Methodology for Formulating LUP Advice in the Vicinity of Natural Gas Pipelines

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ACDS MHSC Working Group on Pipelines, 25 June 2002

UKOPA/02/0067

For what pipelines is LUP advice given?

- **Natural Gas above 8 bar a – 20,000 km**
- **Ethylene – 1,200 km**
- **Spiked Crude – 200 km**
- **Ethane, Propylene, LPG etc – 100 km**
- **Other flammables and toxics – 400 km**

How does it work?

- **For each pipeline notified to HSE under the relevant Regulations, HSE defines a Consultation Distance to the Local Planning Authorities …..**

How does it work?

- …. who are required to consult HSE before granting planning permissions within the Consultation Zone.

How does it work?

- **The sizes of the Consultation Zone and of subdivisions within it are based, at least in part, on a pipeline risk assessment.**

Current basis of pipeline LUP zones

	Inner Zone	Middle Zone	Consultation Zone
Natural gas	Multiple of BPD	Multiple of BPD	Multiple of BPD
Other flammables	Risk of 10 cpm or FBR	Risk of 1 cpm	Risk of 0.3 cpm or 4/3 times MZ
Toxic	Risk of 10 cpm	Risk of 1 cpm	Risk of 0.3 cpm

Risk of what, to whom, from what?

- **The risk that a Typical Householder will receive a Dangerous Dose, or worse, of thermal radiation from a pipeline accident**

Typical Householder?

- **Is present all of the time**
- **Is indoors most of the time**
- **If outdoors will run towards shelter at a typical speed**
- **Has typical sensitivity to thermal radiation**

Dangerous Dose?

- **For thermal radiation**

  HSE’s “dangerous dose”

  is 1,000 $(kw/m^2)^{4/3}*s$

Dangerous Dose?

- **… which is deemed sufficient to give:-**
  - **severe distress to almost everyone;**
  - **a substantial fraction requiring medical attention;**
  - **some people seriously injured, requiring prolonged treatment; and**
  - **any highly susceptible people might be killed.**

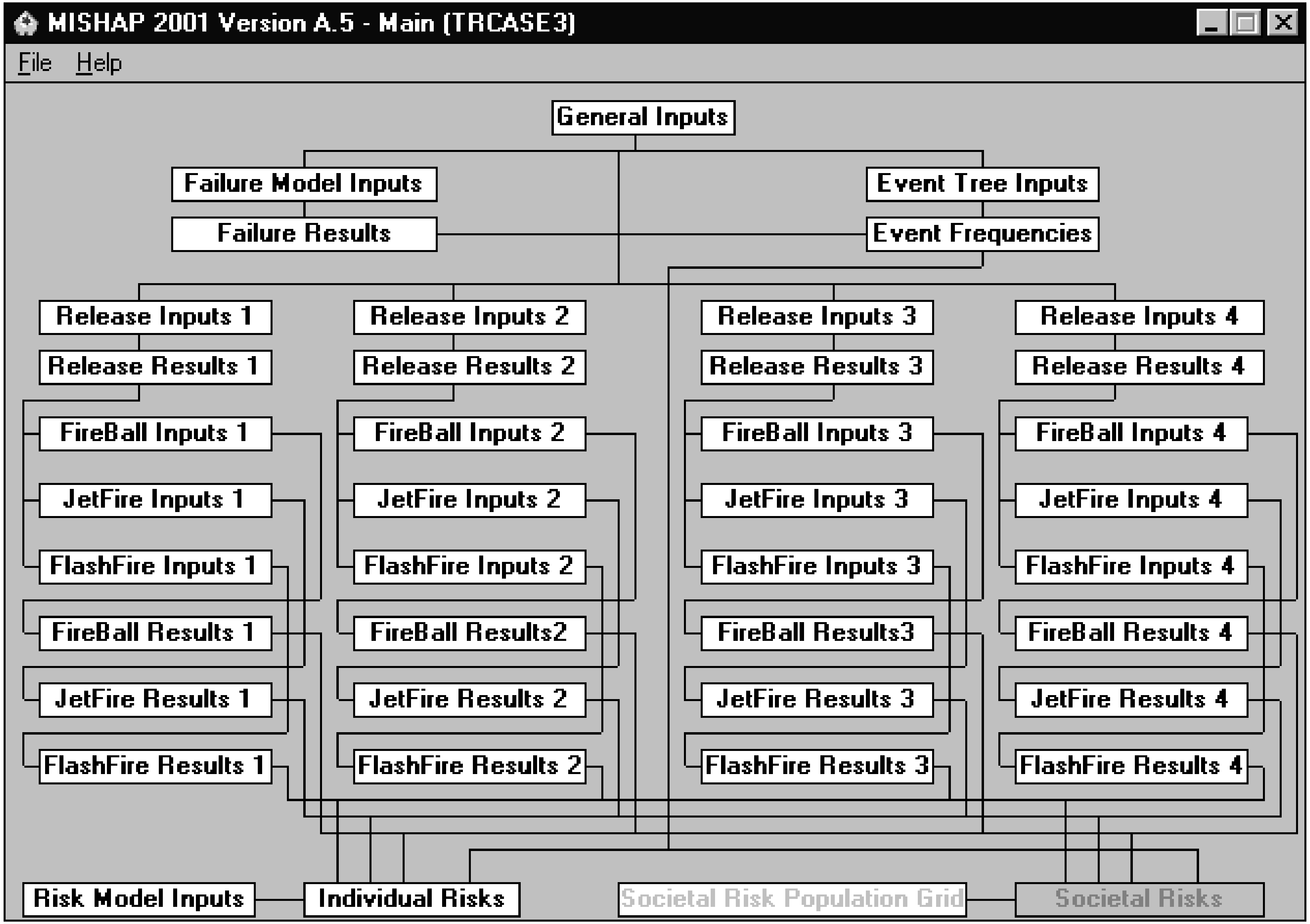
What levels of this risk give us concern?

Precisely these:-

	Inner Zone	Middle Zone	Consultation Zone
Natural gas	Multiple of BPD	Multiple of BPD	Multiple of BPD
Other flammables	Risk of 10 cpm or FBR	Risk of 1 cpm	Risk of 0.3 cpm or 4/3 times MZ
Toxic	Risk of 10 cpm	Risk of 1 cpm	Risk of 0.3 cpm

How do we do it?

- **HSE’s computer programme for pipeline risk assessment is MISHAP**
- **An early version of MISHAP was described in “Pipes & Pipelines International” during 1997**
- **It hasn’t changed a great deal since then**


MISHAP 2001 Version A.5 - Main (TRCASE3)
File
Help
General Inputs
Failure Model Inputs
Event Tree Inputs
Failure Results
Event Frequencies
Release Inputs 1
Release Inputs 2
Release Inputs 3
Release Inputs 4
Release Results 1
Release Results 2
Release Results 3
Release Results 4
FireBall Inputs 1
FireBall Inputs 2
FireBall Inputs 3
FireBall Inputs 4
JetFire Inputs 1
JetFire Inputs 2
JetFire Inputs 3
JetFire Inputs 4
FlashFire Inputs 1
FlashFire Inputs 2
FlashFire Inputs 3
FlashFire Inputs 4
FireBall Results 1
FireBall Results2
FireBall Results3
FireBall Results 4
JetFire Results 1
JetFire Results 2
JetFire Results 3
JetFire Results 4
FlashFire Results 1
FlashFire Results 2
FlashFire Results 3
FlashFire Results 4
Risk Model Inputs
Individual Risks
Societal Risk Population Grid
Societal Risks

How do we do it?

- **MISHAP calculates ….**

  four <u>failure modes</u>:-

  Rupture

  Large Hole

  Small Hole

  Pin Hole

How do we do it?

… <u>release rates</u>;

…. and three <u>fire types</u>:-

fire-ball

jet-fire

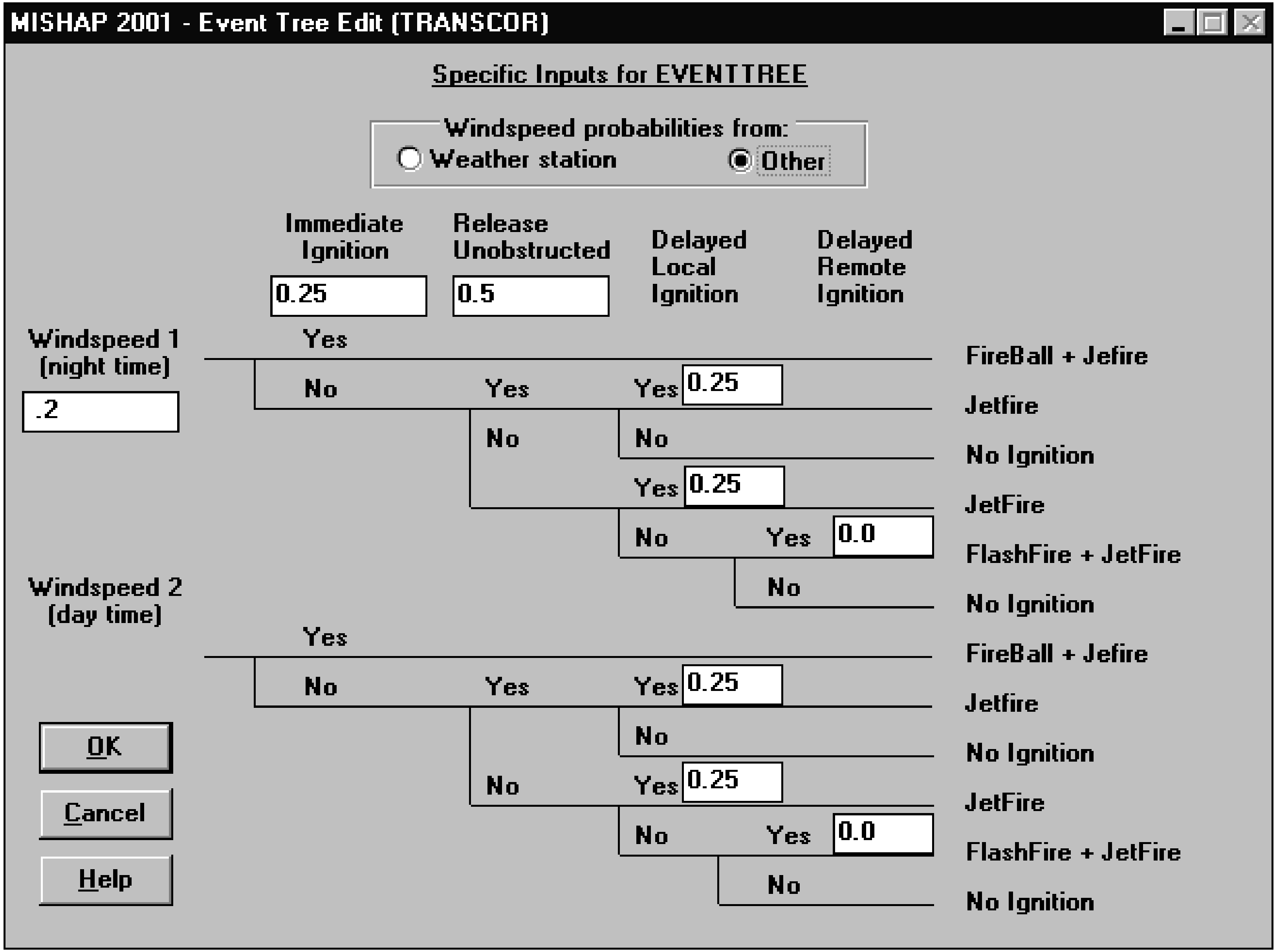
flash-fire

How do we do it?

…. which are combined into <u>scenarios</u>,

defined by an <u>event tree</u>

with <u>branch probabilities</u>


MISHAP 2001 - Event Tree Edit (TRANSCOR)
Specific Inputs for EVENTTREE
Windspeed probabilities from:
Weather station
Other
Immediate Ignition
0.25
Release Unobstructed
0.5
Delayed Local Ignition
Delayed Remote Ignition
Windspeed 1 (night time)
.2
Yes
No
Yes
Yes 0.25
No
No
Yes 0.25
No
Yes 0.0
No
FireBall + Jefire
Jetfire
No Ignition
JetFire
FlashFire + JetFire
No Ignition
Windspeed 2 (day time)
Yes
No
Yes
Yes 0.25
No
No
Yes 0.25
No
Yes 0.0
No
FireBall + Jefire
Jetfire
No Ignition
JetFire
FlashFire + JetFire
No Ignition
OK
Cancel
Help

Frequencies of failure modes

Failure Frequencies

- **Objectives**
  - **Make Operational Use of Third Party Predictive Model**
    - **Required validation and verification**
  - **Review Operational Experience data for other causes of failure**
    - **Make use of UKOPA data?**
  - **Batch running**
    - **Practical requirement**

Failure Frequencies

- **Predictive Model**
  - **Structural Reliability techniques**
    - **Similar to the Advantica model as used by UKOPA**
    - **Uses BG input damage data**
    - **Numerical solution vs. direct integration**
  - **Validation & Verification**
    - **Model developers unwilling to underwrite its use operationally**
      - **Intended for comparative checks only**

Failure Frequencies

- **Predictive Model Validation and Verification**
  - **General Trends**
    - **Change in failure frequency with DF at various diameter/wall thickness combinations**
    - **Covered whole range of the BG network**
    - **Trends logical**
      - » Example Graphs

Failure Frequencies

- **Predictive Model Validation and Verification**
  - **Comparison with Operational Experience**
    - **Statistical Analysis**
      - **Definition of 6 ‘typical’ pipelines based on population of the BG network**
      - **Good correlation between Predictive Model and Operational Experience Data**

Failure Frequencies

Pipeline Diameter (mm)	Failure Frequencies (10^{-9}/m.yr)					
	Total			Rupture		
	Op. Exp	Predictive	Factor	Op.Exp	Predictive	Factor
1067	3.16	2.78	0.88	1.26	1.27	1.01
914	4.42	5.31	1.20	1.26	2.4	1.9
614	3.16	4.34	1.37	1.01	1.97	1.95
457	5.81	4.41	0.76	1.9	1.25	0.66
324	21.7	26	1.2	7.33	8.46	1.15
219	106	36.9	0.35	35.4	12.7	0.36

Comparison of Predictive Model with Operational Experience

Failure Frequencies

- **Predictive Model Conclusions**
  - **Model is robust within the pipeline parameters of the BG network**
    - **Appears more conservative than Transco under some conditions**
  - **Good correlation with operational experience data**
  - **Model does not converge for some low Design Factor and small diameter pipelines**
    - **Estimation of Third Party Frequency necessary**

Failure Frequencies

- Operational Experience Data
  - HSE has, until now, used EGIG data
    - Initial risk results prompted a review
    - Indications that the use of UK specific data could be beneficial
    - UKOPA data adopted for key causes

Failure Frequencies

- UKOPA Data
  - Four ‘causes of failure’
    - Mechanical – fatigue failure
    - Natural – landslip
    - Corrosion
    - Other – a group of miscellaneous causes
  - Key differences with EGIG are in Mechanical and Natural causes

Failure Frequencies

- **Mechanical**
  - **Overall failure frequency very similar between EGIG & UKOPA**
  - **UKOPA biased much more to smaller holes than rupture** <u>Table</u>
    - **Significant for Risk Assessment as Rupture and Large Hole frequencies dominate**
  - **Net result is that failure frequencies for mechanical cause are low, a small proportion of the total** <u>Zero Failures</u>

Failure Frequencies

- **Natural Failures**
  - **A clear difference between UK and Europe generally** <u>Table</u>
    - **Failure frequency much lower for UK**
  - **Very few failures**
  - **Resulting frequency low but still significant**

<u>Further slides on Natural Failures</u>

Failure Frequencies

- **Corrosion Failures**
  - **Currently remain based on EGIG data**
    - **Initial review did not indicate significant differences**
    - **Generally a very low proportion of the total failure frequency**
    - **Time constraints**
    - **Move to UKOPA data in due course**

Failure Frequencies

- **‘Other’ Causes**
  - **A significant proportion of the total number of recorded failures**
  - **Various causes**
    - **Lightning strike,**
    - **Cracking due to wet town gas**
    - **Threaded joints**
    - **etc**

Failure Frequencies

- **'Other' Causes**
  - **Engineering judgement applied to each cause**
    - **Credibility of failure in each hole size**
      - **E.g. Wet town gas failures eliminated, threaded joints = pin hole only**
    - **Net result has no impact on rupture frequency but significant impact on Large Hole frequency.**

Failure Frequencies

	Rupture	Large Hole	Small Hole	Pin Hole
Third Party	PIPIN Predictive Model	PIPIN Predictive Model	PIPIN Predictive Model	PIPIN Predictive Model
Mechanical	8.10^{-12}	8.10^{-12}	2.10^{-11}	9.10^{-8}
Natural	2.10^{-9}	2.10^{-10}	2.10^{-9}	6.10^{-9}
Corrosion	EGIG Data via PIPIN	EGIG Data via PIPIN	EGIG Data via PIPIN	EGIG Data via PIPIN
Other	0	7.10^{-10}	7.10^{-9}	3.10^{-8}

Overall Failure Frequencies (/m.year)

Frequencies of Scenarios

Frequencies of scenarios

- **Combining the <u>frequencies of the failure modes</u> with the <u>branch probabilities</u> gives the frequencies of the scenarios**
- **We're half-way there!**

Consequences of scenarios

- **MISHAP was first frozen in 1998**
- **MISHAP98 included these modules:-**

Release rate:	**LOSSP**
Fire-ball:	**FLAMCALC**
Jet-fire:	**JIF/MAJ3D**
Flash-fire:	**CRUNCH**

Validation of MISHAP98

- **The damage predictions of MISHAP98 were compared with the damage that occurred in real pipeline accidents**

- **We concluded that one of the modules**

  Jet-fire: JIF/MAJ3D

  was not performing well and should be replaced

Consequences of Scenarios

- So in 2001 we created a new version, MISHAP01, with

  Jet-fire: PIPEFIRE

- Its use is limited to natural gas

Validation of MISHAP01

- **As before, the damage predictions of MISHAP01 were compared with the damage that occurred in real pipeline accidents**

SUBSET				
	Observed Burn Area (sq.metres)			
Immediate Ignition				
Bealeton	**20800**			
Beaumont	**29700**			
Cartwright	**46000**			
Lancaster	**60000**			
Delayed Ignition				
Edison	**104000**			
Latchford	**47000**			
Natchitoches	**56000**			

SUBSET				
	Observed Burn Area (sq.metres)	**Calc/Obs Fire-ball**		
Immediate Ignition				
Bealeton	**20800**	**7.0**		
Beaumont	**29700**	**5.6**		
Cartwright	**46000**	**1.3**		
Lancaster	**60000**	**2.6**		
Delayed Ignition				
Edison	**104000**	**-**		
Latchford	**47000**	**-**		
Natchitoches	**56000**	**-**		

SUBSET				
	Observed Burn Area (sq.metres)	Calc/Obs Fire-ball	Calc/Obs Jet-fire OLD	
Immediate Ignition				
Bealeton	20800	7.0	-	
Beaumont	29700	5.6	-	
Cartwright	46000	1.3	-	
Lancaster	60000	2.6	-	
Delayed Ignition				
Edison	104000	-	0.0	
Latchford	47000	-	0.0	
Natchitoches	56000	-	0.6	

SUBSET				
	Observed Burn Area (sq.metres)	Calc/Obs Fire-ball	Calc/Obs Jet-fire OLD	Calc/Obs Jet-fire NEW
Immediate Ignition				
Bealeton	20800	7.0	-	-
Beaumont	29700	5.6	-	-
Cartwright	46000	1.3	-	-
Lancaster	60000	2.6	-	-
Delayed Ignition				
Edison	104000	-	0.0	0.9
Latchford	47000	-	0.0	2.0
Natchitoches	56000	-	0.6	1.0

Validation of MISHAP01

- We have also made comparisons with data from rupture tests, provided to us by Transco
  - Release rate versus time (Canada)
  - Heat fluxes vs distance (Canada & Spadeadam)

Canada Tests

Time (s)	Calc/Obs Release Rate
0	1.74
10	1.50
20	1.07
30	0.95
40	0.89
60	0.91
80	0.95
100	0.98

Test	**Observed parameter**	**Calc/Obs Fire-ball**		
Can-1	**Distance to given heat fluxes**	**1.4-1.6**		
Can-2	**Distance to given heat fluxes**	**1.1-1.3**		
Spad-6	**Heat flux at given distances**	**-**		
Spad-7	**Heat flux at given distances**	**-**		
Spad-8	**Heat flux at given distances**	**-**		
Spad-9	**Heat flux at given distances**	**-**		

Test	Observed parameter	Calc/Obs Fire-ball	Calc/Obs Jet-fire OLD	
Can-1	Distance to given heat fluxes	1.4-1.6	0.0-0.8	
Can-2	Distance to given heat fluxes	1.1-1.3	1.0-1.3	
Spad-6	Heat flux at given distances	-	0.3-1.4	
Spad-7	Heat flux at given distances	-	0.3-0.8	
Spad-8	Heat flux at given distances	-	0.3-0.8	
Spad-9	Heat flux at given distances	-	0.3-0.8	

Test	Observed parameter	Calc/Obs Fire-ball	Calc/Obs Jet-fire OLD	Calc/Obs Jet-fire NEW
Can-1	Distance to given heat fluxes	1.4-1.6	0.0-0.8	0.9-1.3
Can-2	Distance to given heat fluxes	1.1-1.3	1.0-1.3	1.6-1.9
Spad-6	Heat flux at given distances	-	0.3-1.4	0.5-3.0
Spad-7	Heat flux at given distances	-	0.3-0.8	0.6-2.0
Spad-8	Heat flux at given distances	-	0.3-0.8	0.8-1.7
Spad-9	Heat flux at given distances	-	0.3-0.8	0.7-1.7

Validation of MISHAP01

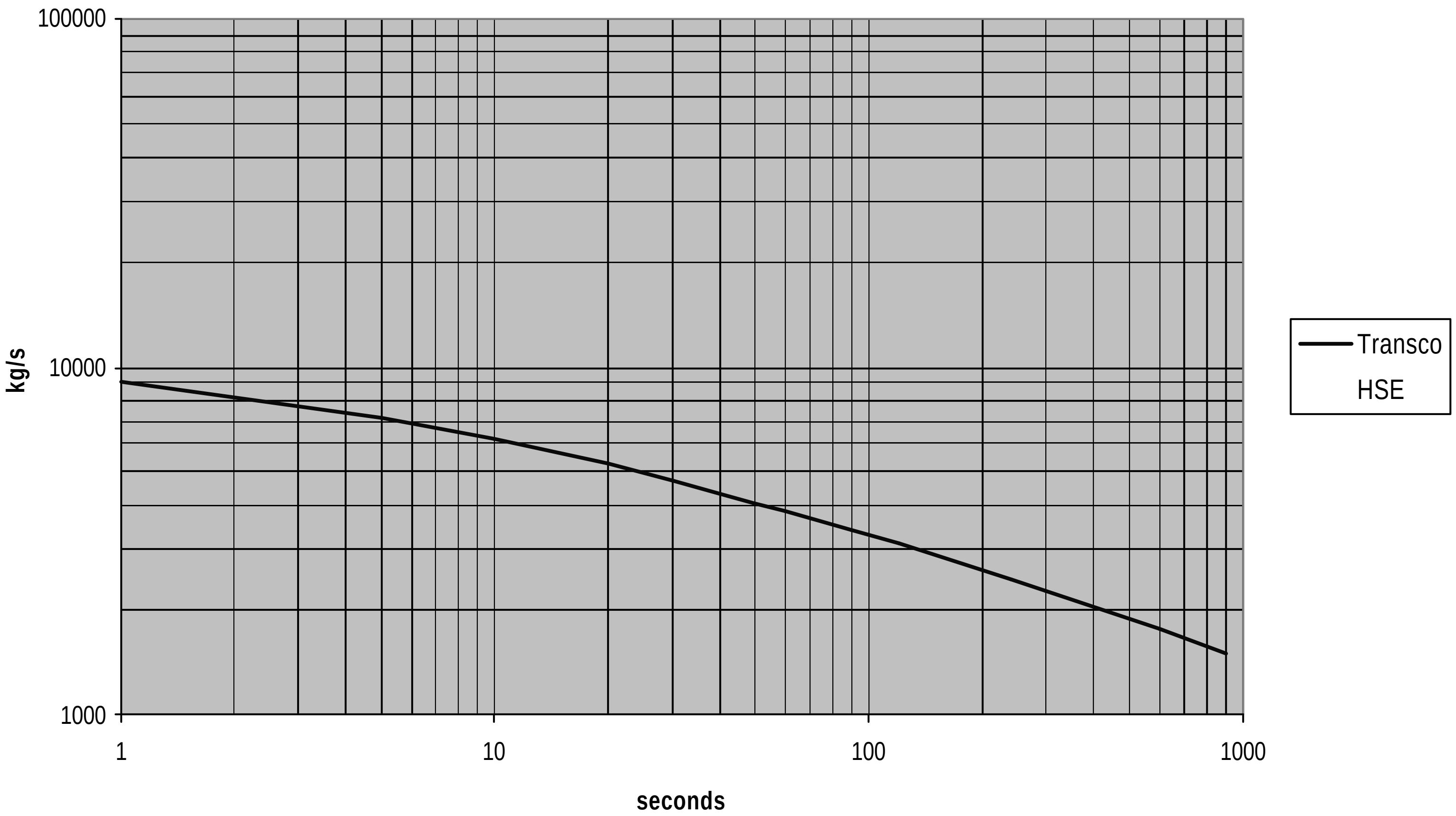
- **The study will be reported as an HSE Contract Research Report during 2002**

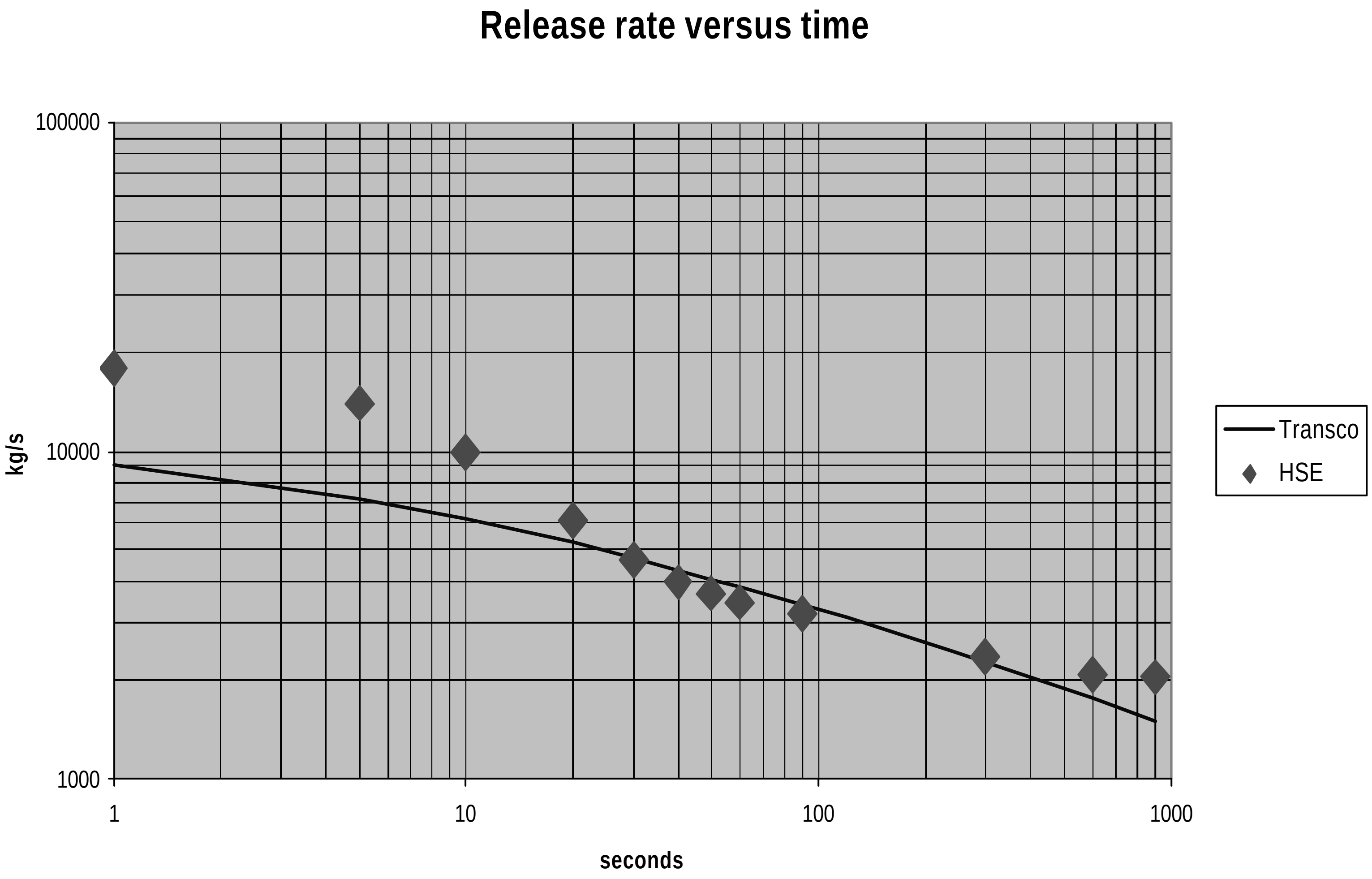
  “Report on a second study of pipeline accidents using HSE’s risk assessment program MISHAP”

Validation of MISHAP01

- **We have also compared MISHAP01 consequence calculations with results from Transco's PIPESAFE programme**

Release rate versus time





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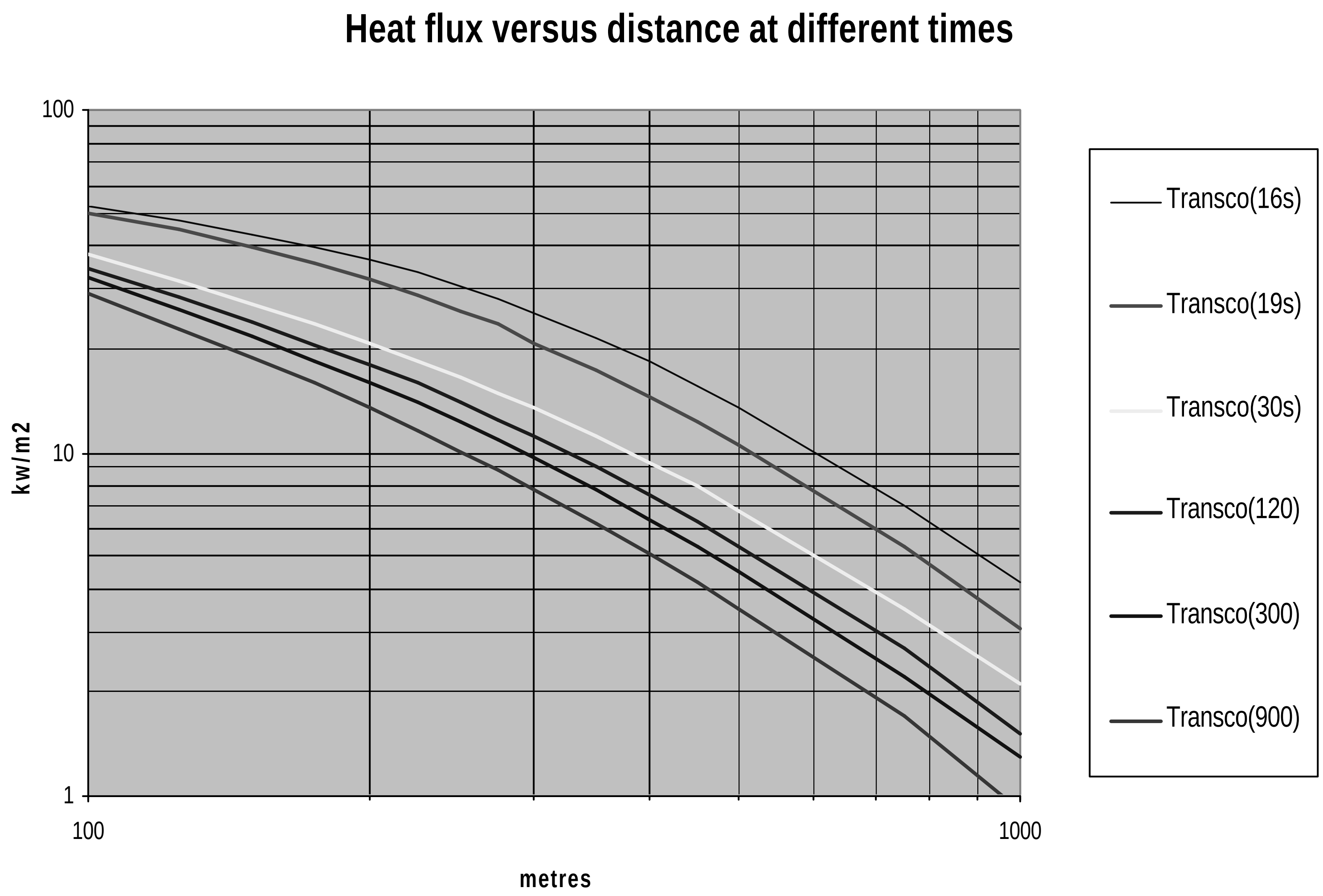
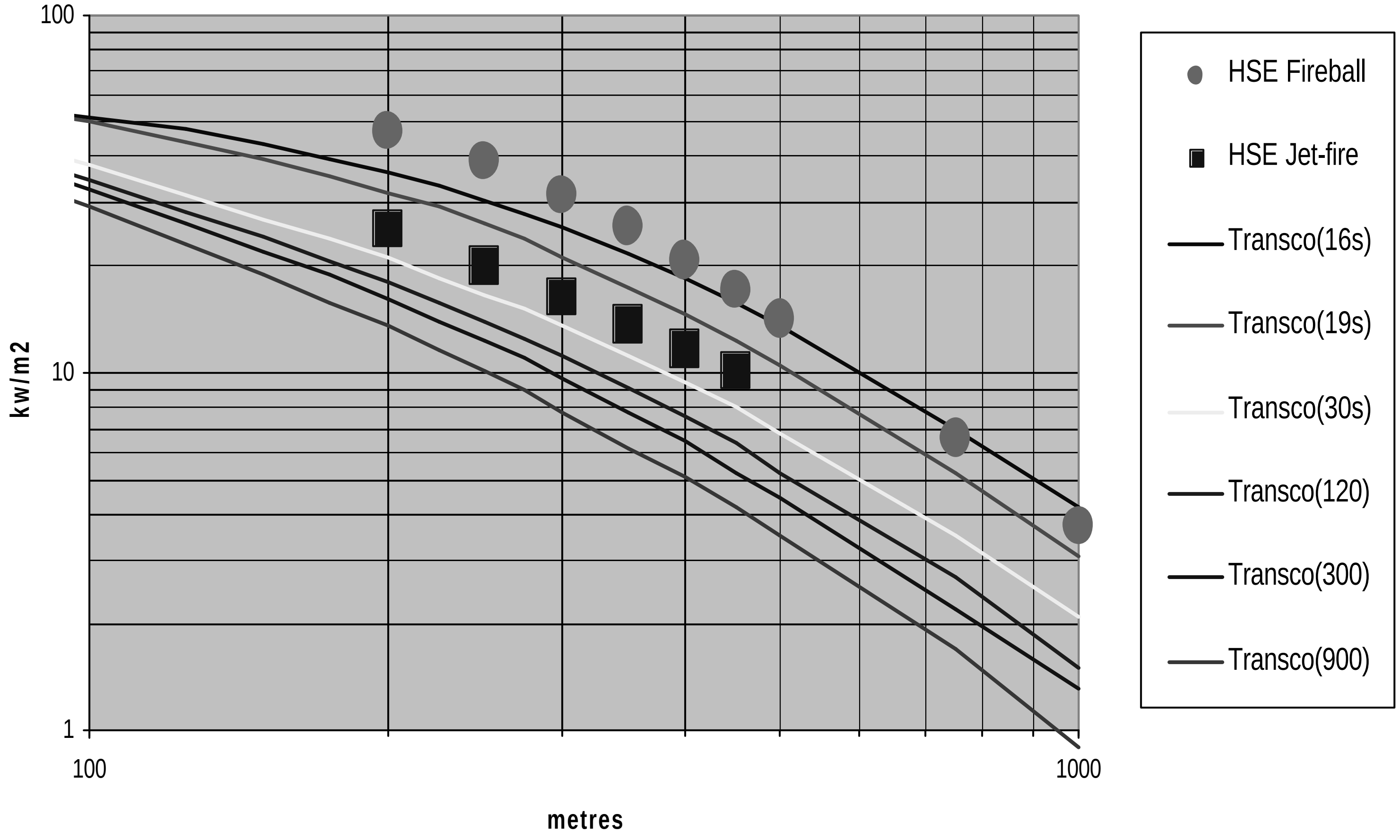
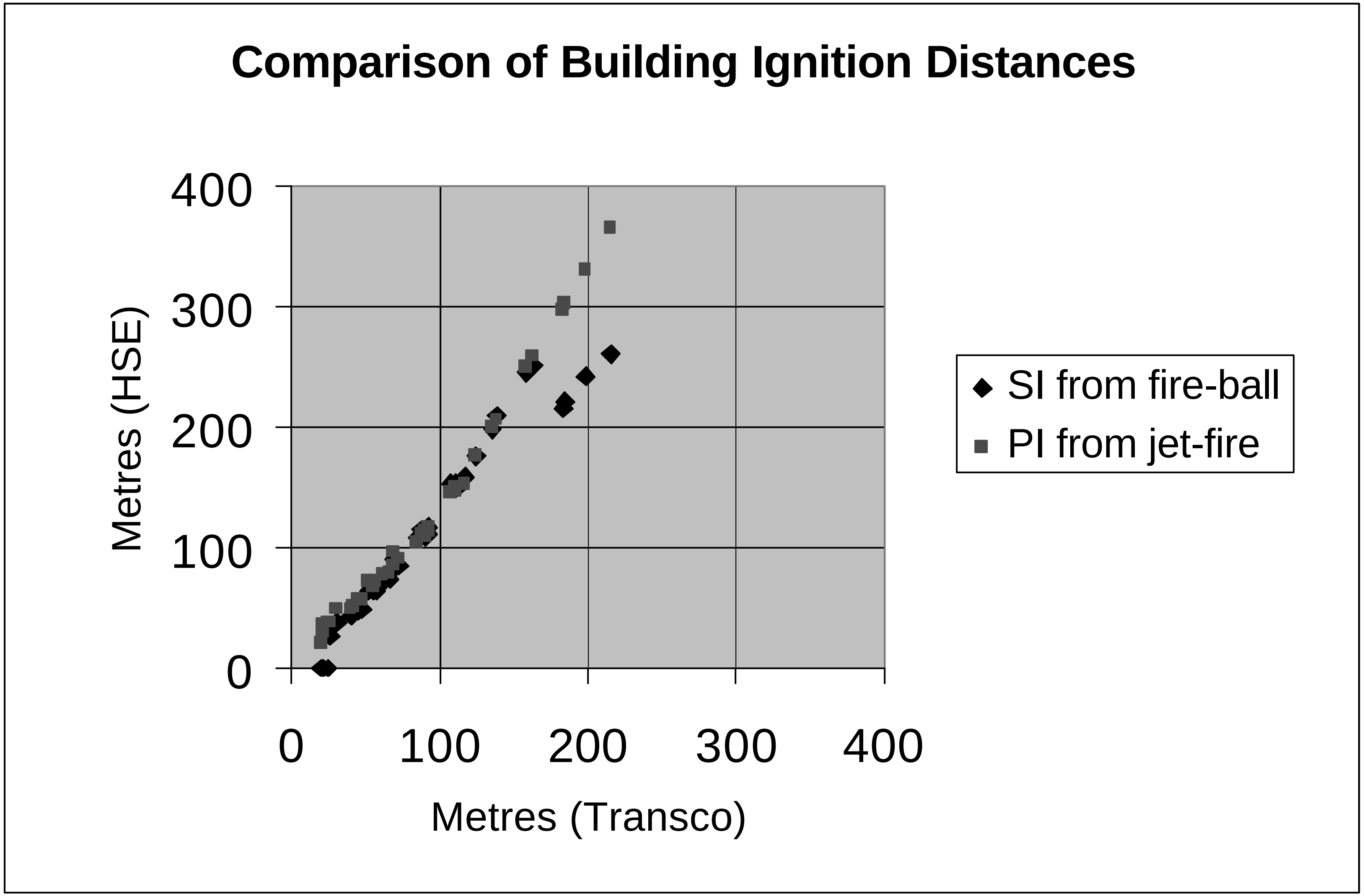


Heat flux versus distance at different times
100
10
1
kw/m2
100
1000
metres
Transco(16s)
Transco(19s)
Transco(30s)
Transco(120)
Transco(300)
Transco(900)

Heat flux versus distance at different times



UKOPA/02/0067


Comparison of Building Ignition Distances
400
300
200
100
0
Metres (HSE)
0
100
200
300
400
Metres (Transco)
SI from fire-ball
PI from jet-fire

Conclusion

Noting:-

- **that the included models are mostly conservative,**
- **but that there is a trend towards non-conservatism nearer to the pipeline**

Conclusion

And:-

- **that some phenomena that may be important near to the pipeline are not included in the model,**

Conclusion

For example:-

- **for ruptures – no blast overpressure, no debris from crater formation, no horizontal jets; and**
- **for punctures – no grounded or angled jets, and no confined gas cloud explosions**

Conclusion

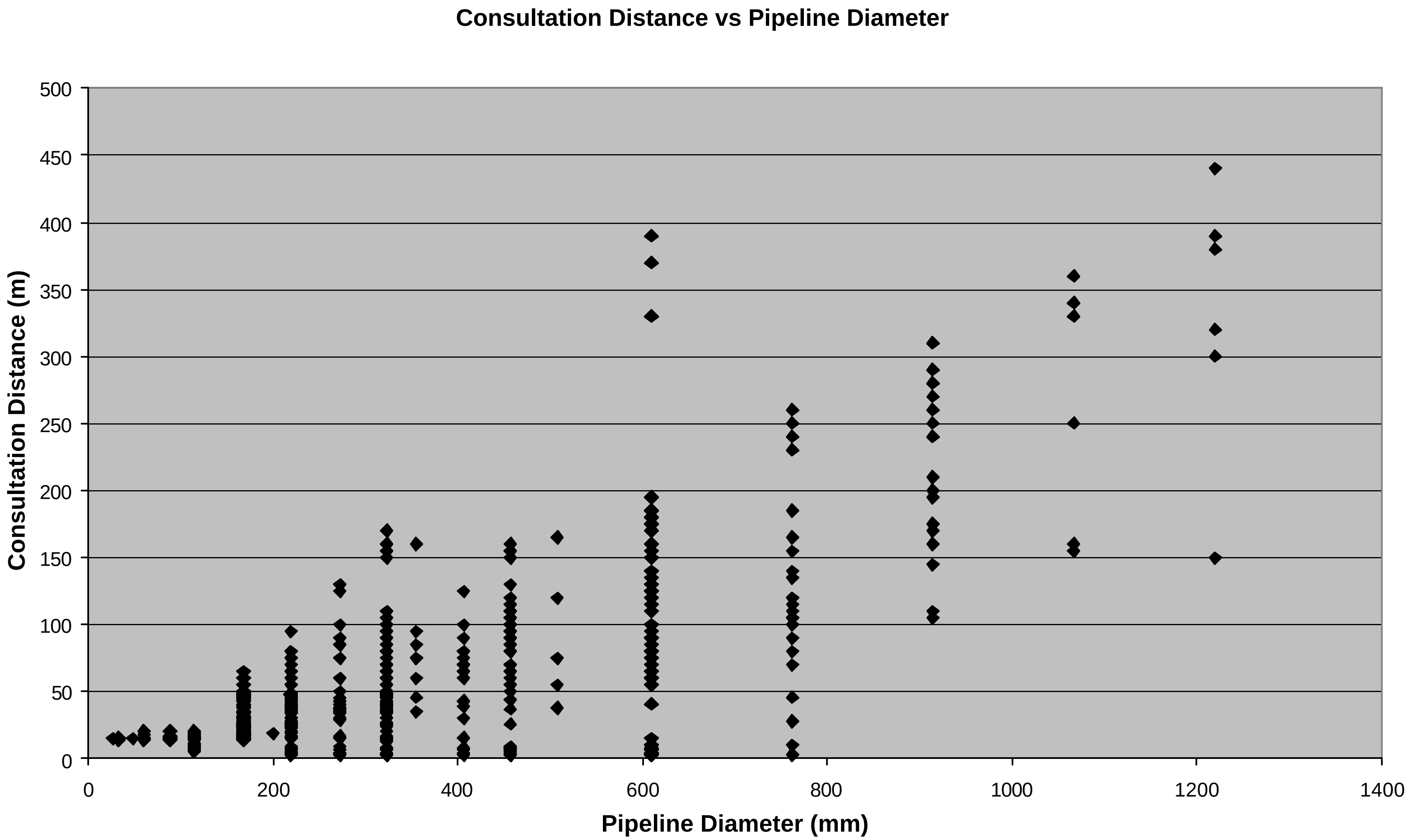
We conclude that:-

- **MISHAP01 is broadly fit-for-purpose; but**
- **we will not trust it entirely in the near field**

New basis for LUP zones for natural gas pipelines

	Inner zone	Middle zone	Outer zone
Natural gas	**Risk of 10 cpm or BPD**	**Risk of 1 cpm**	**Risk of 0.3 cpm**

What are the results?



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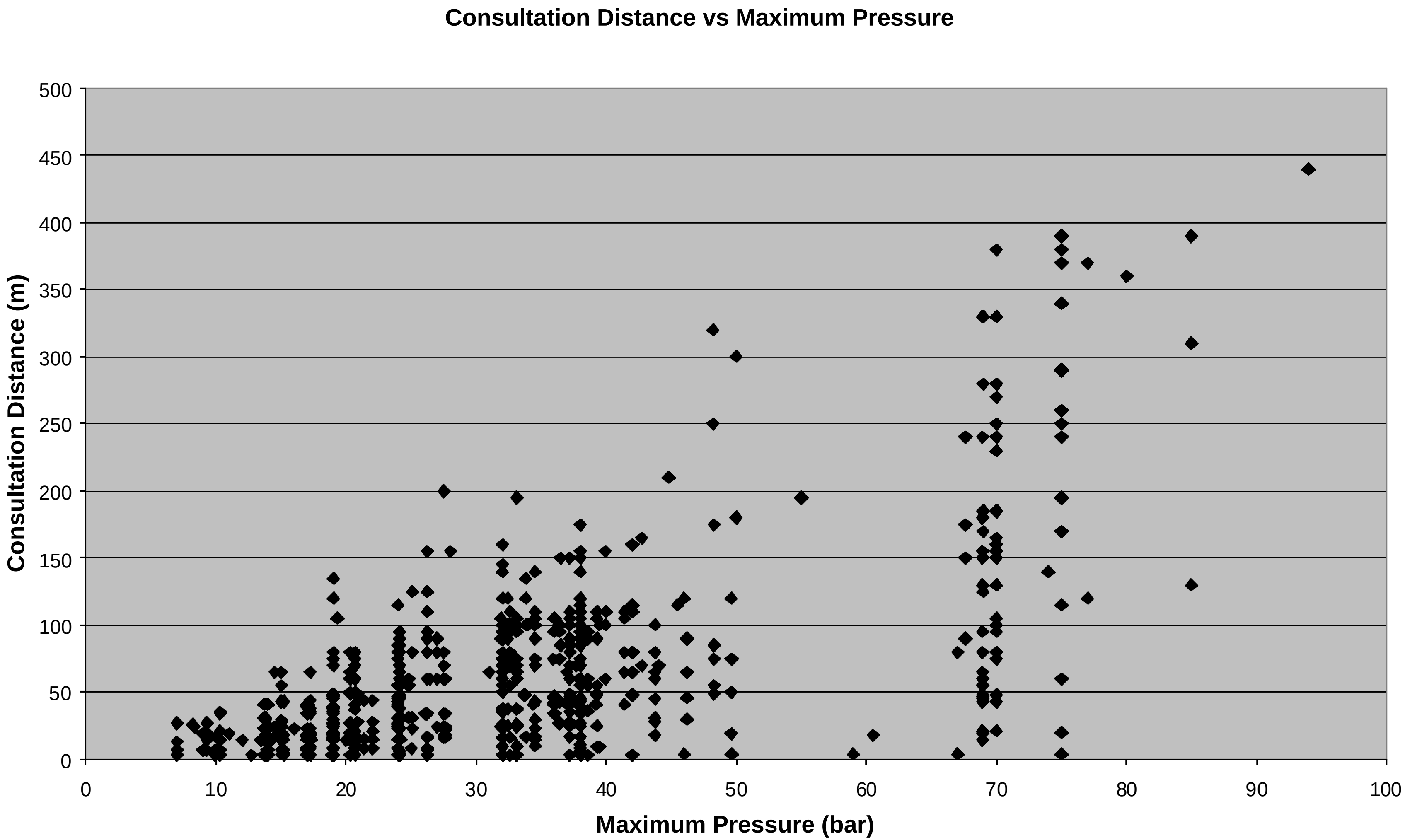
What are the results?



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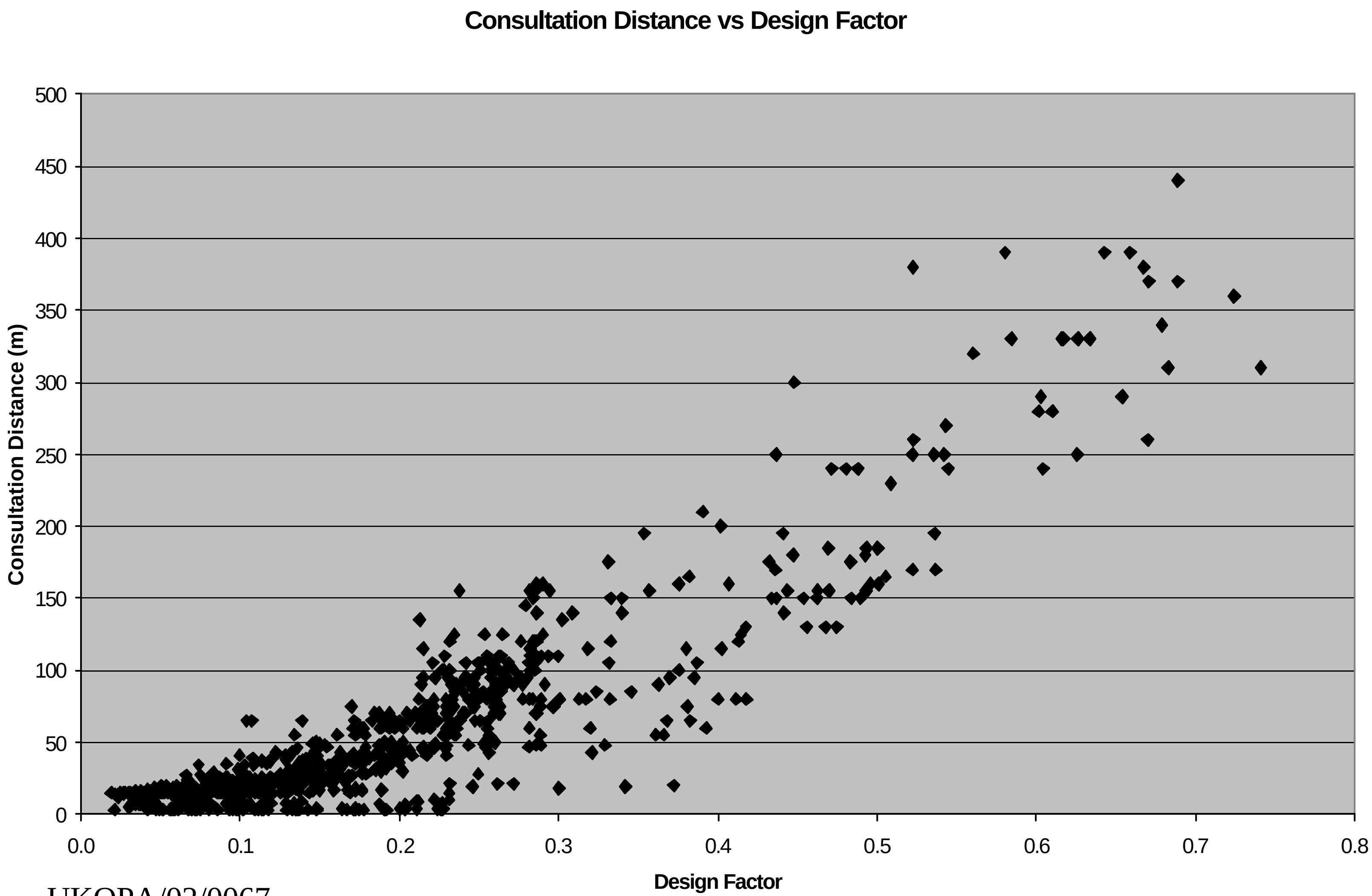
What are the results?



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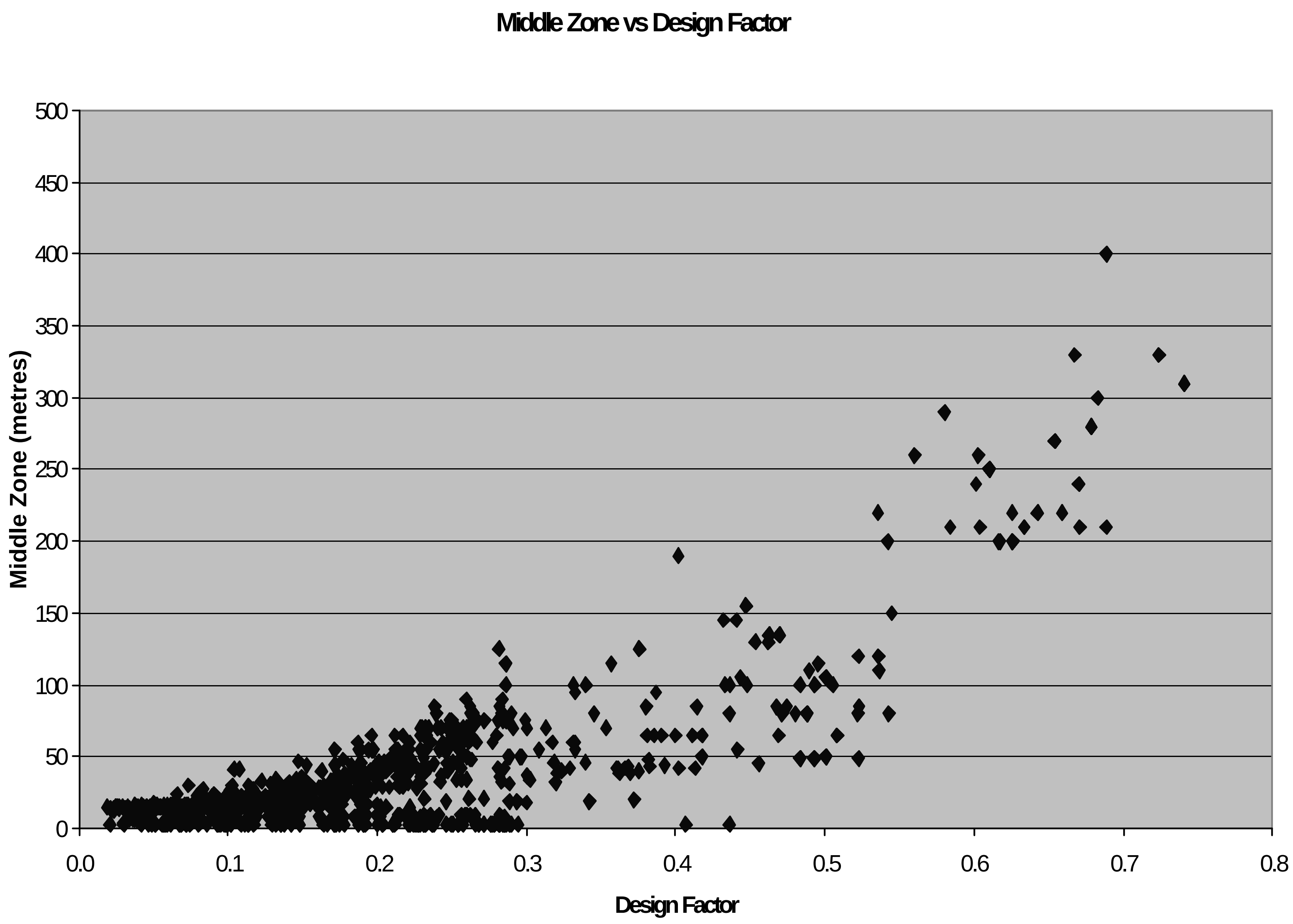
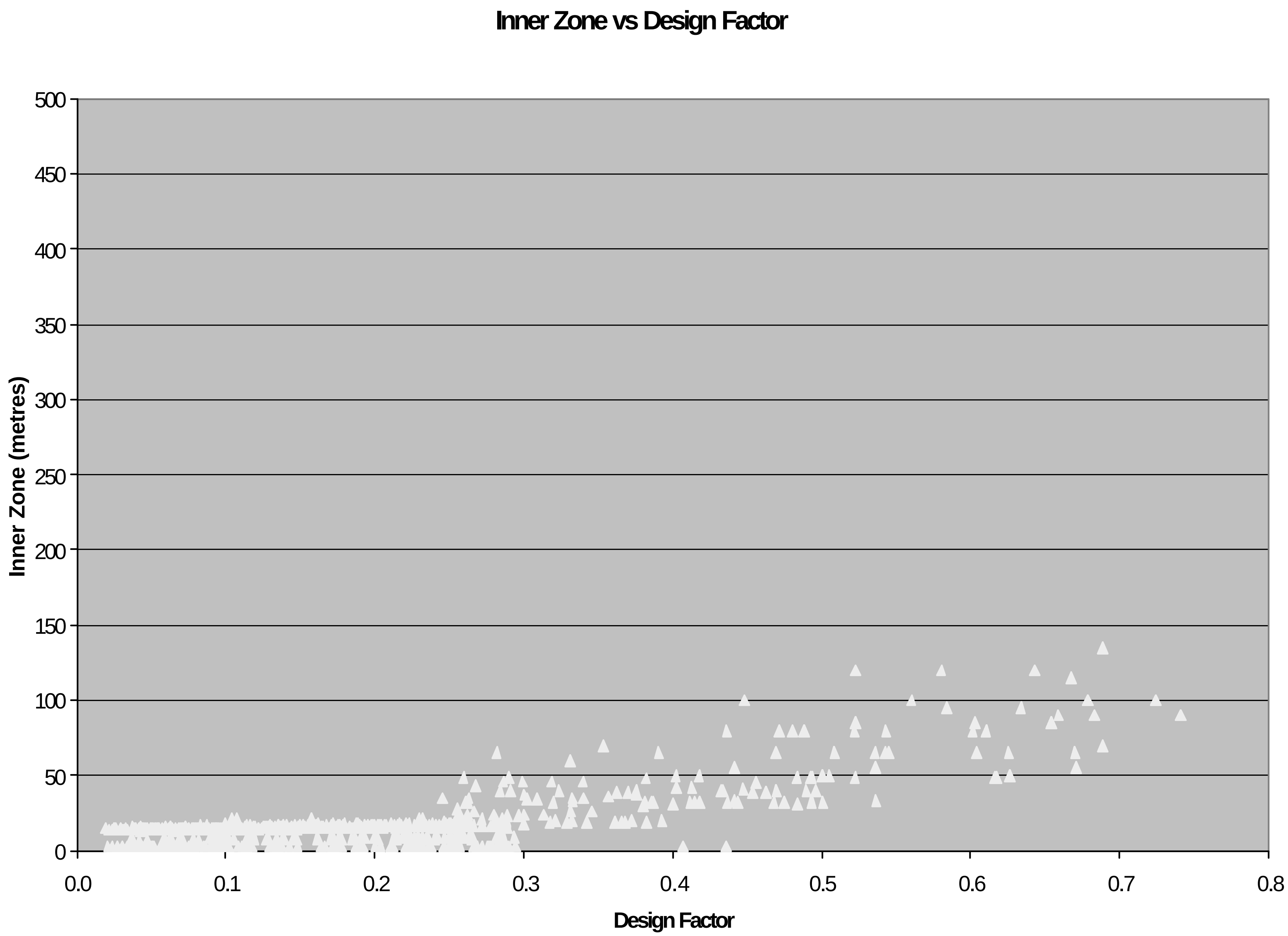


Middle Zone vs Design Factor
Middle Zone (metres)
500
450
400
350
300
250
200
150
100
50
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Design Factor



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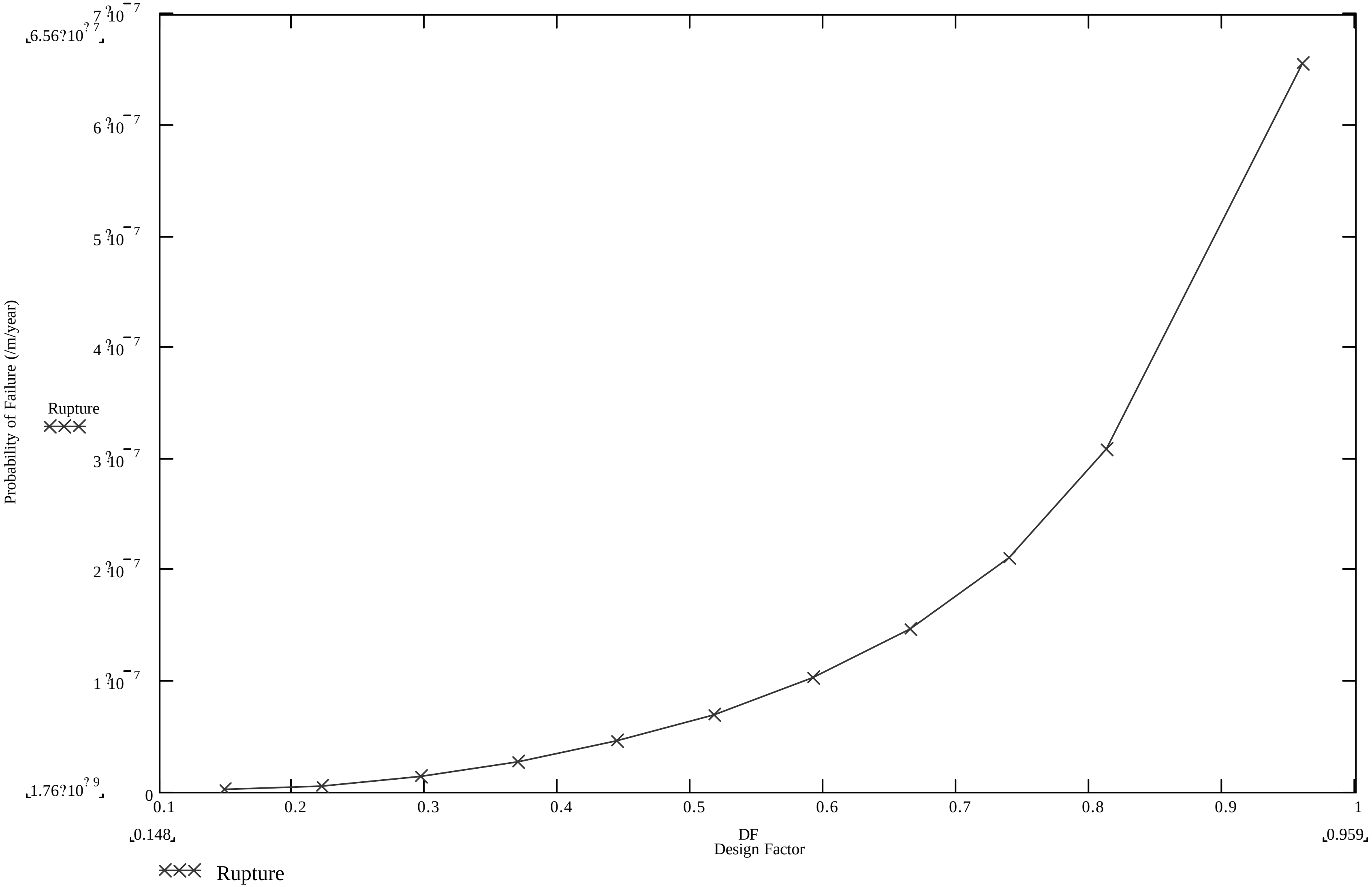
Application

	IZ	MZ	OZ
SensLvl 1	DAA	DAA	DAA
SensLvl 2	AA	DAA	DAA
SensLvl 3	AA	AA	DAA
SensLvl 4	AA	AA	AA

Application

…… where:-

- SL1 = “normal working population”
- SL2 = “general public at home and involved in normal activities”
- SL3 = “vulnerable members of the public”
- SL4 = “large examples of 3 and large outdoor examples of 2”



Rupture of 1219 mm Diameter 10 mm Wall

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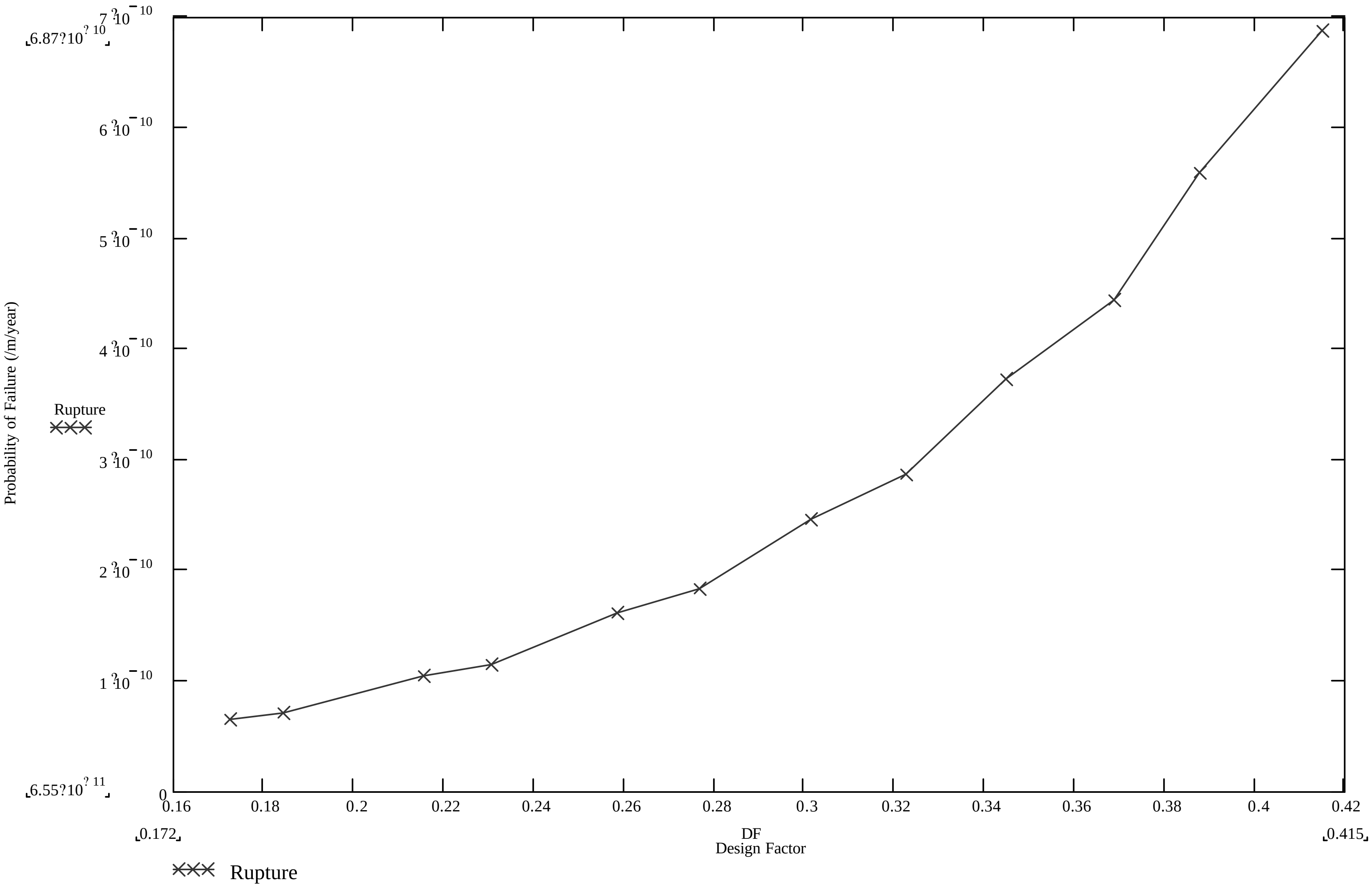

Rupture of 1067 mm Diameter, 15 mm Wall

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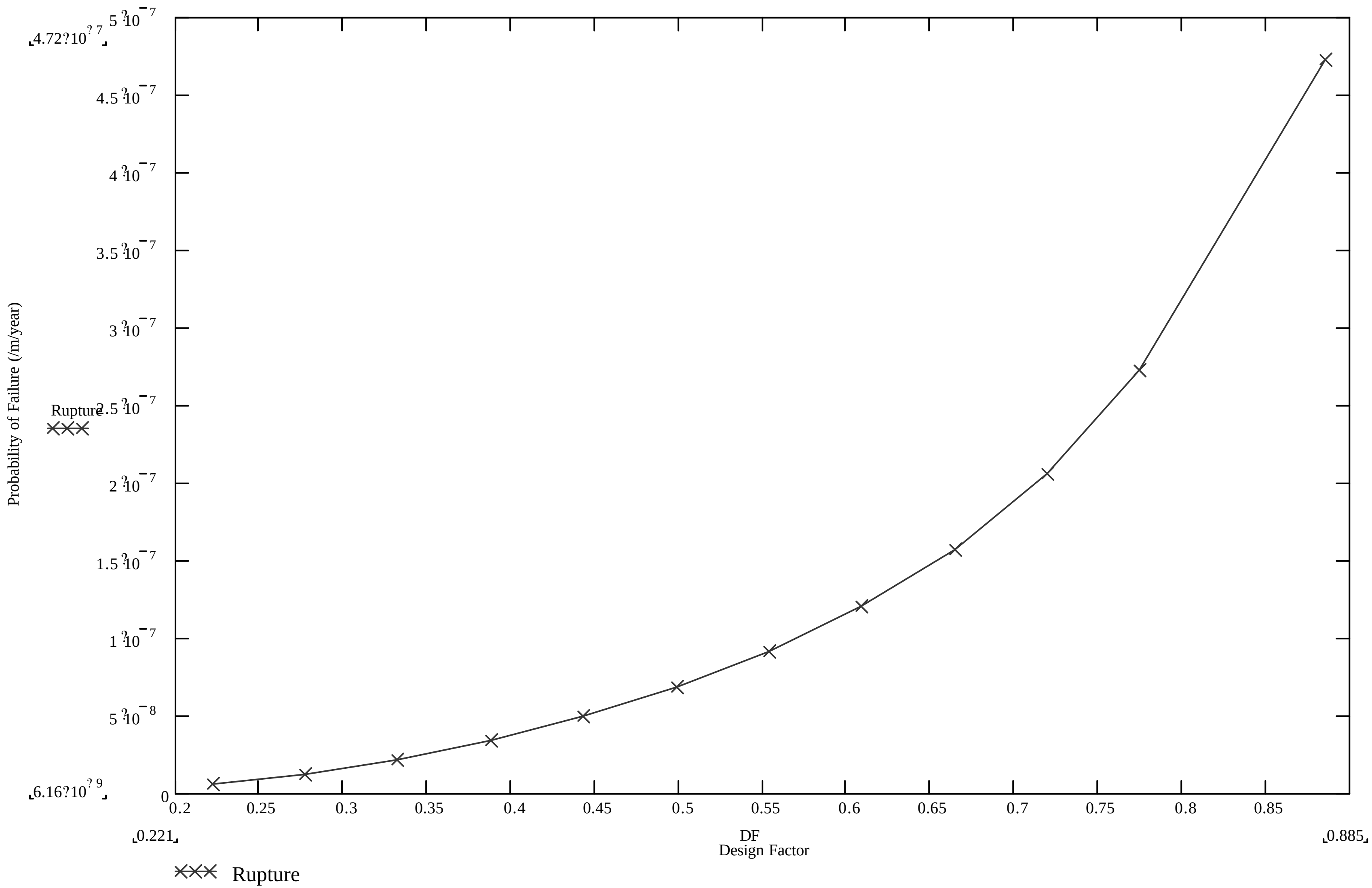

Rupture of 914 mm Diameter, 10 mm Wall

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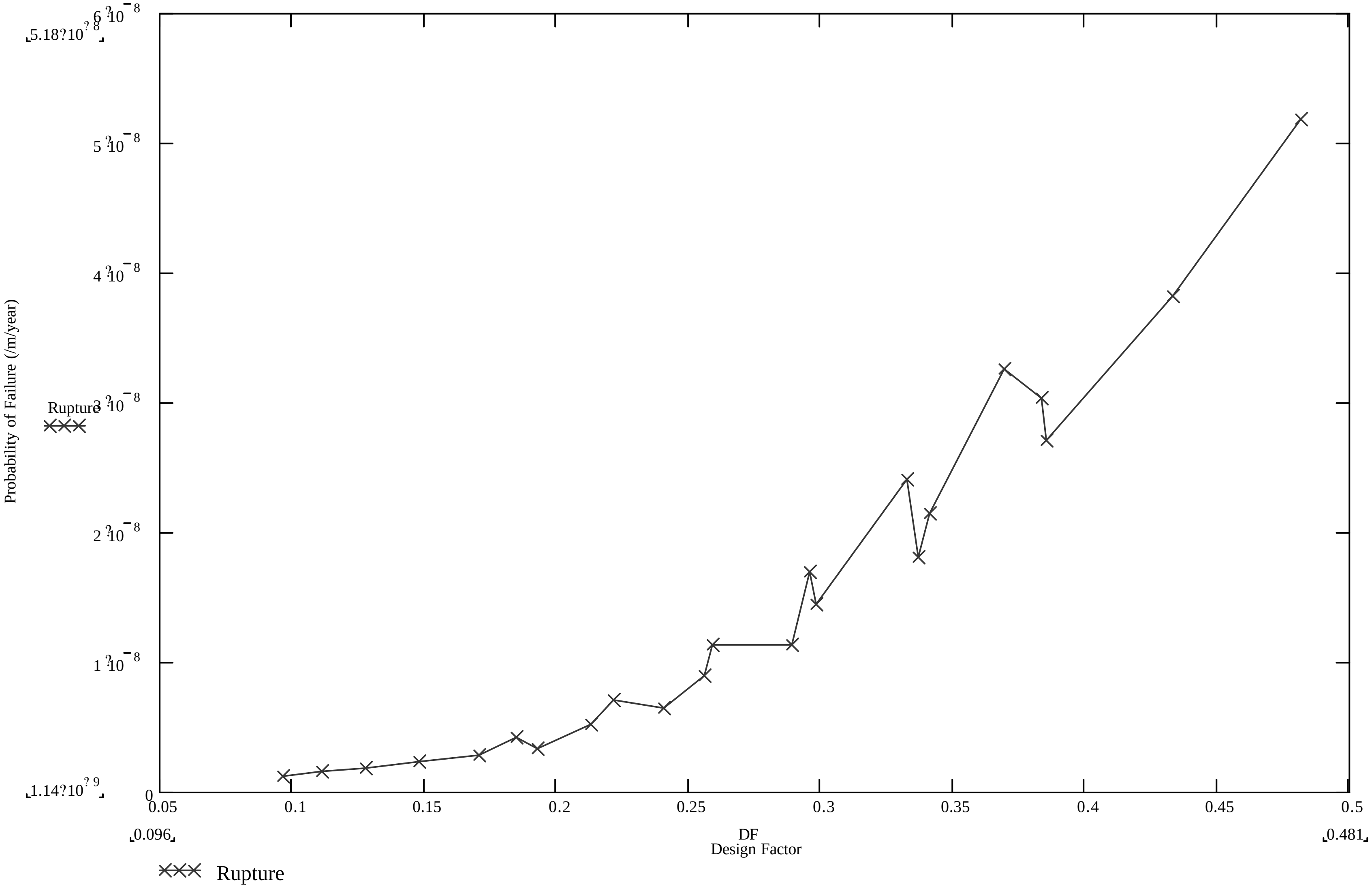

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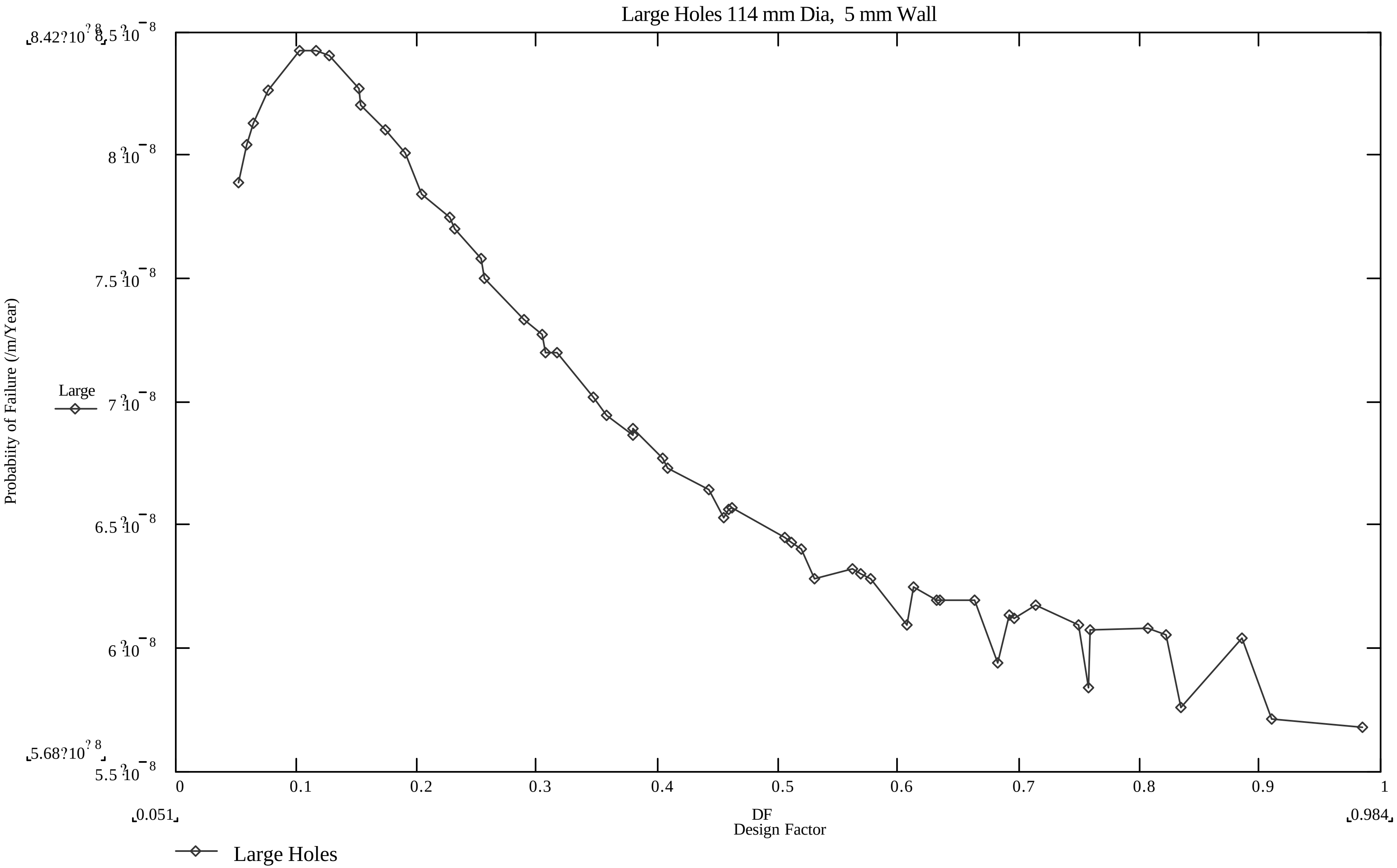
Rupture of 610 mm Diameter, 10 mm Wall



Large Holes 219 mm Diameter, 3 mm Wall ®

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Mechanical Failures

	UKOPA	EGIG
Rupture	0	5
Large Hole	0	12
Small Hole	0	EGIG records only ‘holes’
Pin Hole	49	34

EGIG data factored to match lower operational experience of UKOPA

®

Natural Failures

	UKOPA	EGIG
Rupture	1	9
Large Hole	0	5
Small Hole	1	EGIG records only 'holes'
Pin Hole	3	5

EGIG data factored to match lower operational experience of UKOPA

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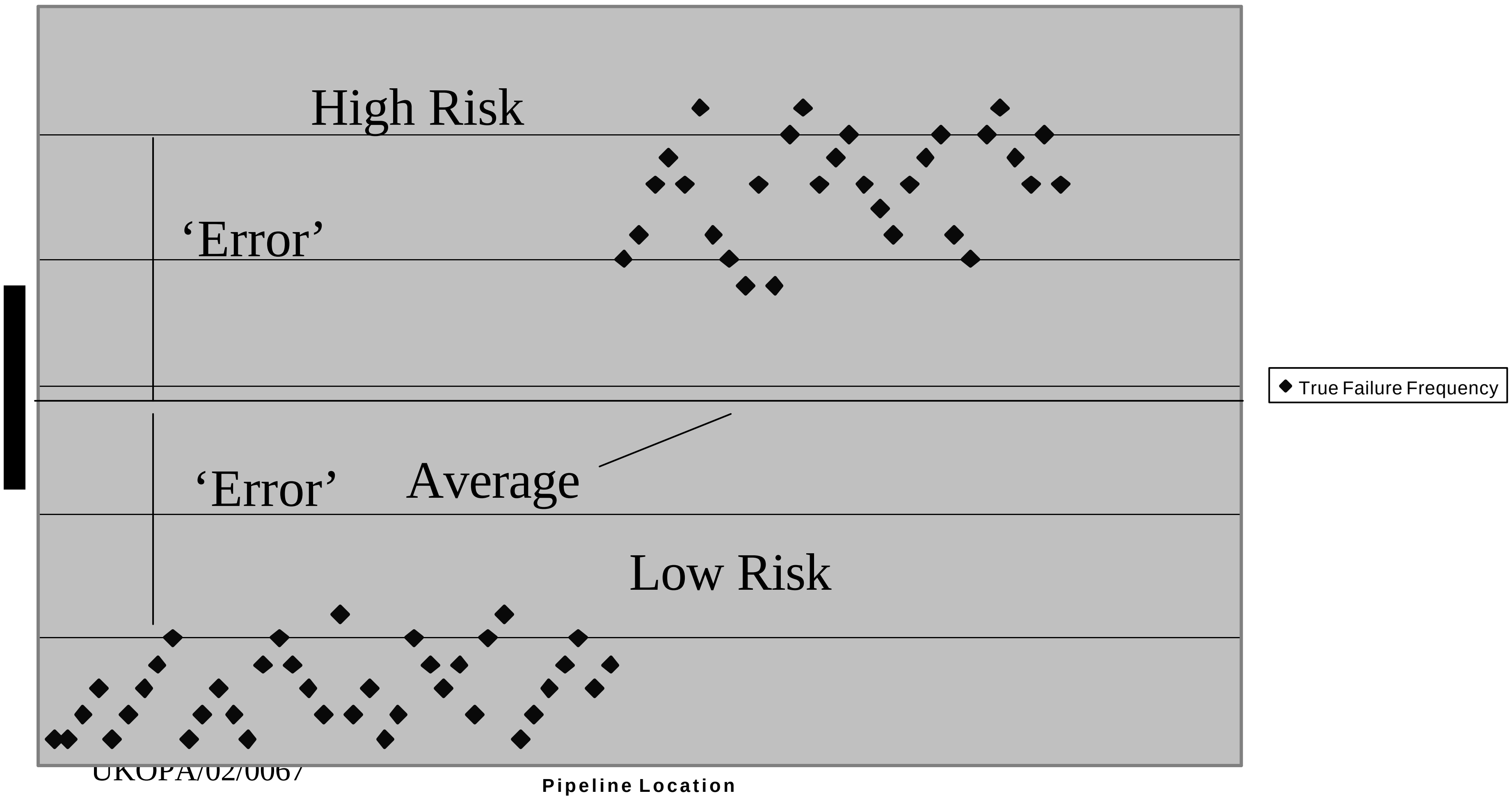
Natural Failure Debate

- Very dependant on geographical location
  - High and Low risk areas
  - Derived value represents and average for the whole network

Natural Failures Debate



Natural Failures Debate

- Mitigating Factors
  - IGE/TD/1 requires specific design and operational controls when the potential for landslip is identified
    - Will drive the ‘high risk’ area frequency down
  - Very small number of pipelines pass through high risk areas
    - Average dominated by low risk areas

Natural Failures Debate

- Conclusion
  - Average frequency not likely to be excessively conservative
  - Further work would be beneficial
    - How effective are additional controls required by IGE/TD/1?
    - Should pipelines in high risk areas be treated separately?

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Dealing with Zero Failures

- Cannot assume ‘zero’ failure frequency
- Assume 1 additional failure split over all four failure categories
  - @50% confidence that ‘true’ value will not be higher
  - Conservative best estimate

Dealing with Zero Failures

Example:

Mechanical Failures:

	Observed Failures	Proportion of Additional Failures	Calculation	Frequency (/m.yr)
Rupture	0	0.25/50	0.005/591282	$8.4.10^{-12}$
Large Hole	0	0.25/50	0.005/591282	$8.4.10^{-12}$
Small Hole	0	0.5/50	0.01/591282	$1.7.10^{-11}$
Pin Hole	49	49/50	0.005/591282	$8.5.10^{-8}$

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