Assessing Risks – Overview of Pipeline QRA & IGEM/TD/2

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Teams Webinar

Thursday 18th June 2020

FARWG Webinar Series

- 4th June - UKOPA Fault Data – Why it's vital for operators and how we collect it
- 18th June - Assessing Risks – Overview of Pipeline QRA & IGEM/TD/2
- 2nd July - ALARP and Cost-benefit Analysis (UKOPA/GP/025)

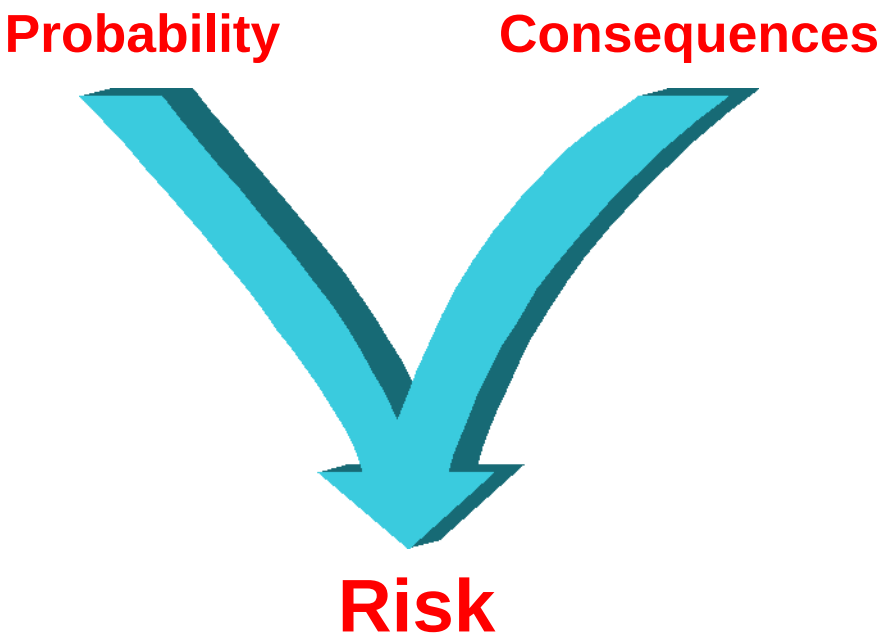
- Please
  1. Ensure your microphone is muted & webcam is off
  2. Sign in to chat so we can keep a record of attendance…
     …and get back to you if we didn't have time to answer your question

Agenda

- Introduction to Risk
- Pipeline QRA Methodology
  - Threat / Hazard Identification
  - Leak & Rupture
  - Failure Frequency
  - Event Trees
  - Consequence
  - Risk Calculation
  - Risk Assessment
- IGEM/TD/2
  - Overview
  - Key Recommendations
- QRA Reports
- Questions

What is Risk?

- Risk is “the chance of loss” – Concise Oxford Dictionary.



- Risk is a function of the probability that a hazard will occur and the consequences of that hazard.

Why assess pipeline risk?

- Occasionally this can happen...

Some Recent Pipeline Failures

We need pipeline risk assessment because...

- Accidents with high consequences can occur
  - Control and reduction of impact of accidents
    - Casualties
    - Cost
    - Corporate Image / Public Relations
  - Compliance with legislation, codes and standards
  - Control and reduction of insurance costs
  - Improve effectiveness of integrity or safety management program

History of Pipeline QRA Methodology in UK

- Developed in British Gas from 1980's on
  - Following work in Nuclear and Chemical Industries
  - Driven by step changes in TD/1 and lack of tie up with LUP legislation
    - Leading to small diversions for single dwellings within 1 BPD
      - Meets code but expensive and actually increases risk
- Methodology included in BG Transpire software from early 1990s
  - Further developed under Pipesafe JIP
  - HSE methodology based on BG and Pipesafe work
- Societal risk criteria derived by assumption that what had been built to date was acceptable
  - 30 years operation of transmission system and no deaths
  - Assessed cases were TD/1 pipelines with 0.72 or 0.3 design factor and population density of 2.5, 14 or 42 per ha
    - NB British Gas didn't build to limits of TD/1 - standard US pipe wall thicknesses, design factor based on minimum wall etc.
- Key methodology codified by UKOPA for IGEM and BSi
  - Guidance for expert practitioners
  - Move discussions with HSE away from methodology and onto acceptability

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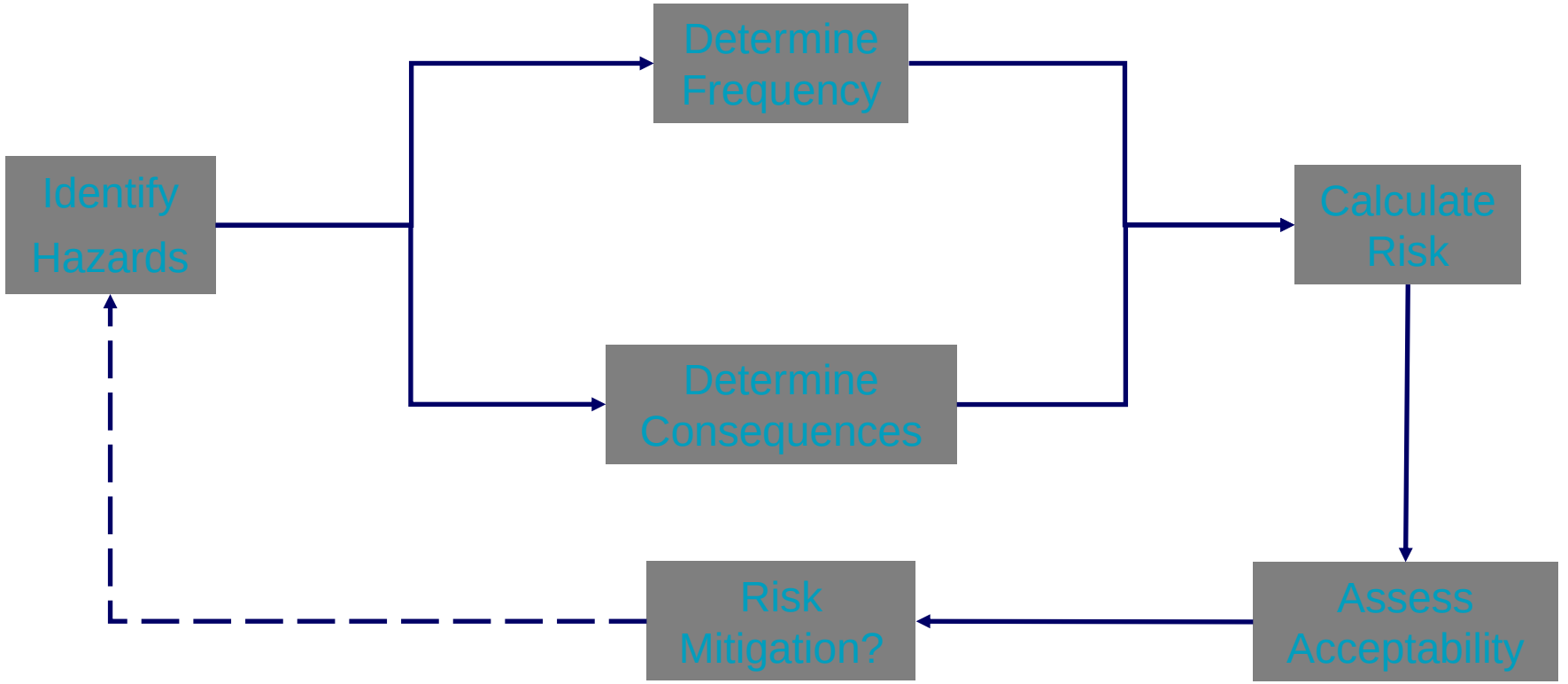
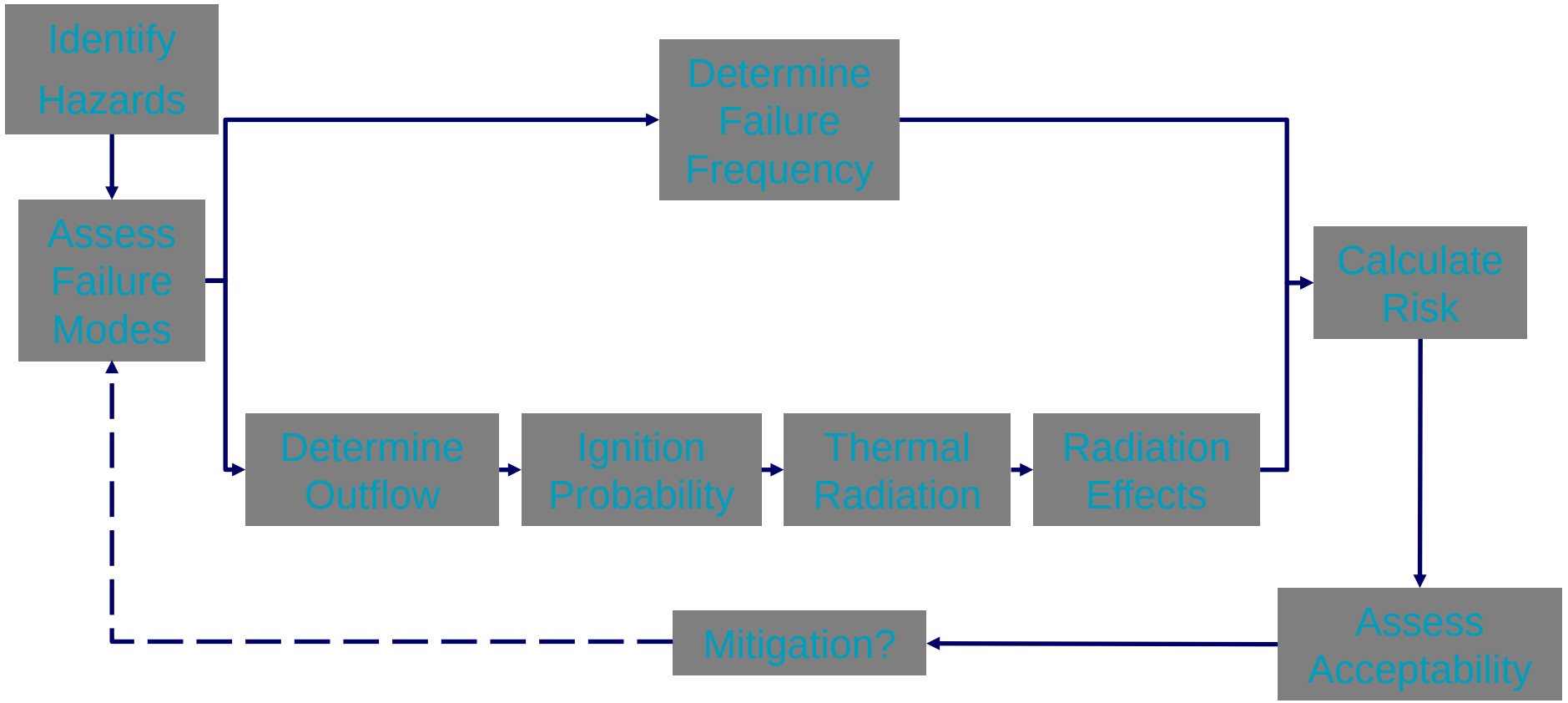
General QRA Methodology



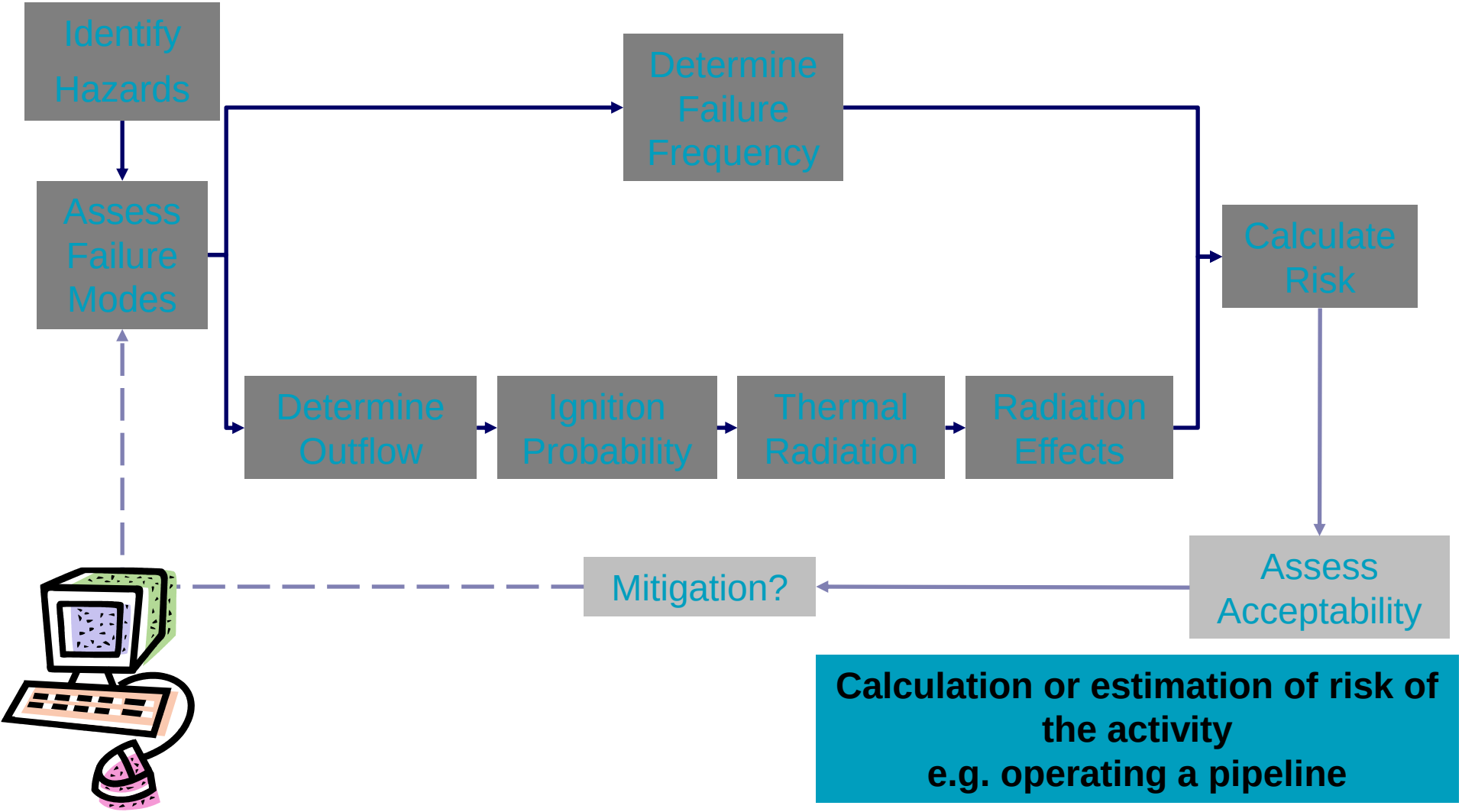
Qualitative
Estimate frequency and consequences

Quantitative
Quantify frequency and consequences & calculate risk

Pipeline QRA Methodology

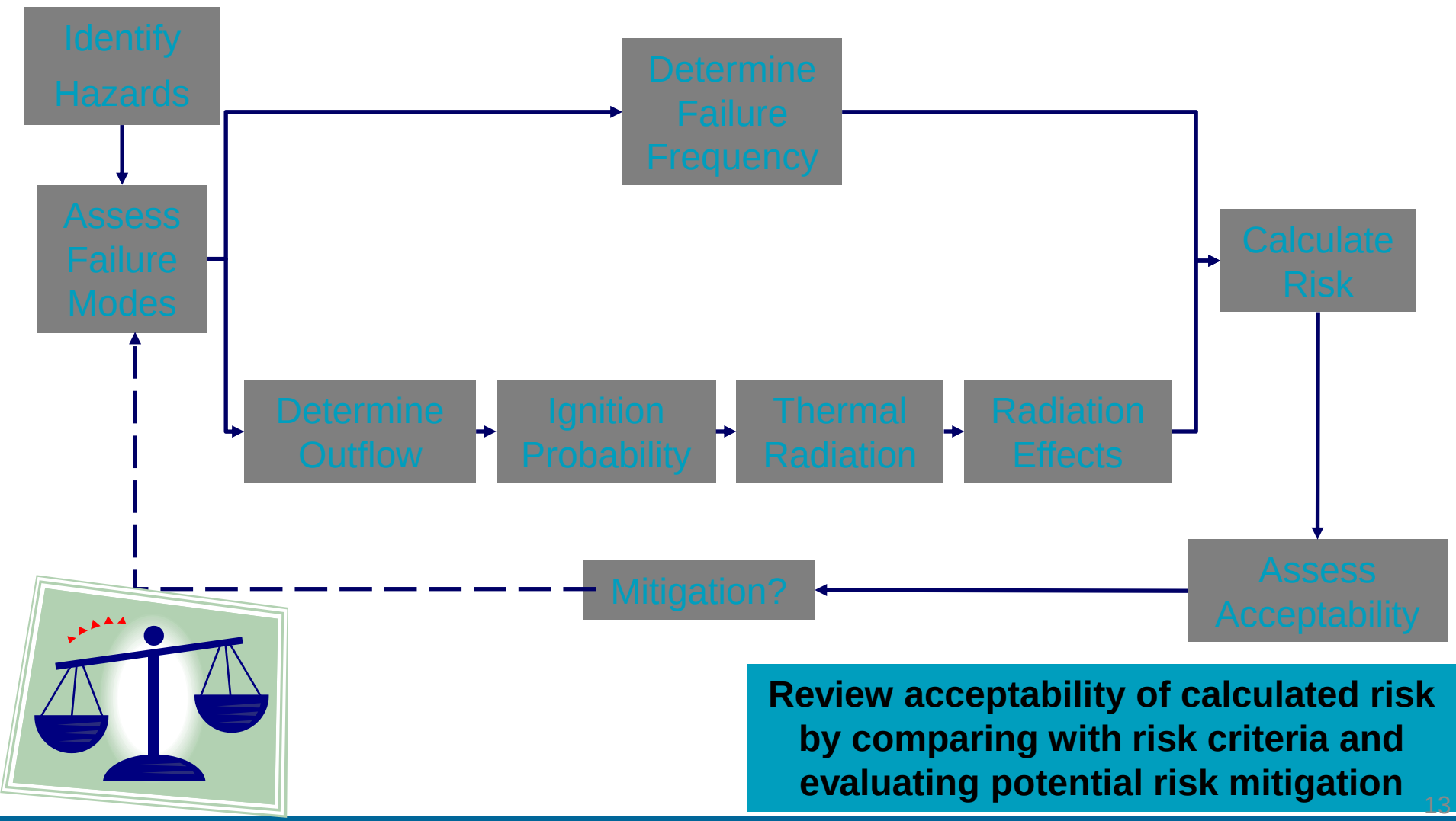


Risk Analysis



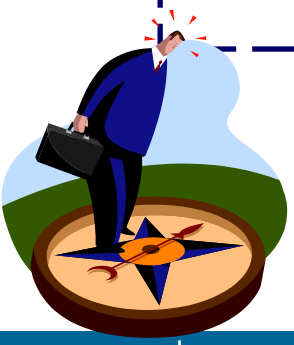
Calculation or estimation of risk of the activity
e.g. operating a pipeline

Risk Assessment



Review acceptability of calculated risk by comparing with risk criteria and evaluating potential risk mitigation

Risk Management



Identify Hazards

Assess Failure Modes

Determine Failure Frequency

Determine Outflow

Ignition Probability

Thermal Radiation

Radiation Effects

Calculate Risk

Assess Acceptability

Mitigation?

Make Decision!

Select appropriate risk mitigation measures & implement on-going risk management

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Threat / Hazard Identification

- QRA's typically only consider the residual risk
  - Integrity threats not 'fully' controlled by IMR policy
    - External Interference
    - Ground Movement

  - Probably controlled
    - Corrosion
    - Fatigue
    - Material/Construction Defects

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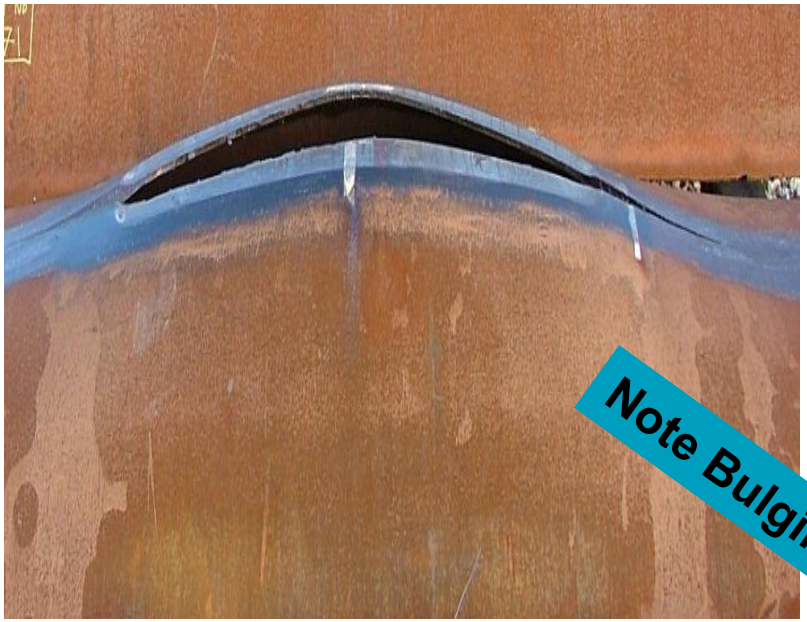
Determine Failure Mode – Leak or Rupture

Leak
Stable defect – no extension in length

Rupture
Unstable defect – extension in length

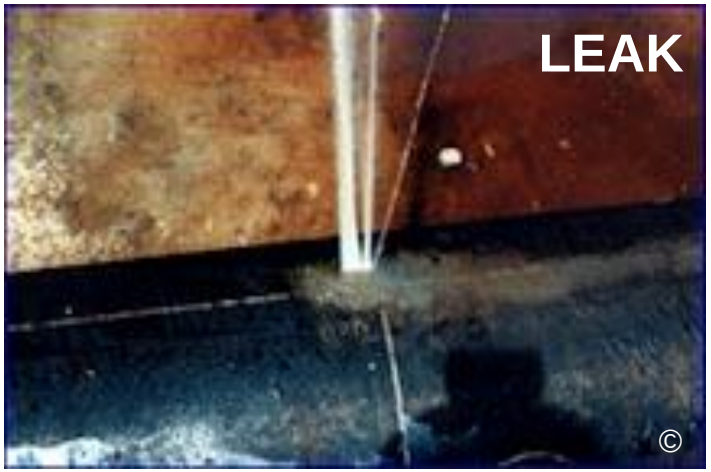


Rupture can then arrest or propagate – depending on pipeline toughness

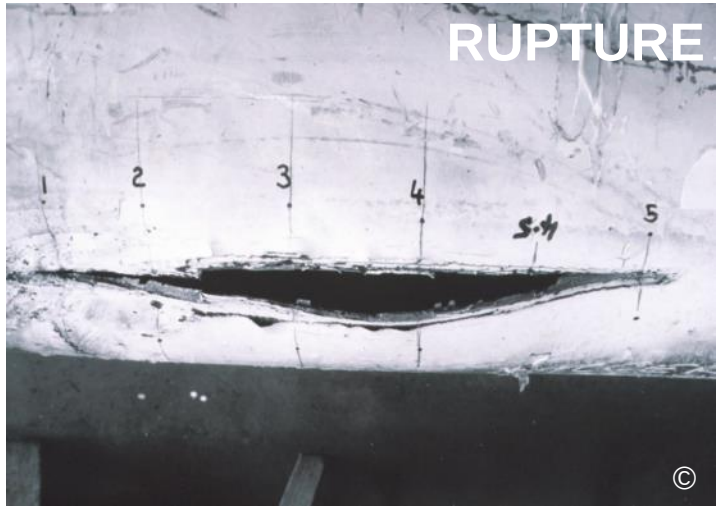
Leak image taken from SES Houston, Website

Pipeline Defect Failure

Fails As



If Defect is Long



If Low Toughness

Determine Failure Mode – Key Issues

- Leak
  - Not likely to cause significant casualties (if any) for high pressure natural gas pipelines
  - More significant for high vapour pressure, toxic or liquid pipelines
- Only small leaks are stable at high hoop stress
- Be careful with rupture definitions
  - Fracture mechanics – any unstable defect that extends
  - Safety – hole greater than diameter – 'full-bore' rupture

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Determine Failure Frequency

- 3 Main Approaches
  1. Probabilistic (& Deterministic) Prediction Models
     - External Interference
     - Ground Movement
     - Corrosion Growth / Remnant Life Assessment
  2. Use Historic Failure Data
     - UKOPA
     - EGIG
     - CONCAWE
     - PHMSA
     - CER
  3. Generic Failure Frequency model in IGEM/TD/2 for External Interference

External Interference Failure Frequency Prediction

- Draft report issued to FARWG in September 2019

  Recommendations for Predictive Modelling of External Interference Failure Frequency

- Recommendations in following key areas:
  - Limit State Models
  - Spring back and Re-rounding
  - Leak-Rupture Boundary
  - Dent Force
  - Split Distributions for gouges inside and outside dents
  - Damage Distribution Parameters
  - Frequency of External Interference (aka the ‘hit rate’)

Recommendations (1/2)

- Limit State Models
  - NG-18 for plain gouges
  - EPRG (Hopkins-Cairns) model for dent-gouges

$$\frac{\sigma_f}{\bar{\sigma}} = \frac{1-\left(\frac{d}{t}\right)}{1-\left(\frac{d}{t}\right)\frac{1}{M}}$$

$$\frac{\sigma_f}{\bar{\sigma}} = \frac{2}{\pi}\cos^{-1}\left[\exp-\left\{113\frac{1.5\pi E}{\bar{\sigma}^2 Ad}\left[Y_1\left(1-1.8\frac{H_o}{D}\right)+Y_2\left(10.2\frac{R}{t}\frac{H_o}{D}\right)\right]^{-2}\exp\left[\frac{\ln(0.738C_v)-K_1}{K_2}\right]\right\}\right]$$

- Spring-back & Re-rounding
  - Use EPRG simple correlation

$$H_o = 1.43H_p$$

- Leak-break boundary
  - Flow stress dependent form of NG-18 through wall equation
    - 3 term Folias factor

$$M = \begin{cases} \sqrt{1+0.314\left(\frac{2c}{\sqrt{Rt}}\right)^2-0.00084\left(\frac{2c}{\sqrt{Rt}}\right)^4} & \text{for } \left(\frac{2c}{\sqrt{Rt}}\right) \le 8.0 \\ \sqrt{1+0.26\left(\frac{2c}{\sqrt{Rt}}\right)^2} & \text{for } \left(\frac{2c}{\sqrt{Rt}}\right) > 8.0 \end{cases}$$

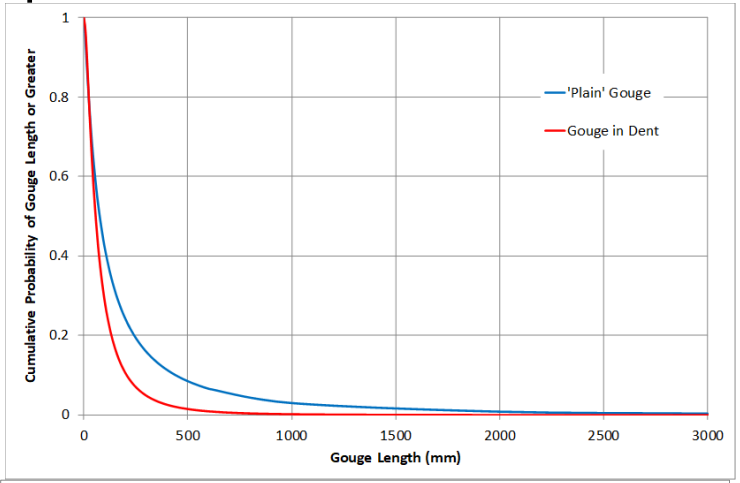
Recommendations (2/2)

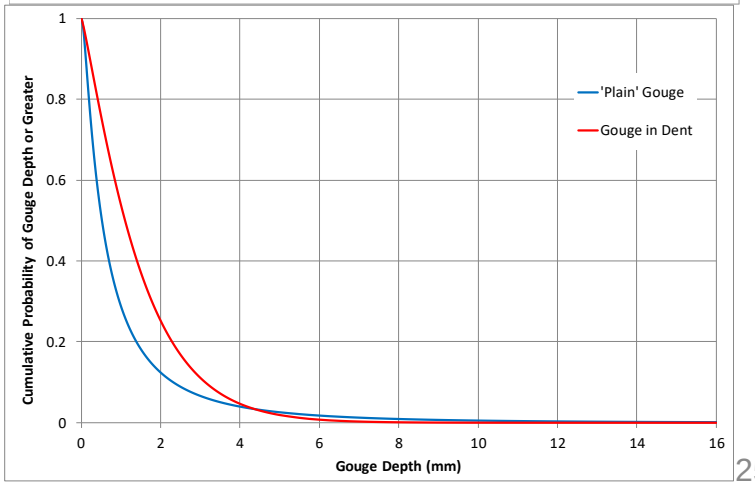
- Dent Force Distribution not Dent Depth
  - Use EPRG semi-empirical relationship

$$F_{dent} = 0.49\sqrt{P_r}H_P^{0.42}$$

- Split Distributions
  - ‘Plain’ Gouge Length
  - ‘Gouge in Dent’ Gouge Length
  - ‘Plain’ Gouge Depth
  - ‘Gouge in Dent’ Gouge Depth
  - Dent Force

  - Lognormal distribution for all except Weibull used for ‘Gouge in Dent’ Gouge Depth





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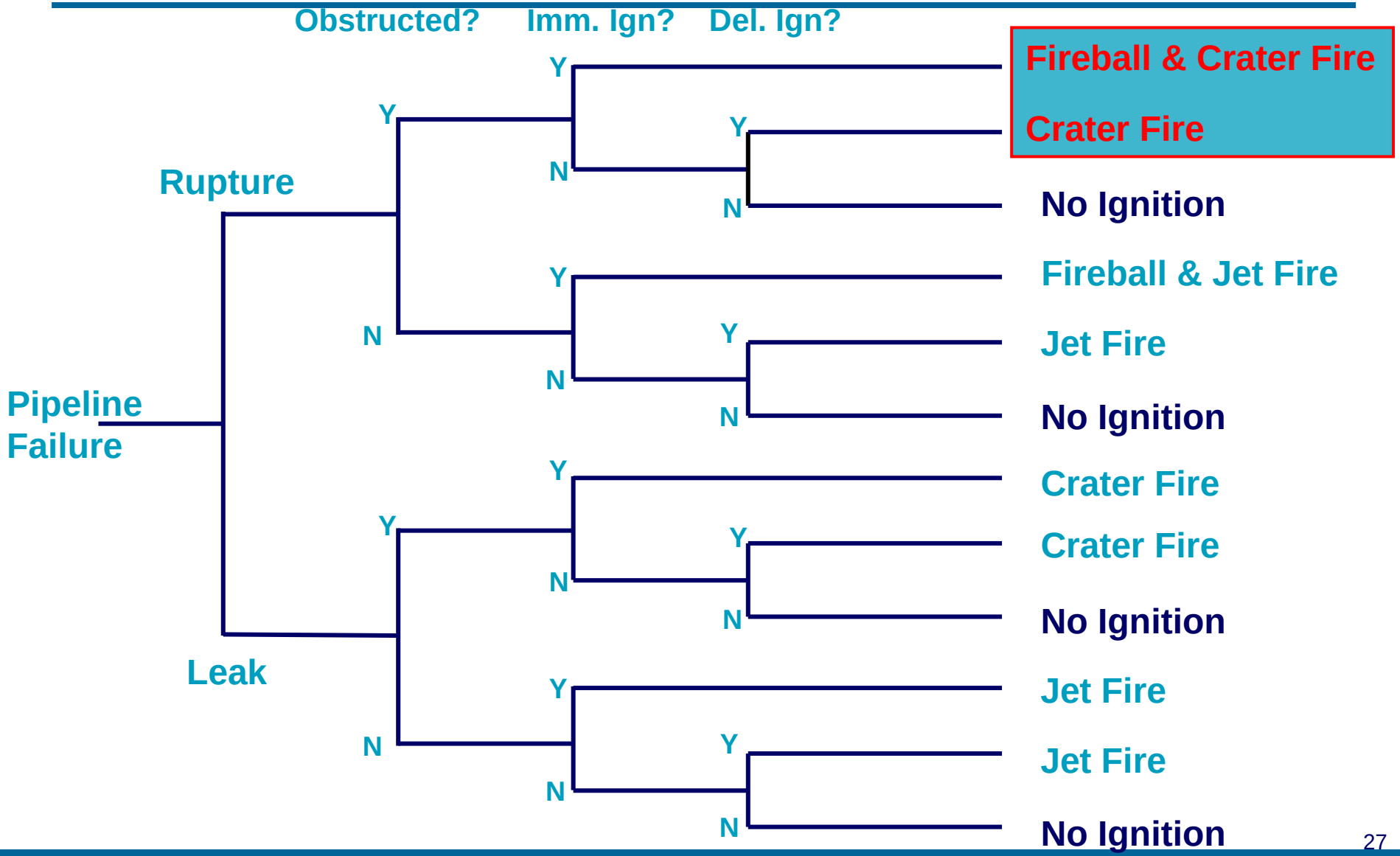
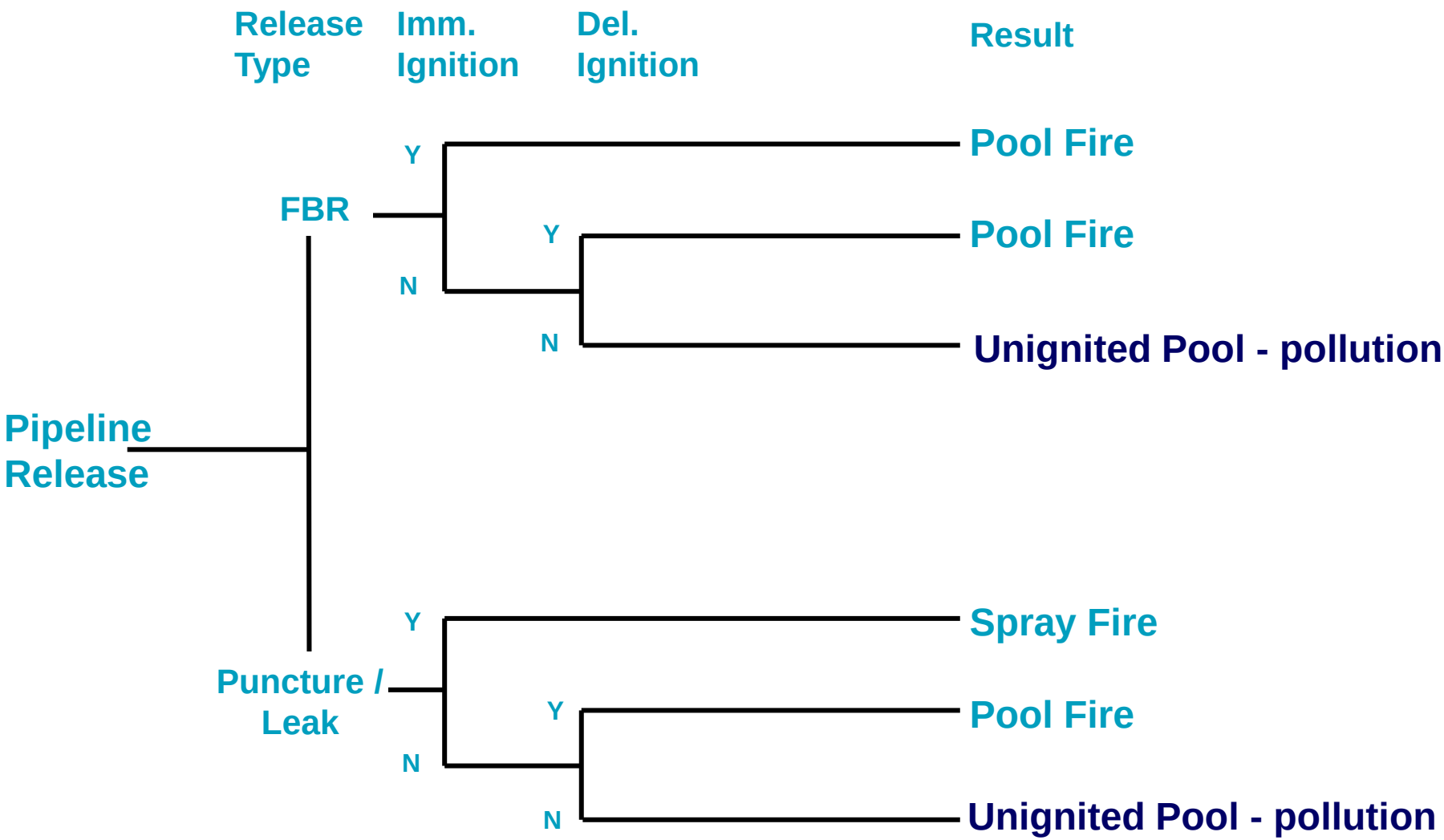
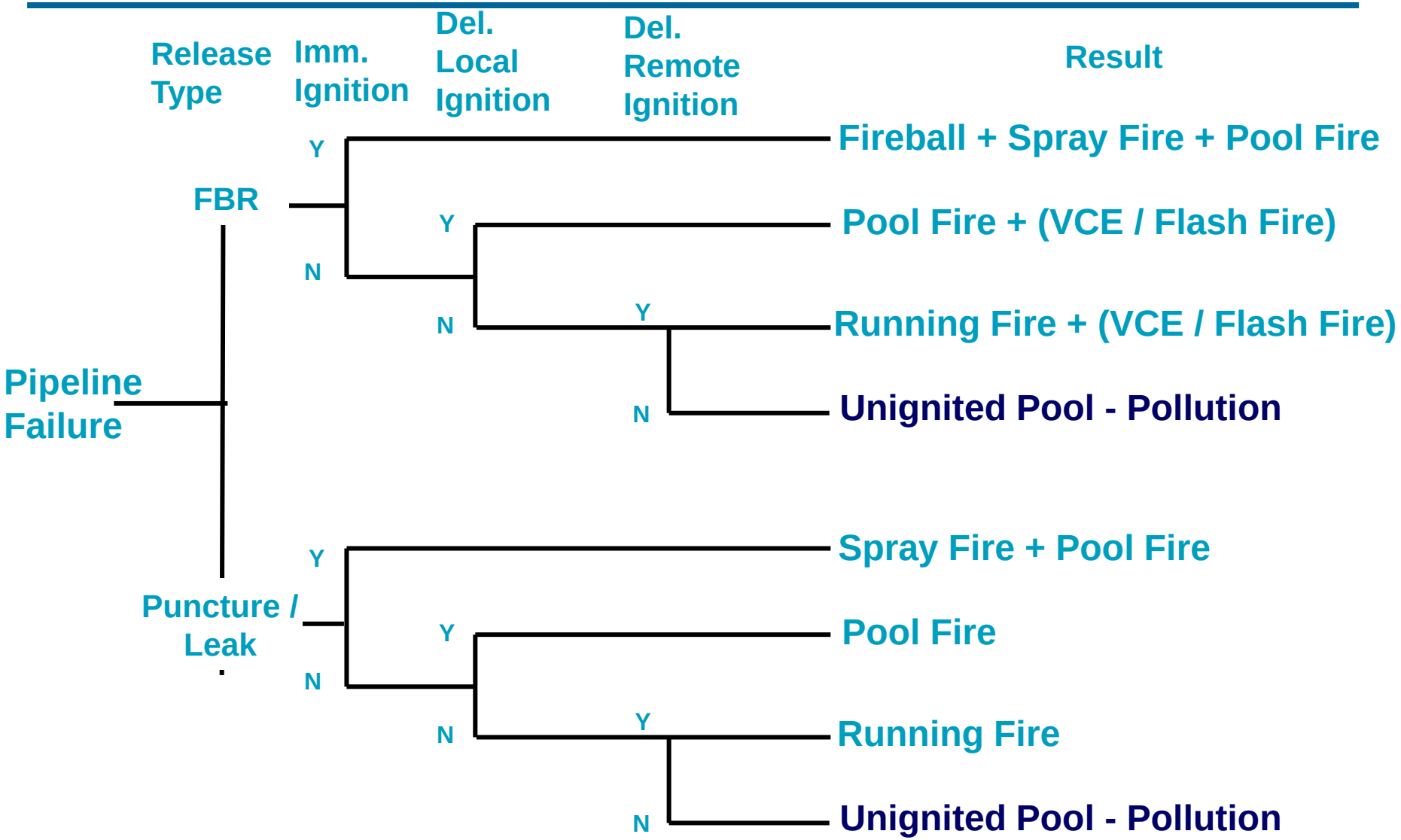
Event Tree – Natural Gas



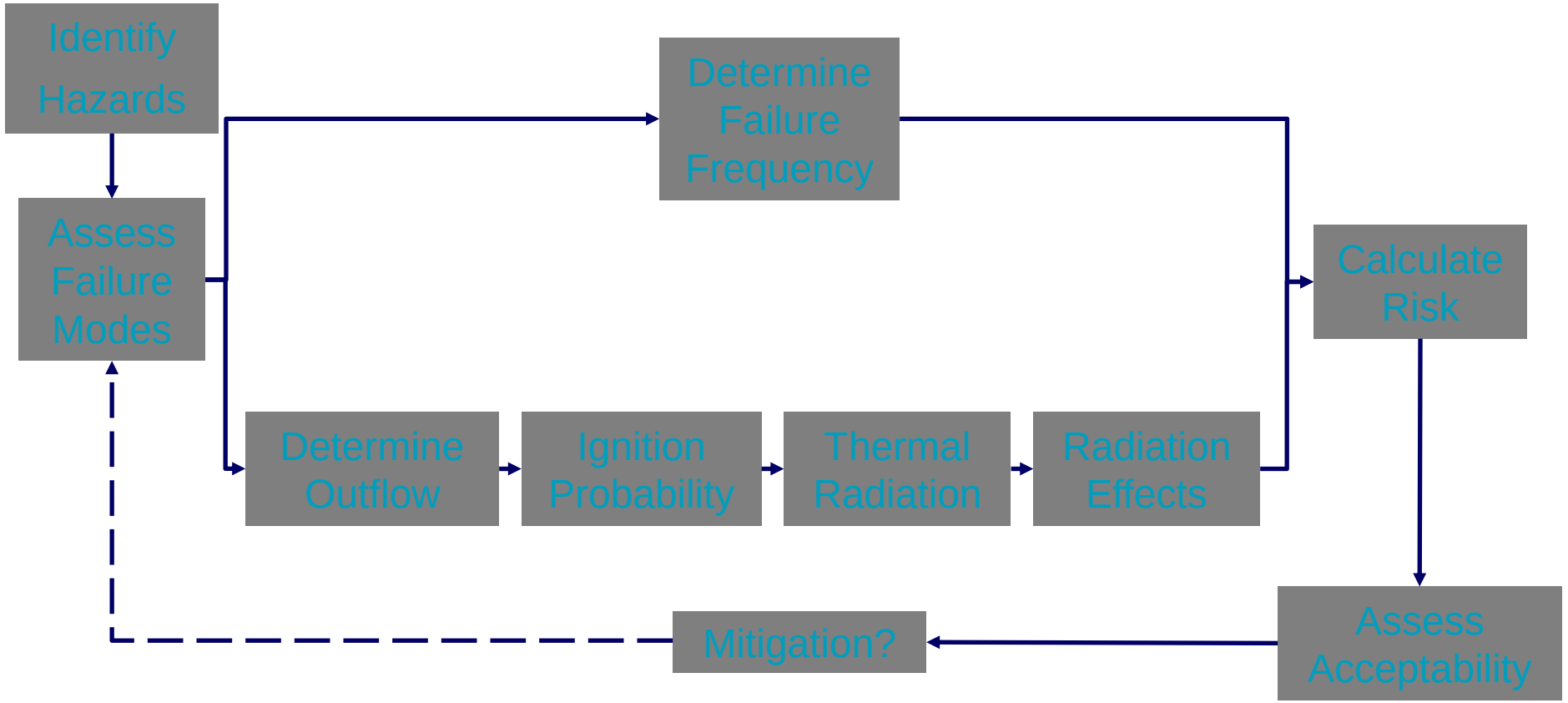
Event Tree – Stable Liquids



Event Tree – Unstable Liquids



Pipeline QRA Methodology



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Consequence Assessment

Outflow → Dispersion → Ignition Probability → Thermal Radiation → Radiation Effects

- Outflow
  - How much comes out of the pipeline?
- Dispersion
  - Where does it go?
- Ignition Probability
  - How often will it go bang?
- Thermal Radiation
  - How big is the fire?
- Radiation Effects
  - How many people/buildings are affected?

Usually requires specialist software

Fireball

- Billowing highly turbulent mushroom shaped cap
- Increases in height due to momentum of release and buoyancy of natural gas
- Fed by escaping gas jets and entrained air
- Typically burn out within 30 seconds to leave jet fire

Jet Fire

Rate of combustion equals release rate

Natural gas @ 80 bar through a 20 mm flange

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Risk Calculation

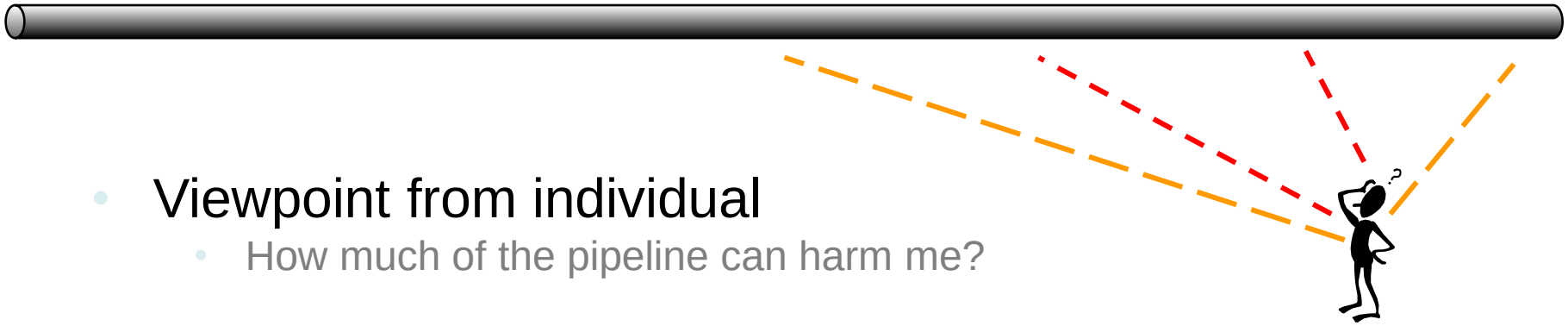
- 2 types of risk for people

- Individual Risk
  - Chance of an event affecting any one person per year
    - e.g. 1 in ten million chance of being killed by lightning
    - Typically presented as a transect or contour
    - Easy comparison to historical/statistical data

- Societal Risk
  - Range of consequences from a single event
    - Frequency of N or more casualties per year
    - Typically presented as an FN curve
    - Useful in cost benefit analysis

Individual Risk - Pipelines

"Individual risk is a measure of the frequency at which an individual, at a specific distance from a pipeline, may be expected to sustain a specified level of harm from the realisation of a specific hazard"

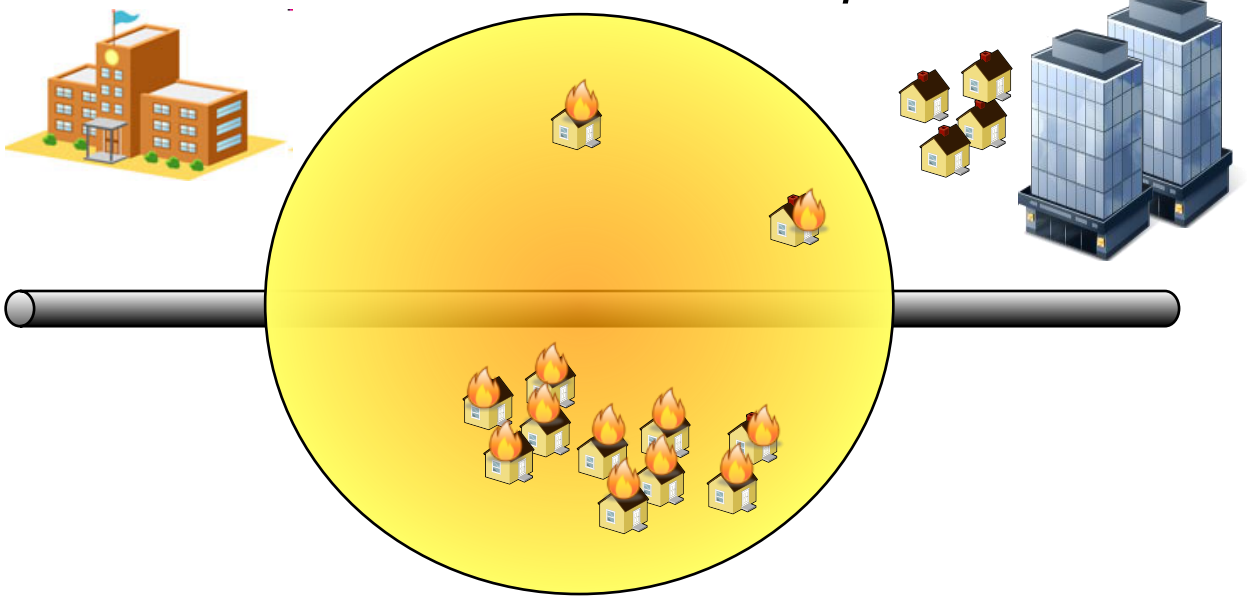


- Viewpoint from individual
  - How much of the pipeline can harm me?

If you live near a pipeline you are interested in the individual risk!

Societal Risk - Pipelines

"Societal risk is the relationship between the frequency and the number of people suffering from a specified level of harm in a given population from the realisation of a specific hazard"



- Viewpoint from pipeline
  - How many people are affected if the pipeline fails here?

If you are the operator of the pipeline (or the regulator) you are interested in societal risk

Risk Calculation - General

- To calculate risk due to a pipeline we need to know
  - Failure mode
    - Leak or rupture
  - Frequency of failure
  - Failure consequences
    - Varying with time
  - Location of failure
  - Number of people present at this location
    - Indoors/outdoors
    - Normal or Vulnerable
    - Availability of Shelter
  - Interaction length

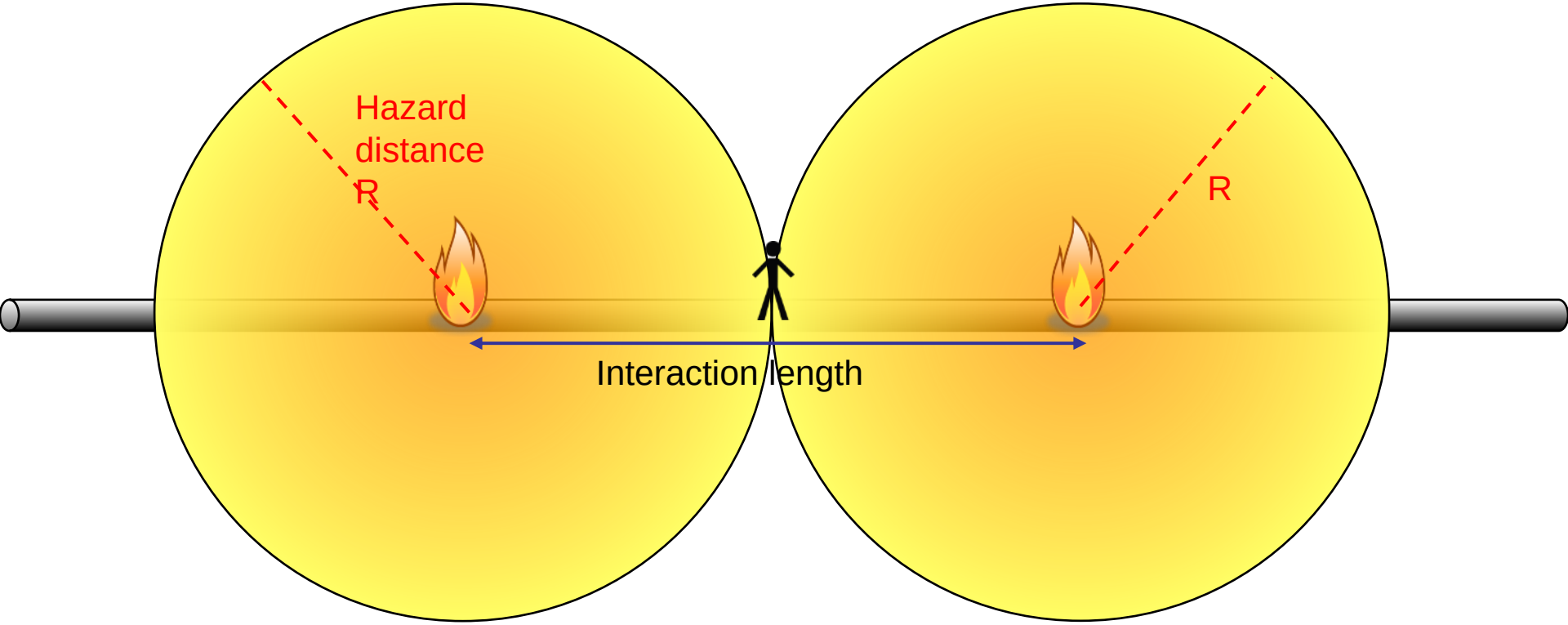
Interaction Length

- Interaction length is critical in calculating risk
- Defined as the full length of pipeline over which a hazard could affect any specific location
  - This length of pipeline must be considered in the risk assessment
- Easier to understand visually…

Interaction Length

- If you are standing on the pipeline

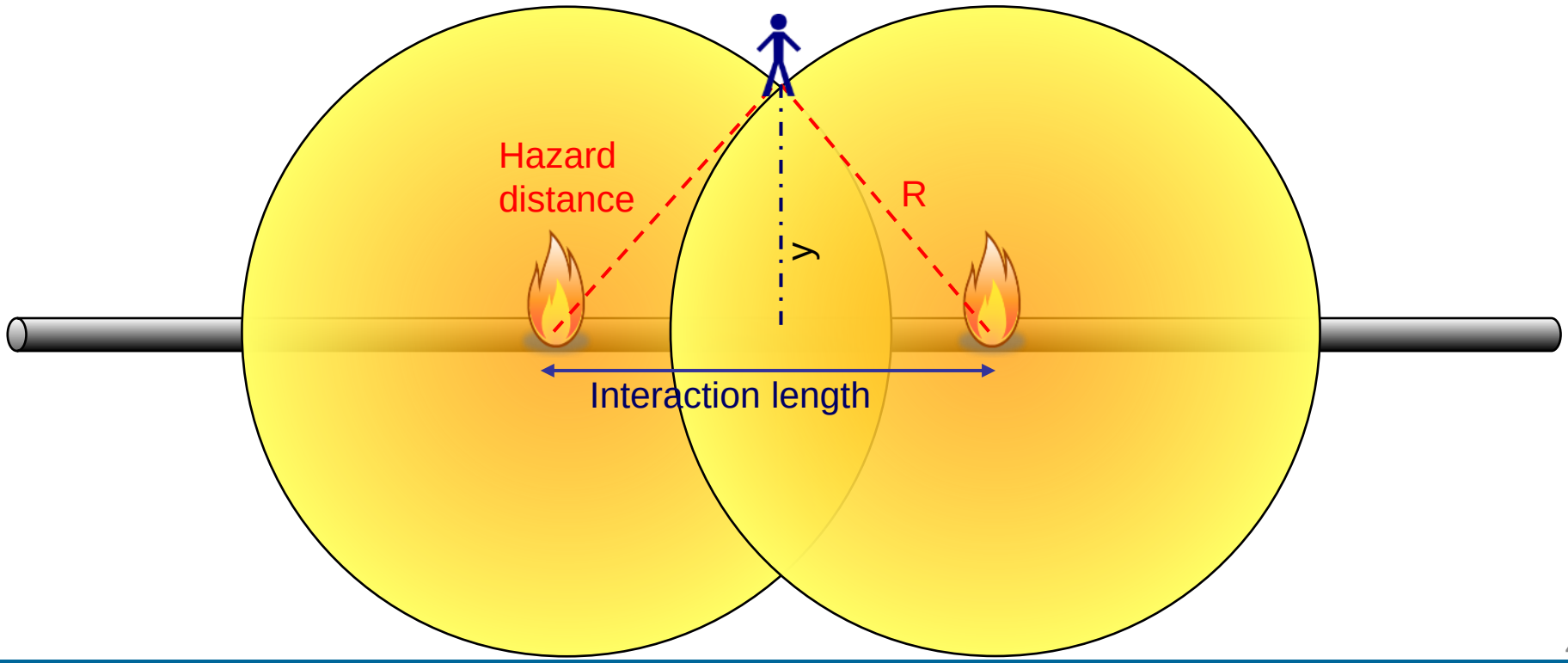
Interaction length = 2 R



Interaction Length

- If you are at distance y from the pipeline

$$\textit{Interaction length} = 2\sqrt{(R^2 - y^2)}$$



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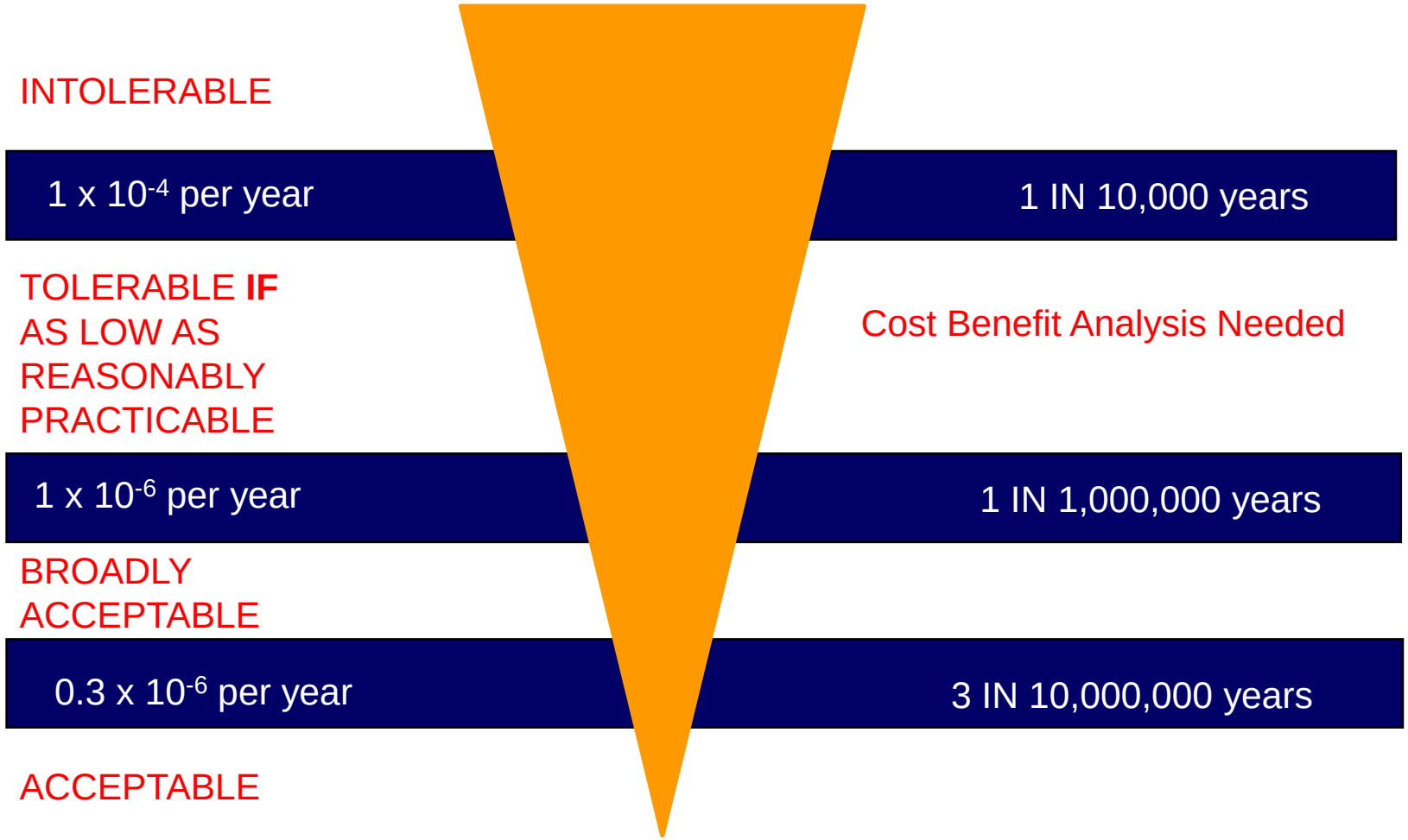
Risk Assessment – Individual Risk

- UK HSE publications state an unacceptable level of individual risk to a member of the public of 1×10^{-4} per year
  - Approximately ten times less than the historical fatality rate for dangerous industries such as deep sea fishing or offshore oil and gas extraction in the North Sea*

- From this value, a level of risk below which there is typically no concern is set at 1×10^{-6} per year or one chance per million (cpm)

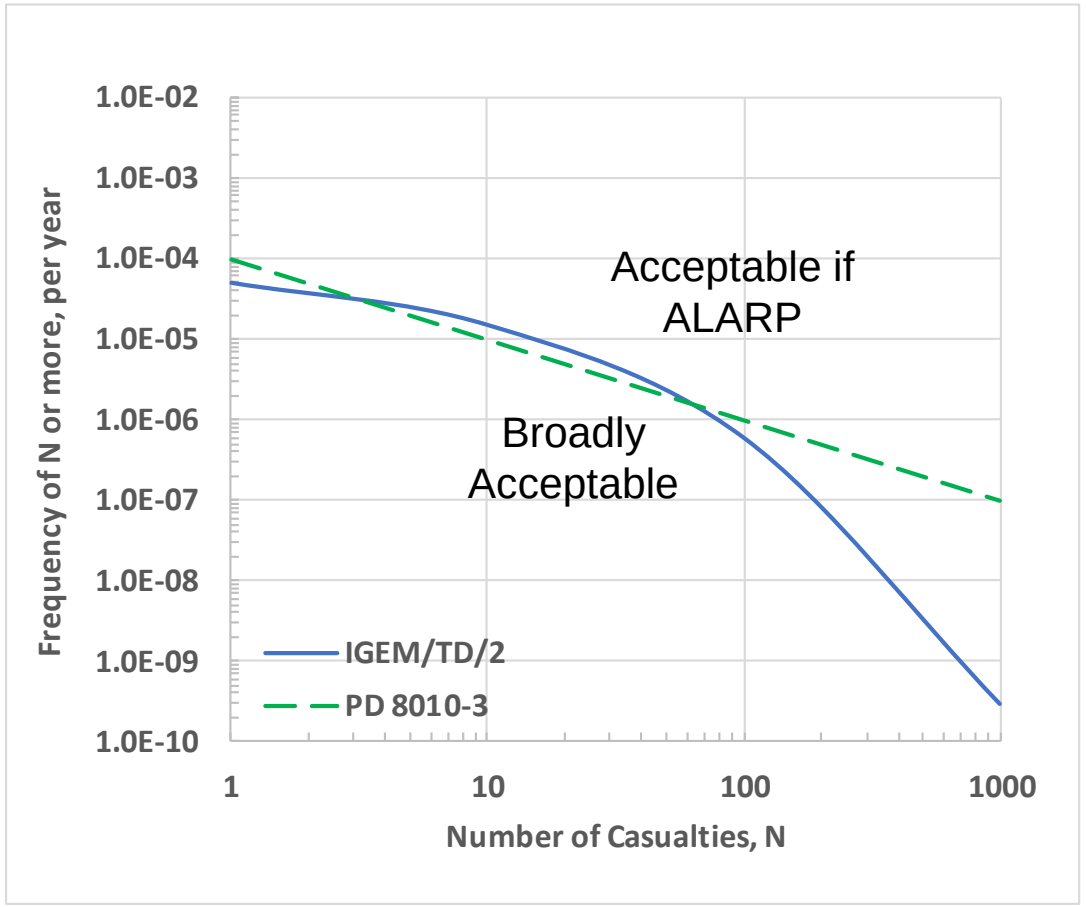
*Anon, *The Tolerability of Risk from Nuclear Power Stations*, HMSO, London, 1992.

UK HSE Individual Risk Criteria



Risk Assessment – Societal Risk

- IGEM/TD/1 & IGEM/TD/2
  - 1.6 km of pipeline
- PD 8010-3
  - 1 km of pipeline



Important Points to Remember

- Both Individual and Societal Risk
  - Must compare like with like!
- Individual risk
  - Person always present?
  - Exposure included?
- Societal Risk
  - What threats / hazards included?
  - Rupture and leaks?
  - How long a length of pipeline has been assessed?

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UKOPA
United Kingdom
Onshore Pipeline Operators' Association

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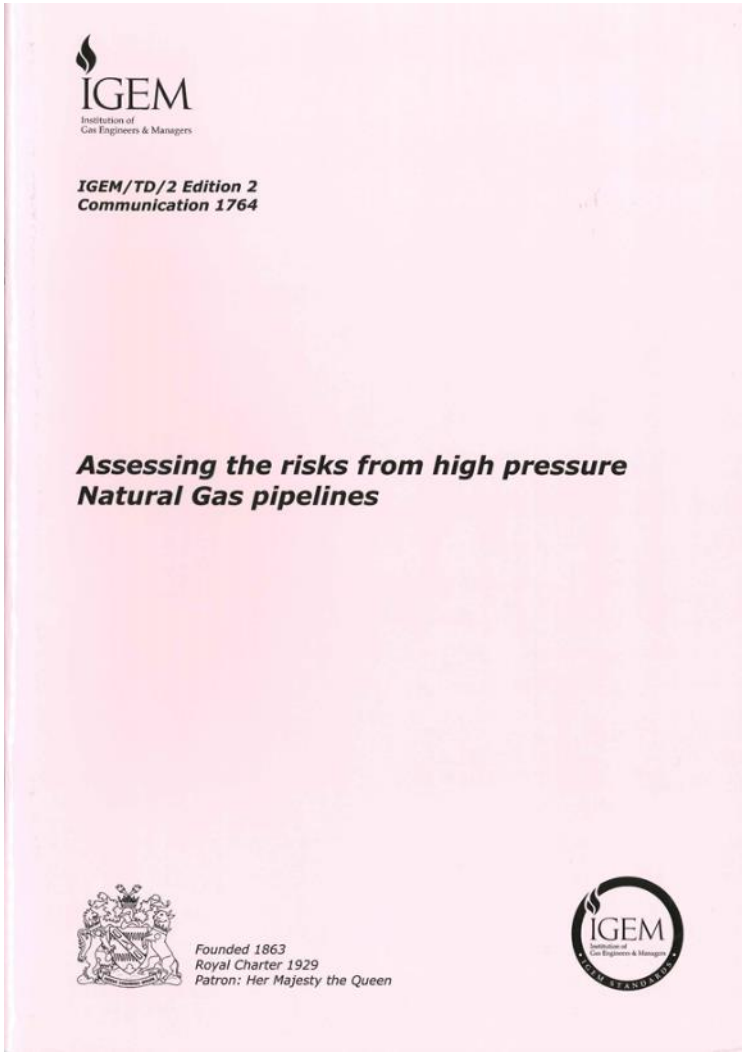
IGEM/TD/2

- "Assessing the risk from high pressure Natural Gas pipelines"
- Developed by Risk Assessment Working Group of UK Onshore Pipeline operators Association (UKOPA)
  - Updated after comments from users
- Based on established best practice
  - Guidance for competent practitioners
- 1st edition designed to move discussions with regulator & 3rd parties
  - On to risk acceptability…..
  - …….and away from models, methodologies and assumptions



IGEM/TD/2 – Key Recommendations

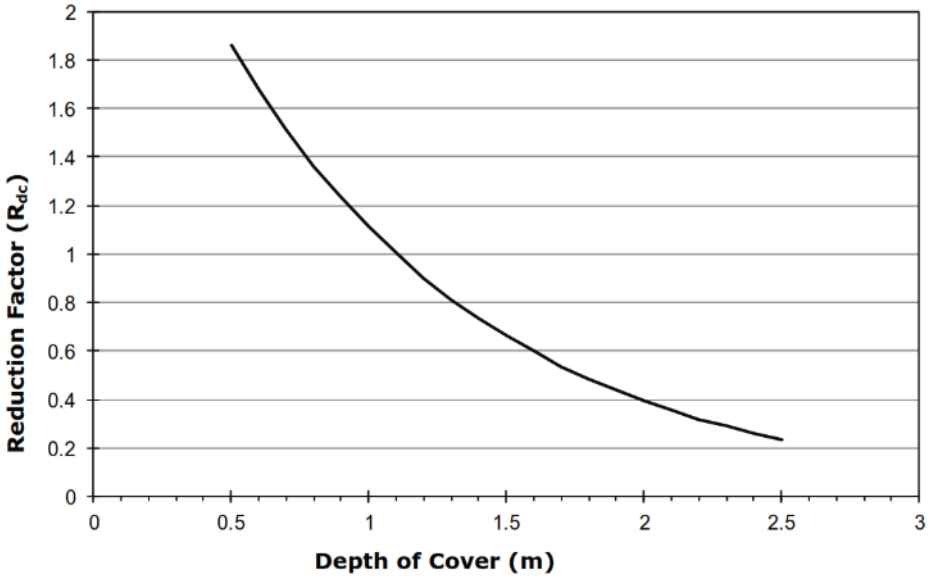
- Threat / Hazard Identification
  - List of typical causes of pipeline failure
  - Ruptures from External Interference and Ground Movement dominate
- Frequency Assessment
  - Use recognised published operational data or predictive model validated with such data
  - Predictive Model for Natural Landslides
  - Generic Failure Frequency for External Interference
    - Reduction Factors for design factor and wall thickness
  - UKOPA data presented for
    - External Corrosion
    - Material & Construction Defects

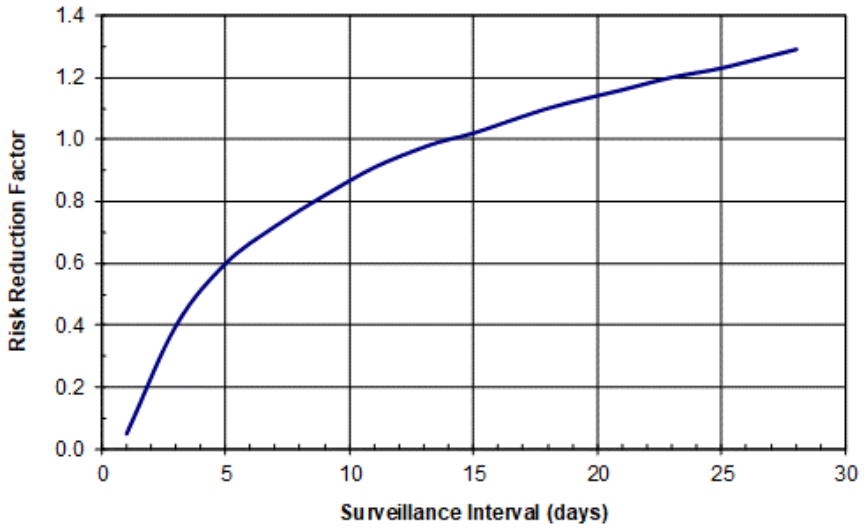
IGEM/TD/2 – Key Recommendations

- Consequence Assessment
  - Consider full bore rupture and range of leak sizes
  - Equivalent hole size for critical defect length
    - Baum & Butterfield correlation
  - Transient Outflow for Rupture
    - Consider Upstream and Downstream Boundary conditions
  - Steady state outflow from leaks
  - Ignition Probability Model $P_{ign} = 0.0555 + 0.0137pd^2$
    - 50% immediate, 50% delayed by 30 seconds
  - Thermal radiation effects on people
    - 1800 tdu for normal population
    - 1000 tdu for sensitive or vulnerable
  - Summary of HSE Assumptions
    - Escape speed for normal population 2.5 m/s
    - Average householder present 100%
      - 90% indoors during the day, 99% at night

IGEM/TD/2 – Key Recommendations

- Risk Calculation
  - Factor F by 1.6 km / IL if IL < 1.6 km
- Risk Mitigation for External Interference
  - Models for
    - Depth of Cover (R_{dc})
    - Surveillance Frequency (R_s)
    - Concrete Slabbing (R_p= 0.1)





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QRA Reports

- Operators unlikely to perform pipeline QRA
  - But do request QRAs and receive QRA reports

- How do you tell if report (and calculated risk levels & recommendations) are OK?

QRA Reports – Key things to look for

- Author
  - Experience and track record
- Point of report
  - IGEM/TD/1 Infringements / Uprating
- Code compliance
  - Should state completion in accordance with IGEM/TD/2 (or PD8010-3)
- Software
  - Proprietary software used
    - is it validated for buried pipeline releases?
- Conclusions & Recommendations
  - Are they clear?

QRA Reports – Details to look for

- Are key assumptions & input data stated?
  - Threats/hazards
    - Which are considered credible?
  - Failure Frequency Analysis
    - Predictive model or historic data?
    - Pipeline parameters
  - Consequence Analysis
    - Transient outflow
    - Boundary conditions
    - Leak sizes?
    - Population data
    - Harm criteria and escape speed
      - Normal and vulnerable
  - Risk Calculation
    - Individual Risk – permanent resident or including exposure?
    - Societal Risk – interaction length
  - Risk Mitigation
    - Lengths of slab or relay & costs

QRA Reports – Results to look for

- Hazard Distances
  - Has all population at risk been modelled?
- Individual Risk Transect
  - Does it extend as far as hazard distance?
- Societal Risk FN Curve
  - Is maximum number of casualties credible?
- Cost-Benefit Analysis
  - Disproportion factor?

Would this guidance be useful as a UKOPA TBN?

Questions?

- Please use chat function
  - Any questions not answered now will be covered in a follow up written response.

- Next Webinar
  - 2nd July 2020 - ALARP and cost-benefit analysis (UKOPA/GP/025)

- To sign up, and any suggestions for future topics, please email Nikki Barker (nikki.barker@pieuk.co.uk)