburne
- To accommodate regulatory drive towards zero incidents
RELIABILITY TARGETS IN CARLO AND CRACK ANALYZER
Limitations of Deterministic Approach

• Does not acknowledge and account for any uncertainties

• Consequently, conservative in general, but not necessarily assure safety

  E.g. conservative when assessing long defects, but...

**Example of Critical Defects Identified by Probabilistic Criteria for Immediate Excavation**

- **ILI-Reported FPR**
- **In-Field FPR**

**Critical**

**Non-Critical**

- **Repaired Defects in Class 1 Location**

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**Figure Notes:**

- In-Field FPR (Field FPR) values:
  - 1.00
  - 1.05
  - 1.10
  - 1.15
  - 1.20
  - 1.25
  - 1.30
  - 1.35
  - 1.40
  - 1.45
  - 1.50
  - 1.55
  - 1.60

- ILI-Reported FPR values:
  - 1.00
  - 1.05
  - 1.10
  - 1.15
  - 1.20
  - 1.25
  - 1.30
  - 1.35
  - 1.40
  - 1.45
  - 1.50
  - 1.55
  - 1.60

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**Graph Details:**

- **Unity Line**
- **Critical Defects Identification**
- **Non-Critical Defects Identification**
- **Repairs in Class 1 Location**
Reliability-Based Approach for Defect Assessment

- Reliability-based approach provides more consistent safety levels

**Reliability targets available for assessing defects in the industry?**

- **CSA Annex O Reliability Targets** – not in per-defect basis
  - Rupture (in per km-yr)
    - Function of OD, pressure and population density
    - developed for total reliability
    - average of all design cases
  - Leak
    - Max. allowable POL = 1.0E-03 (per km-yr)
TCPL’s Reliability-Based Criteria for Rupture

- Pipeline- and ILI-run-specific
- Location-class specific
- Rationales
  - Benchmarked to demonstrated acceptable safety levels;
  - Explicitly account for all uncertainties - more risk-consistent
  - Appropriate for defect assessment

FPR = 1.25 for Class 1 location

POF Threshold = 2E-03

All features from one ILI run
TCPL’s Reliability-Based Criteria for Leak

- **1E-03 per year (per defect)**

- **Rationales**
  - Equivalent to CSA Z662 Leak Reliability Target, i.e. 1-1E-03 per km-yr
  - Equivalent to 72%wt ILI depth
  - Practically aligned with TCPL’s ILI depth criteria of 70%wt for excavation, since
    - MFL’s limitation in sizing pinhole or complex corrosion features
Benefits of Reliability-Based Approach and Criteria

**Repaired-to-excavated ratio**

\[
\text{Repaired-to-excavated ratio} = \frac{\# \text{ of repair sites}}{\text{total } \# \text{ of excavated sites}}
\]

- **Critical defect for repair (cutout or sleeve)**
  - i. In-field FPR \(\leq\) FPR safety factor, and/or
  - ii. Field-measured maximum depth \(\geq\) 70%wt

- **Comparison** (based on 2011 and 2012 excavation data)

<table>
<thead>
<tr>
<th>Approach</th>
<th>Repaired-to-excavated ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterministic</td>
<td>15%</td>
</tr>
<tr>
<td>Probabilistic / Reliability-Based</td>
<td>Overall 25%</td>
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<tr>
<td></td>
<td>Immediate response 32%</td>
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</tbody>
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Developing similar approach for crack assessment!
RISK AND RELIABILITY TARGETS IN ENGINEERING ASSESSMENTS
• Two types of reliability targets are used in EAs
  
  • Defined targets – recommended values in code and standards (e.g., CSA Z662 Annex O) or TransCanada’s internal targets (e.g., SWRA and Carlo)

  • Relative targets – calculated values for the code accepted mitigation options (such as pipe replacement or derate).

• Use of defined or relative targets are determined on a case by case basis
Relative Targets

Use a target that meets safety level implicit in code
Comparison Between Annex O Target and Target Used in Out-of-Class EAs

The relative targets used in our EAs are similar and consistent with the targets defined in CSA Z662 Annex O.
Ensuring Acceptable Risk Level in EAs

Compliance with IR and SR are also demonstrated in EAs by comparing mitigation option with the risk criteria
Summary – Risk & Reliability Targets

• Target Risk levels
  • QRA methods can achieve more consistent levels of risk
  • SWRA targets
    • Follows best practice in industry IR and SR,
    • Consistent with actual statistics
    • Are aligned to practical TC scenarios to be realistic
  • Risk targets are smeared (averaged) - appropriate for segment risk

• Target reliability levels
  • Location specific explicit reliability targets - more consistent
  • Consistent with code safety factors, code accepted safety levels
  • In line with IR, SR, and Annex O targets
Consistency between best practices in industry

- Deterministic designs based on Codes or Standards provide higher reliability for higher consequences on average – high variability
- Codes and Standards provide minimum standards for broad categories (e.g., class based designs) and common hazards
- Actual reliability varies around common cases based on site specific conditions not considered in design e.g., Ptape vs FBE, defects
- Risk and reliability criteria is often benchmarked to successful code practice (avg) and statistics but gives more consistent safety
- Reliability criteria - Site specific/local considerations make the calculation more precise and accurate (avoids failures)
- Risk and reliability methods have reasonable agreement when based on same assumptions
Questions?