RBI of Offshore Platforms

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Reliability and Integrity Unit

Inspection Team provides risk based inspection, NDE, and integrity management support to CVX operations worldwide.

- Graduated with a BSc in Mech Engineering from University of Alberta.
- Started with Chevron Canada Resources in 1995 at the 495 MMscfd Kaybob South #3 Sour Gas Plant as a facilities engineer. Became the facility's corrosion engineer in 1997.
- In 2000 he joined Chevron Research and Technology Company in Richmond, CA.
- Hold API 510 and 570 certificates
- Currently chair of the Pipeline Research Council International (PRCI) Corrosion Committee

Purpose of the Presentation

- Discuss our methodology
  - Discuss which types of methods
  - Discuss ways to integrate approaches
- Discuss issues that have been seen from assessments
- Discuss integration of qualitative and quantitative methods
- Share Lessons Learned

What is Risk Based Inspection

Term is becoming extremely widely used and often not with consistent terminology

Per API 580:

- **"3.1.25 risk-based inspection:**

  A risk assessment and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.

Our Approach

Company has been involved in RBI since its start with API, sitting on original committee.

- Utilize for entire range of equipment – upstream, downstream, marketing, pipelines, facilities…

Company uses the range of methods available - qualitative, semi-quantitative, and quantitative – depending on the objective.

Our approach is to focus on a Qualitative approach for an initial assessment.

- Why? Good Experience with results.
- Provides a good relative ranking of equipment within a facility
- Flexible and adaptable based on the amount of data available.
- Accesses the best source of data → People
  - Records get updated as a result
  - Takes people through the process (not "black box")
  - They understand how their input is used
  - Generates buy in for the results – they understand why a particular recommendation is made

Participants

Important to get people knowledgeable about the facility/equipment under review

Typically two operators, at least one sr. operator

- Looking for at least 5 yrs experience at facility
- Ops has two important roles:
  1. Identify Operational problem and issues
  2. Identify consequences of a failure
     - Includes criticality – if equipment goes down, what are the effects to the system
     - Share consequences of past failures

At least one maintenance hand – preferably a highly experienced, long term person

- What has broken/failed/been repaired/changed out
- Time and cost to repair

Participants

Facility and Process Engineering

- Operating limits of the facility

Reservoir (Resource)

- Provide information on life of the field
- Likely changes in field over life

Chemical Vendor (Resource)

- Provides input on chemicals, injection locations, and often, the results of the monitoring program

Facilitator

- within our company this is typically from outside the local operation
- Provides an independent perspective – breaks the "group think" and "we have always done it this way"

Scribe

- Responsible for distilling discussion into a clear summary of the scenario and consequences

Initial Steps

Data gathering and preparation is probably the most commonly underestimated task, but it will make or break the assessment

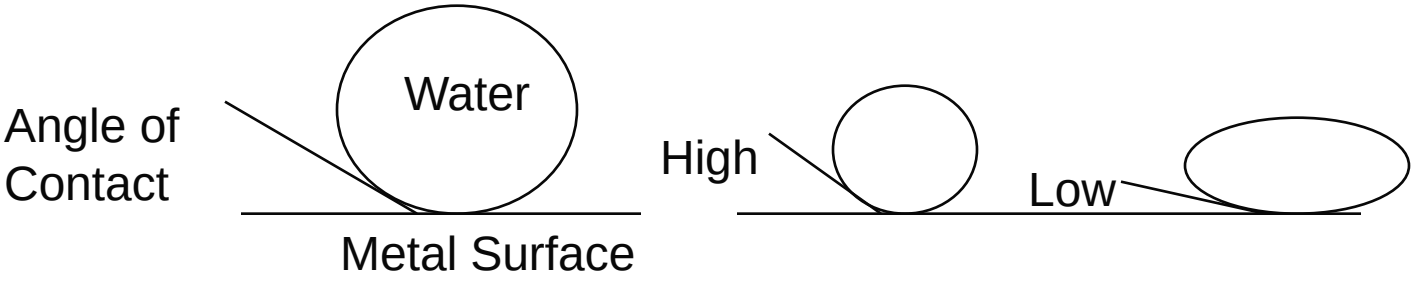
- Circuitizing the PFDs
  - Are they correct and reflect current flows?
- Historical data
  - Single events are often precursors to major problems
  - If record keeping is poor – may lose data, can result in erroneous conclusions
  - Event causes are often erroneously assigned
    - "Erosion" is often assigned for all corrosion events
    - "Fatigue" for cracking
  - Root cause analysis is important

Aging of Assets

- Production Characteristics change
- can change degradation mechanisms
  - Eg Souring of production
  - Common in 10-20yr old sea water flood fields
  - Can reach several hundred ppm H2S
  - Exceed the NACE criteria on sweet built facilities
  - Often first shows up in gas lift systems
  - Potential for significant events “bad day”
    - Crack to rupture
    - Gas release/fire
    - Personnel knockdown/fatality

Increasing Water Cut

- Systems are “dry” when new
- Oil rates decrease or are stable
- Water rates increase, often rapidly when break through occurs
- Initially surfaces are oil wet – no corrosion
- Production rates drop, water drops out occurs and surfaces become water wet



Decreasing Production Rates

- When rates drop, change in flow regime and water drop out and solids accumulation is possible
  - Stokes Law and the horizontal bulk velocity can be used to predict whether solids will settle
  - Solids cause scale/film disruption and initiation of corrosion due to differential corrosion cells beneath settled solids
- If do not have a regular inspection program and you find corrosion…
  - "When did it start?" – Time for initiation is unknown
  - How do you calculate the corrosion rate in order to get the half life per API 510/570?
  - Can make a large difference in the results
- Try to make estimates using modeling
- Install monitoring devices

Changing Composition

- In order to keep facilities full we tie in new wells/fields/zones
- Can get compatibility issues – e.g. scaling
- Changes in composition, e.g. blending low levels of H2S with CO2
  - H2S may be protecting you initially through passive film formation
  - If you blend it down too far, unable to form protective film and get accelerated attack at localized spots.

Operating Above the Dew Point

- System starts experiencing rapid attack after the installation of a new gas system
- Check to see if system is operating above the dew point
  - During the meeting, ask ops if getting any liquids/water in the knock outs
    - If “yes”, ask color
      - “Almond”
      - “Black”
      - “Blood”
  - Ask if the pots are on level control and if are shown on SCADA
    - If yes, can estimate amount of water drop out and therefore corrosion

Operating Above the Dew Point

- Outside of meeting –
  - Take sample, measure pH, and leave exposed to air to see if turns red
  - Run HYSYS models to see if there is the likelihood of liquid water
    - Note “likelihood” – models are an approximation of real life

Contamination Events

- Introduction of contaminants that make passive systems aggressive…
- Oxygen Contamination
  - Chemical Tanks – may need to be blanketed
    - Methanol for hydrate prevention
  - Mixing in sewage water from accommodation platforms to production systems
  - Drain systems – separate open and closed drains – where does the open drain water go?

Cooling Water Loops

- Sea Water Contamination of Fresh Water cooling systems
  - Often from contaminated tanks on boats
  - Improper make up
  - Can lead to MIC – once established only way to restore is acidizing to break down the tubercles
    - In pipelines you pig, but typically not feasible in process piping
    - Very very difficult to fix.
- Periodically monitoring cooling loop fluid is essential as is tracking any make up
  - If making up, where is the fluid going?

Heat Exchanger systems

- Heat Exchanger failures – which side is it coming from?
- Failure in process side introduces produced water, sea water, CO2/H2S
- If Initial failure is on the process side and is repaired, failures will continue until the cooling loop side issues are resolved.

Risk Assessment vs Risk Based Inspection

- Inspection is only 1 way to reduce likelihood and therefore risk

Risk = Likelihood x Consequence

Monitoring – Better for event based

Inspection – Issue is picking the frequency

Material Change – Is material impervious?

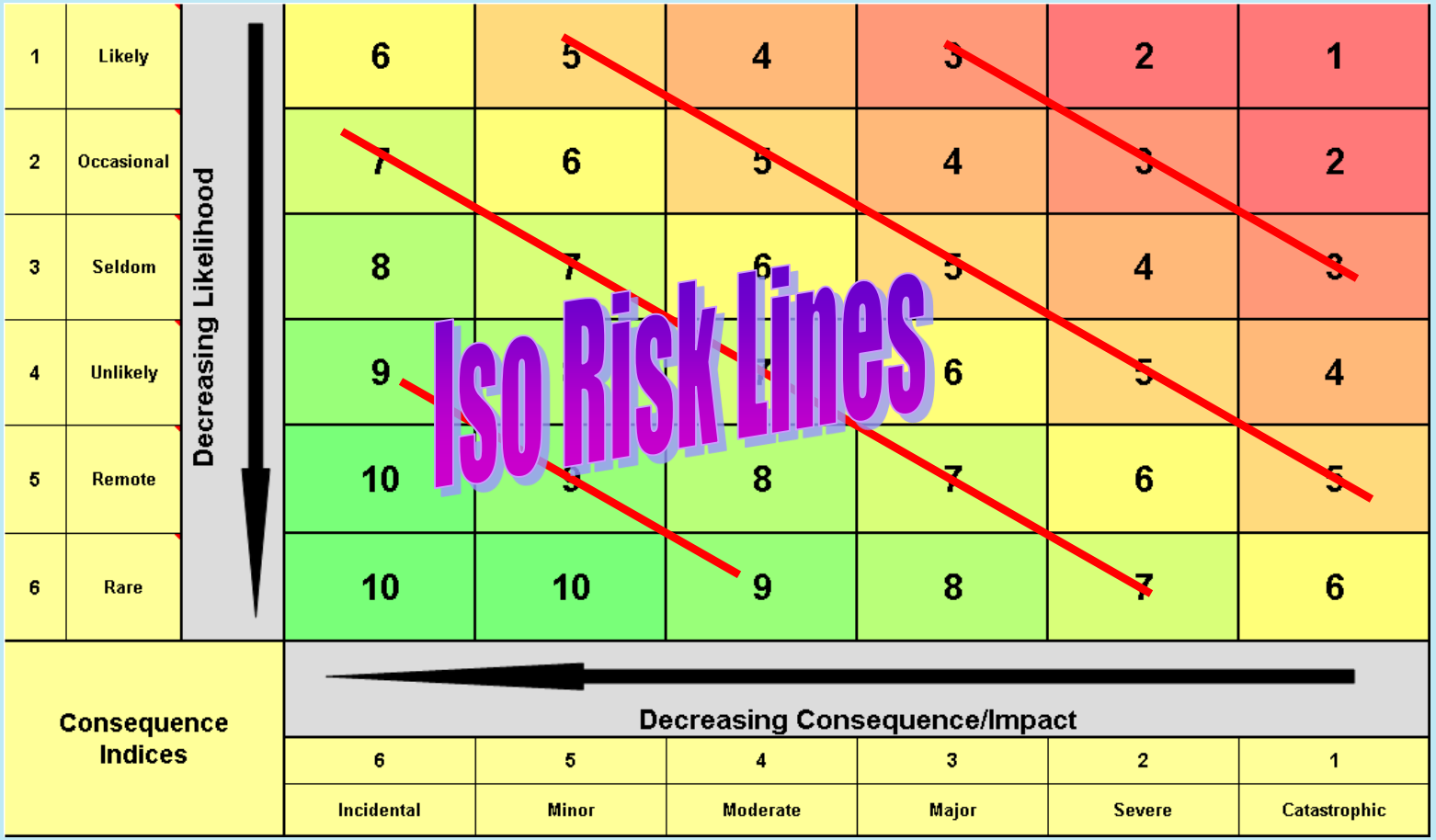
Maintenance/Planned Replacement

RCM – developed by aircraft industry

Reliability = 1 - PoF

Assess quantitatively based on inspection data

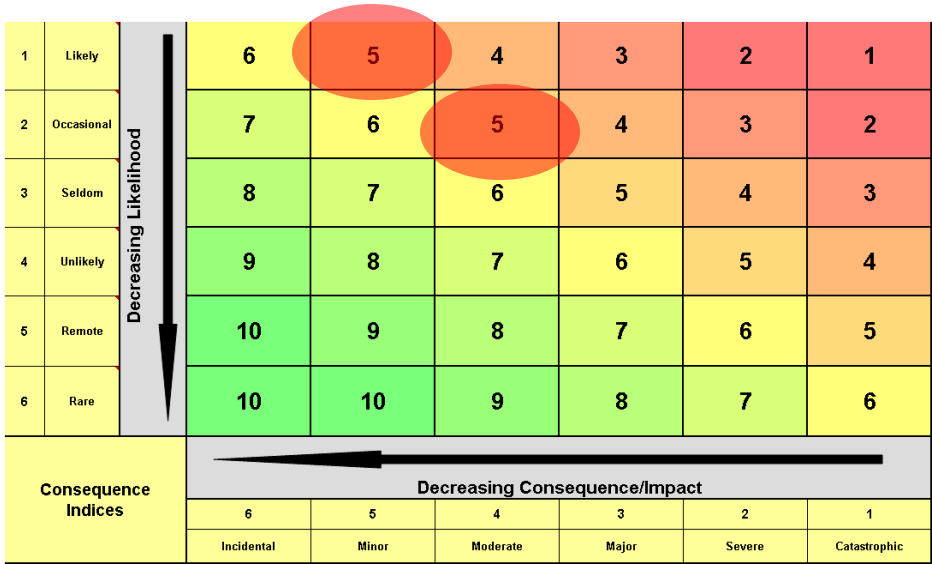
Risk Matrix


1 Likely
2 Occasional
3 Seldom
4 Unlikely
5 Remote
6 Rare
Decreasing Likelihood
6 5 4 3 2 1
7 6 5 4 3 2
8 7 6 5 4 3
9 8 7 6 5 4
10 9 8 7 6 5
10 10 9 8 7 6
Iso Risk Lines
Consequence Indices
Decreasing Consequence/Impact
6 Incidental
5 Minor
4 Moderate
3 Major
2 Severe
1 Catastrophic

Risk Matrix

- Creation of a risk matrix is an involved task. To get the isorisk lines, both axes must increase in orders of magnitude so the product is the same on the diagonal, e.g.
  - 0.01 *1e4 = 1e3
  - 0.001 * 1e5 = 1e3

For matrix to have meaning it must be calibrated.



Matrix Exercise

ENVIRONMENTAL: HC release to ocean from pipeline failure on deck (C6, L3=R8)

SAFETY: Riser failure resulting in gas release in moon pool (C2, L6=R7)

ASSET: Loss of asset due to Hurricane (C3, L1=R3)

		Decreasing Likelihood						
1	Like		6	5	4	3	2	1
2	Occasional		7	6	5	4	3	2
3	Seldom		8	7	6	5	4	3
4	Unlikely		9	8	7	6	5	4
5	Remote		10	9	8	7	6	5
6	Rare		10	10	9	8	7	6
Consequence Indices			Decreasing Consequence/Impact					
			6	5	4	3	2	1
			Incidental	Minor	Moderate	Major	Severe	Catastrophic

Estimating Likelihood

- Estimating the likelihood of an event is the hardest part of the process for any group
- People have issues with believing events can occur at their facility e.g. fire, injury
- Biggest obstacle is often "it's never happened [here]"
- Over the long term people lose sense of vulnerability
- The frequencies involved simply exceed the normal experience of an individual
  - Important to consider whether there is even a basis of comparison in a field, or the industry
  - Even a 4x4 matrix ranges 4 orders of magnitude or 10,000 times. Are there 10,000 identical pieces of equipment?

Estimating Likelihood (cont.)

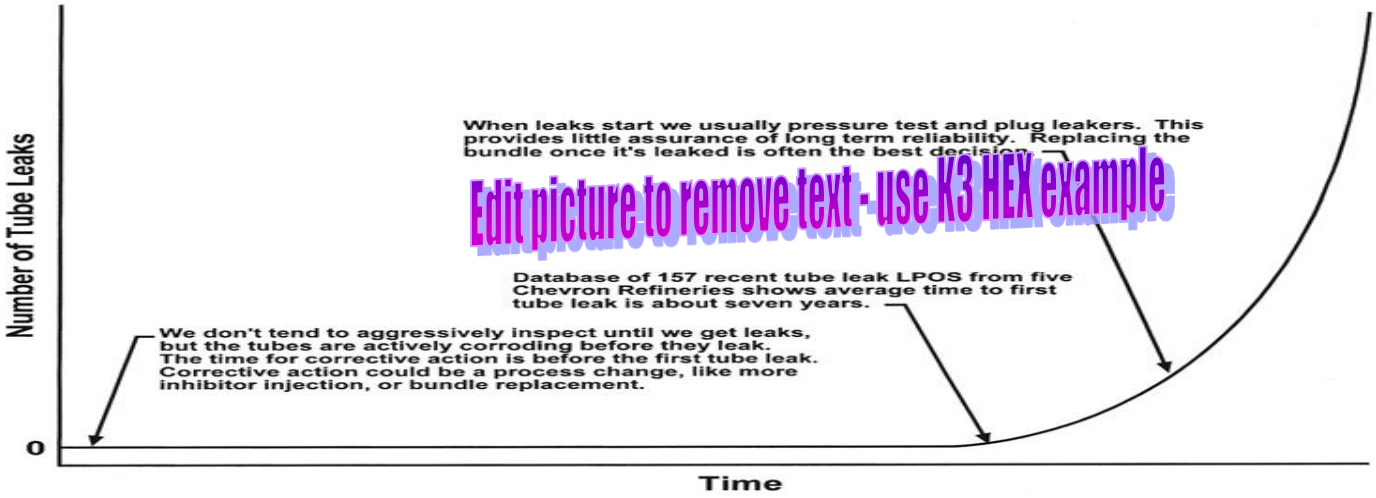
- Events escalate from a single initiating event
- Local thinning to leak
  - Leak to fire
    - Ignition to Explosion
      - Explosion to Fatality…
- In qualitative assessments, one argument is to reduce the likelihood by one level for each independent event
- How to establish the likelihood of the initiating event?

Increasing Probability of Failure

Corrosion is the most common time dependent threat.

- If the equipment has not been replaced then the PoF is increasing over time,
  - Likelihood of an event is increasing
  - Depending on inspection and shutdown frequencies, the critical point may not be caught.

Schematic Showing Number of Tube Leaks Versus Time – Inspection and Life Prediction Are Needed Before the First Tube Leak Occurs



Integrating Approaches

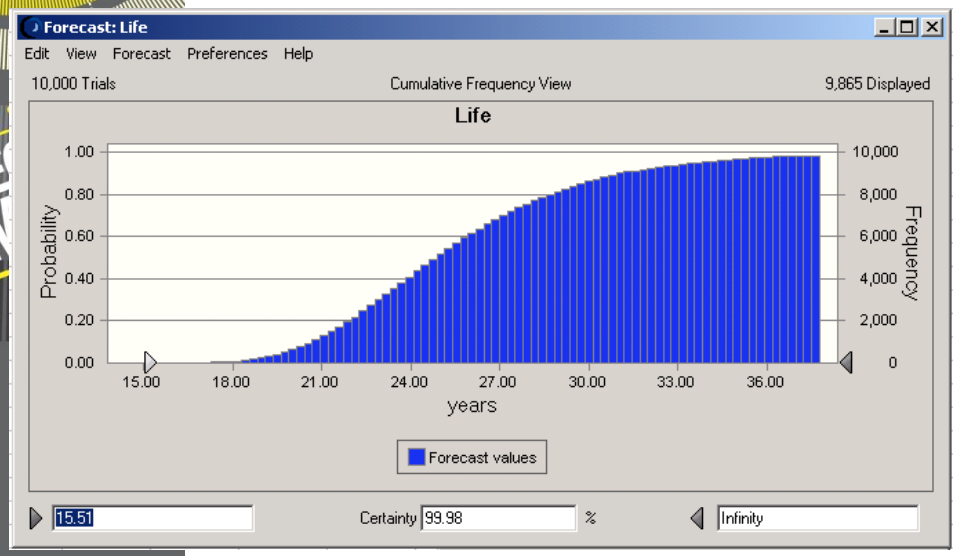
Possible to use a qualitative approach, but utilize a quantitative method to provide the likelihood of the initiating event…

Thickness = $T_{initial}$ – CR * time

- Thickness established based on inspection or manufacturing data (new equip)
- Corrosion Rate established based on inspection, modeling or similar service/published data

Optimizing Inspection/Maintenance Scheduling Using Reliability

Time to failure = f(P,T,CO2,H2S,Cl^-,HCO_3^-,thk, …)

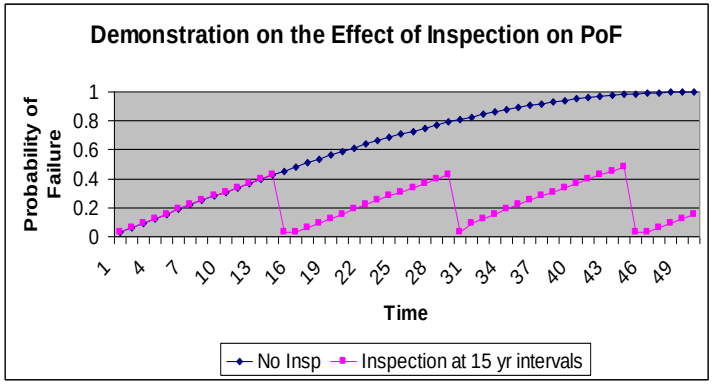


Probability

Time

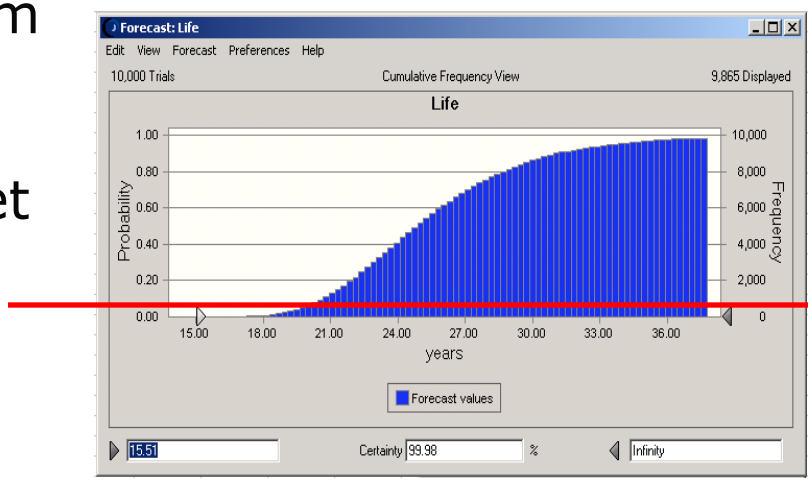
Benefit of Inspection

Inspection decreases the probability of failure (PoF) down to some "acceptable" level.



Typically set a maximum acceptable PoF.

Inspection interval is set to keep the maximum PoF below the maximum.



1x10-4/km*yr
16 yrs

Optimizing Inspection/Maintenance Scheduling Using Reliability

Currently working on the next generation…

Consider the:

- Inspection method and POD
- Corrosion mechanism
- Adjust inspection timing, calculate corrosion growth, determine the probability of successfully detecting defect

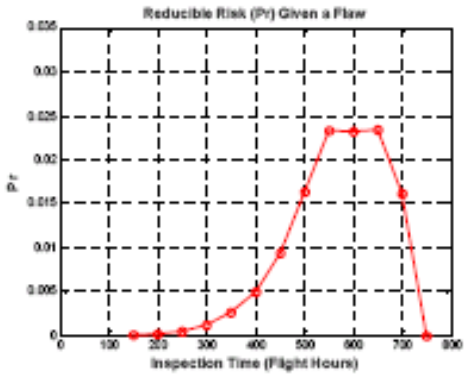


Figure 7. Risk Reduction Using Equation 10

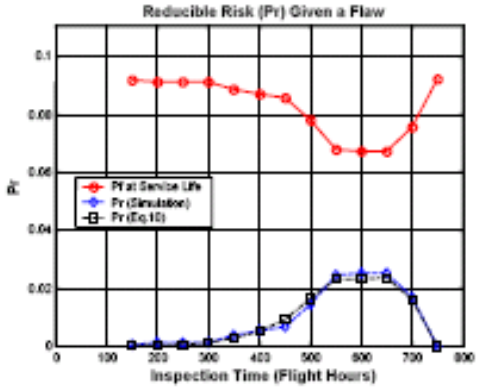


Figure 8. Comparisons of Risk Reduction using Equation10 and using Simulation

PROBABILISTIC DAMAGE TOLERANCE METHODOLOGY FOR RELIABILITY DESIGN AND INSPECTION OPTIMIZATION

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Assess the Entire System

- Important to take a holistic approach and assess the entire system and interlinking systems
  - Production string to flow line to platform
  - Gas lift to pipeline to injection string
- Integration of data
  - Monitoring, inspection, production, process, maintenance
  - Utilize data from interlinking systems – i.e. smart pig data from pipeline as indicator of platform health and vice versa

Use Scaled Approach

- Qualitative approaches are effective for initial reviews
  - Relatively Fast
  - Maximize use of employee experience
    - Best source of data
    - Generates buy in
- Records data for future assessments
  - Especially important during the current "Shift Change"

Utilize Quantitative Methods to "Tune"

- Quantitative methods can help to provide a starting point or "calibrate" the qualitative results
  - Simple Monte Carlo for likelihood of failure due to corrosion
    - Calibrate range of corrosion rates based on inspection and monitoring data
    - Calibrate Thickness based on inspection data or manufacturing tolerances

Questions ???

Contact information

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