RAWG/2007/027

ATKINS boreas

Reduction Factors for Mechanical Damage due to External Interference

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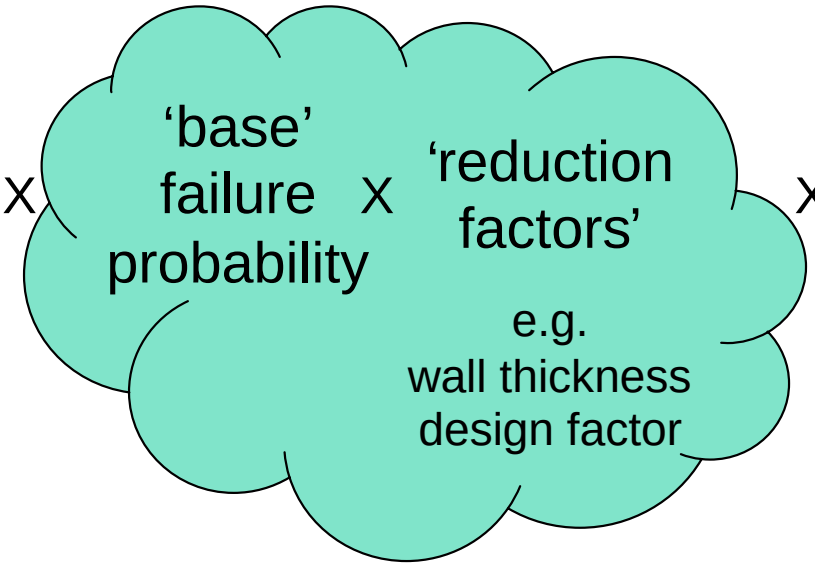
presentation to UKOPA, 04 December 2007

Estimating the Failure Frequency using Reduction Factors

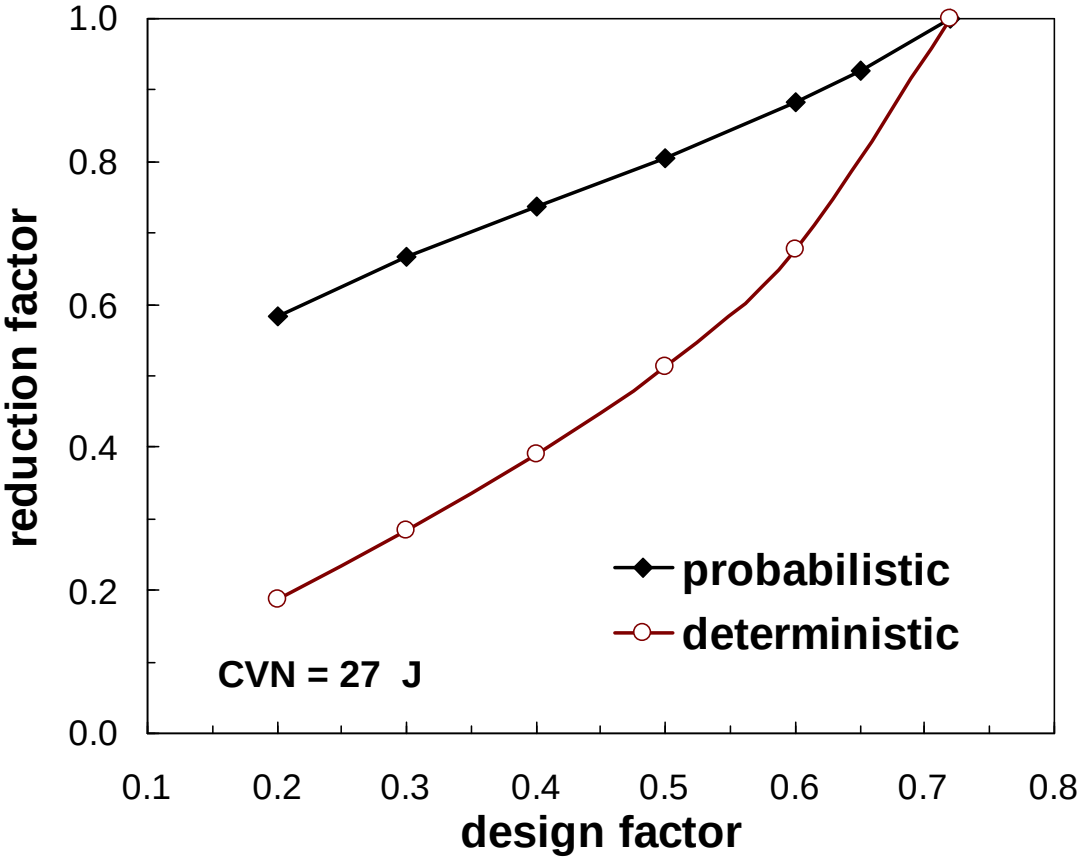
failure frequency = incident frequency X ‘base’ failure probability X ‘reduction factors’ X historical ‘reduction factors’

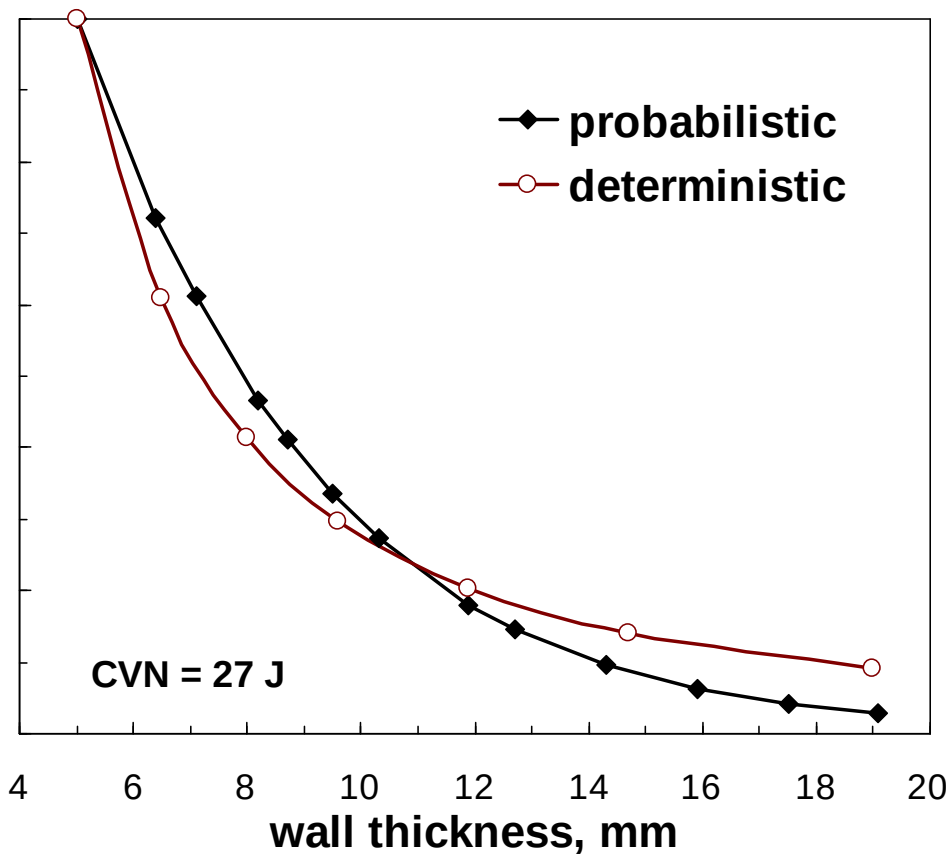


e.g.
location class
depth of cover

The simple methodology replaces the detailed structural reliability-based analysis in the ‘screening’ assessment.

Probabilistic or Deterministic Reduction Factors?





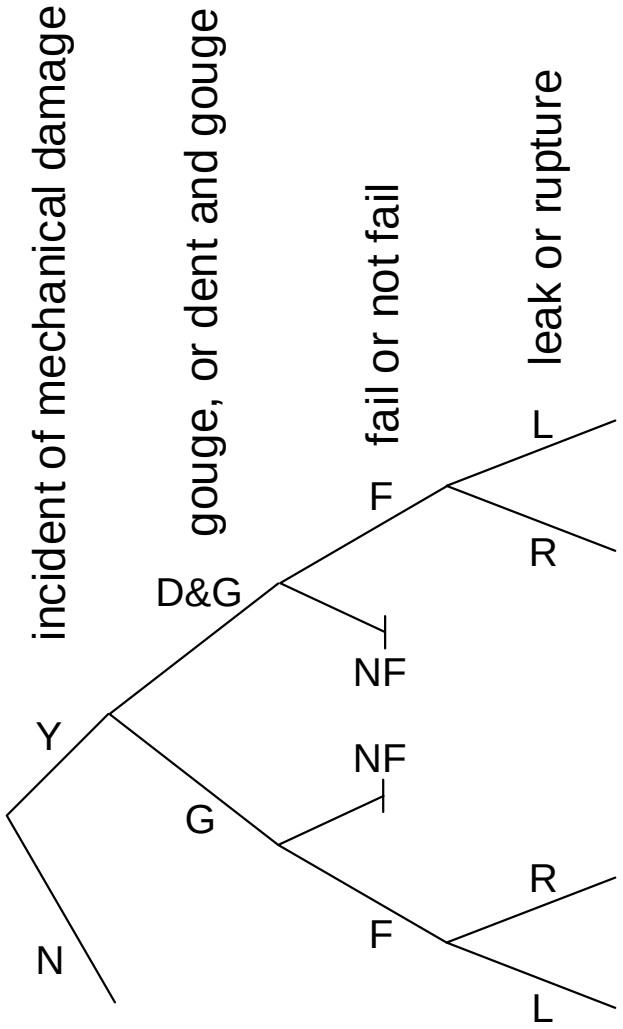
Mechanical Damage due to External Interference

- dent
- gouge
- dent and gouge

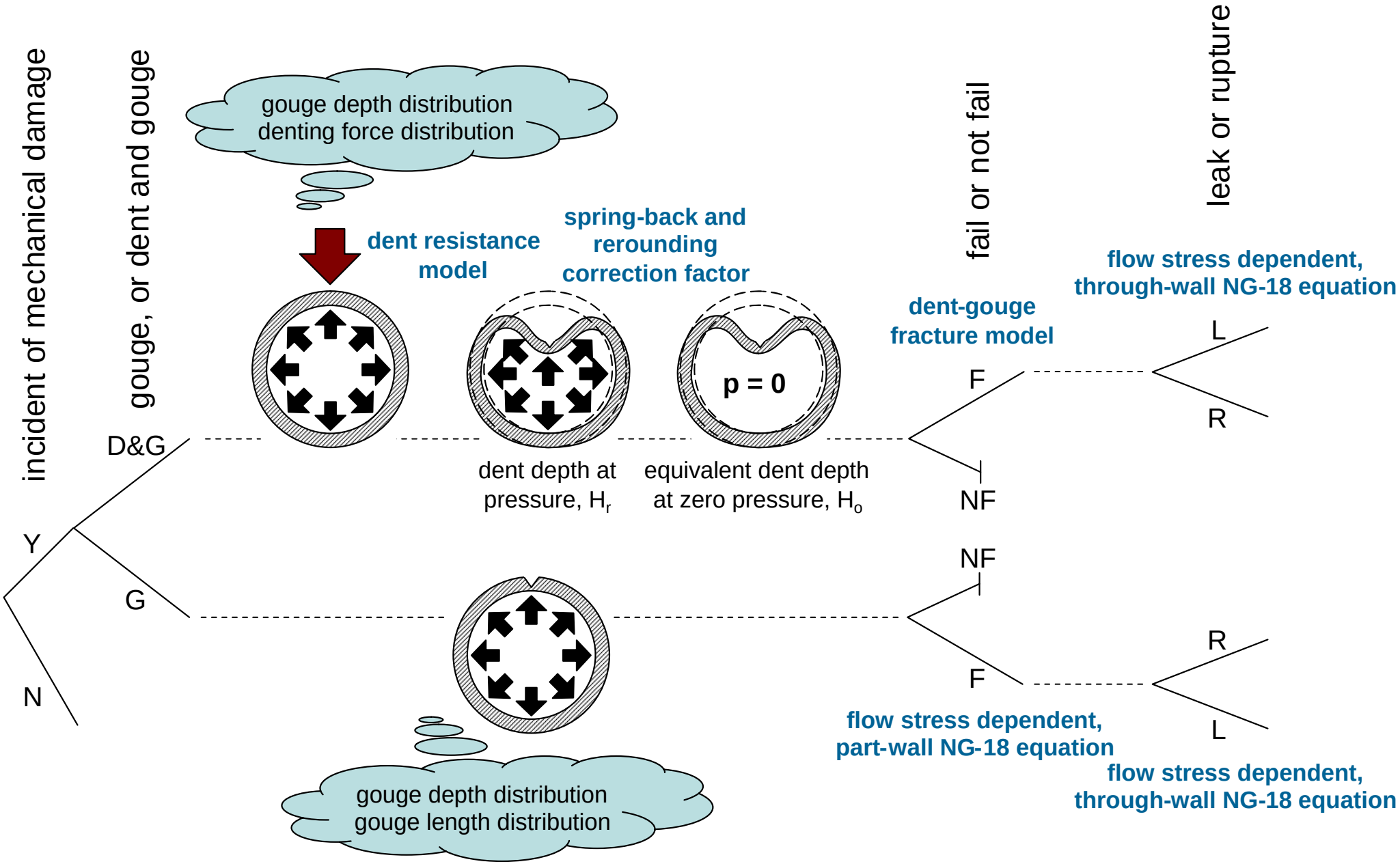
Not included in the calculations are other forms of damage due to external interference, such as

- punctures,
- ‘hot-tap in error’, and
- damage to ‘branches and flanges’ (fittings)

Event Tree for Mechanical Damage



Event Tree for Mechanical Damage



Limit State Functions

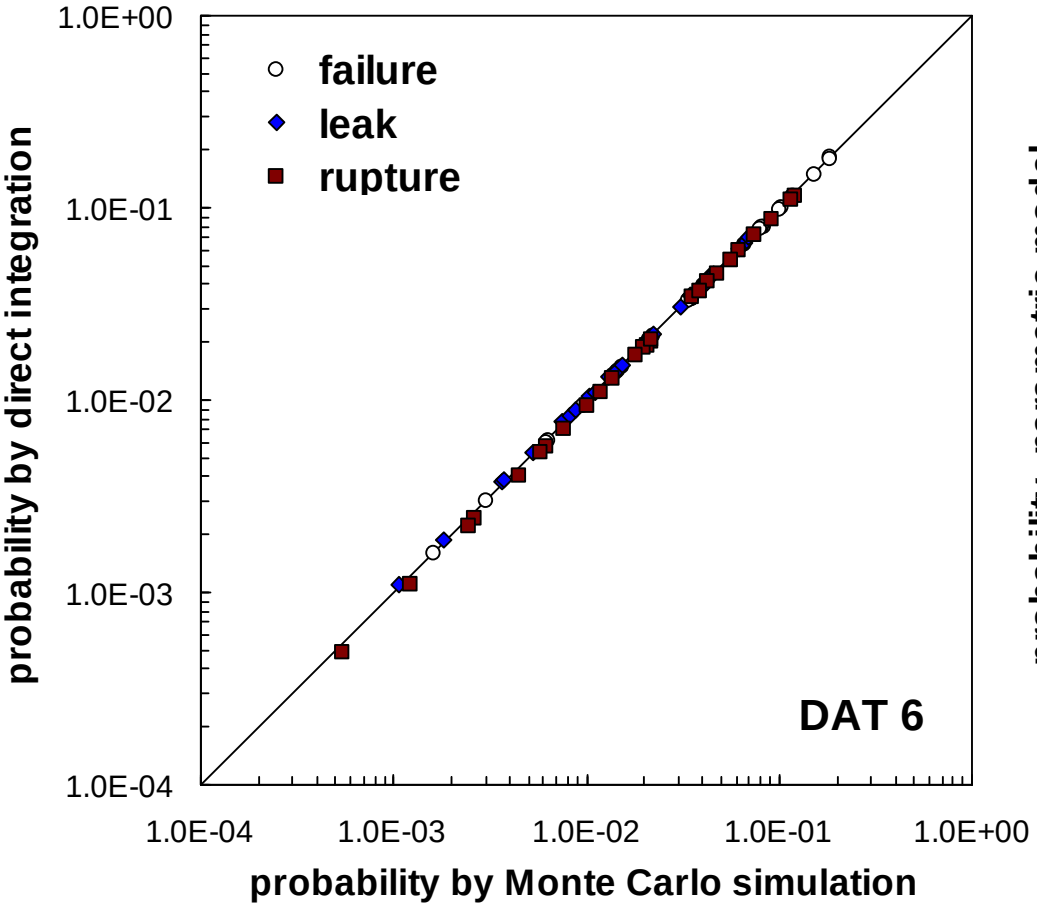
- the flow stress dependent part-wall NG-18 equations ⁎
- the Hopkins (1992) dent-gouge fracture model ⁎
- the Corder and Chatain (1995) spring-back and rerounding correction factor
- the Corder and Chatain (1995) dent resistance model
- the flow stress dependent through-wall NG-18 equations ⁎

⁎ identical to FFREQ (as re-constituted by PIE)

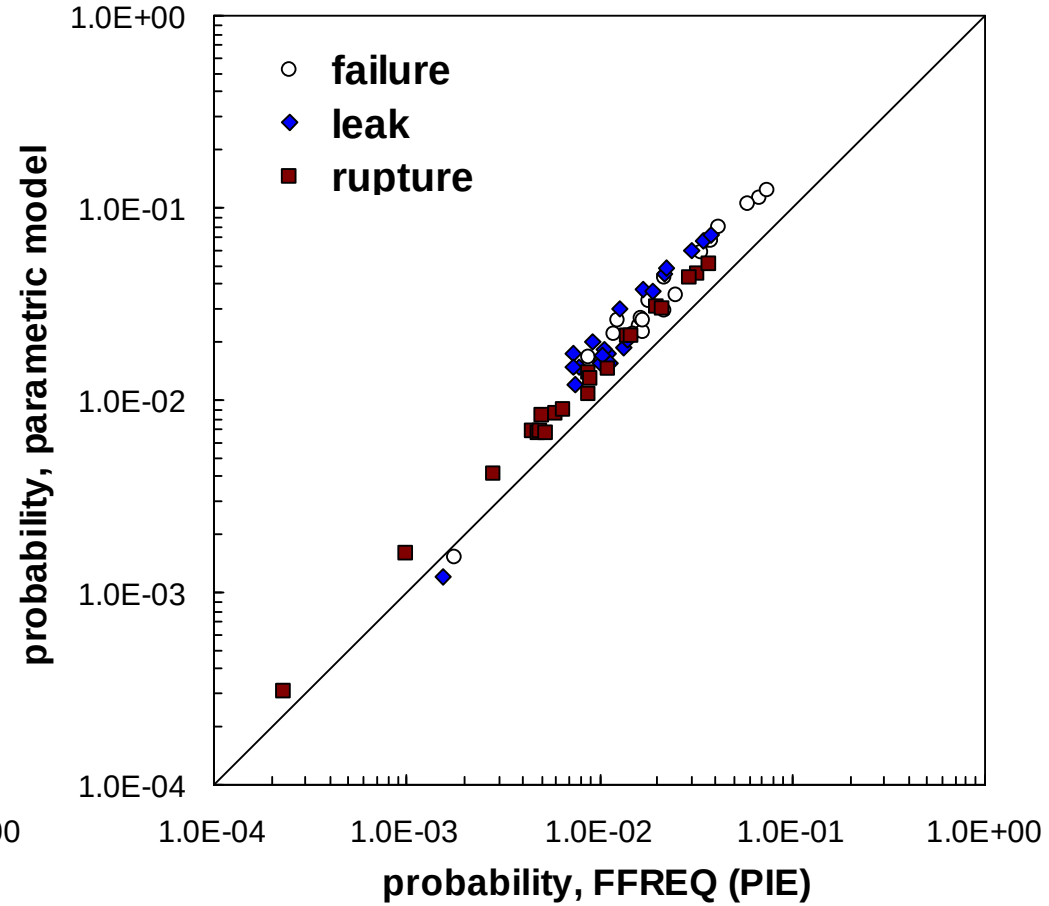
Distributions

gouge length	Weibull	UKOPA
gouge depth	Weibull	UKOPA
denting force	Weibull	Advantica (review of Corrib)

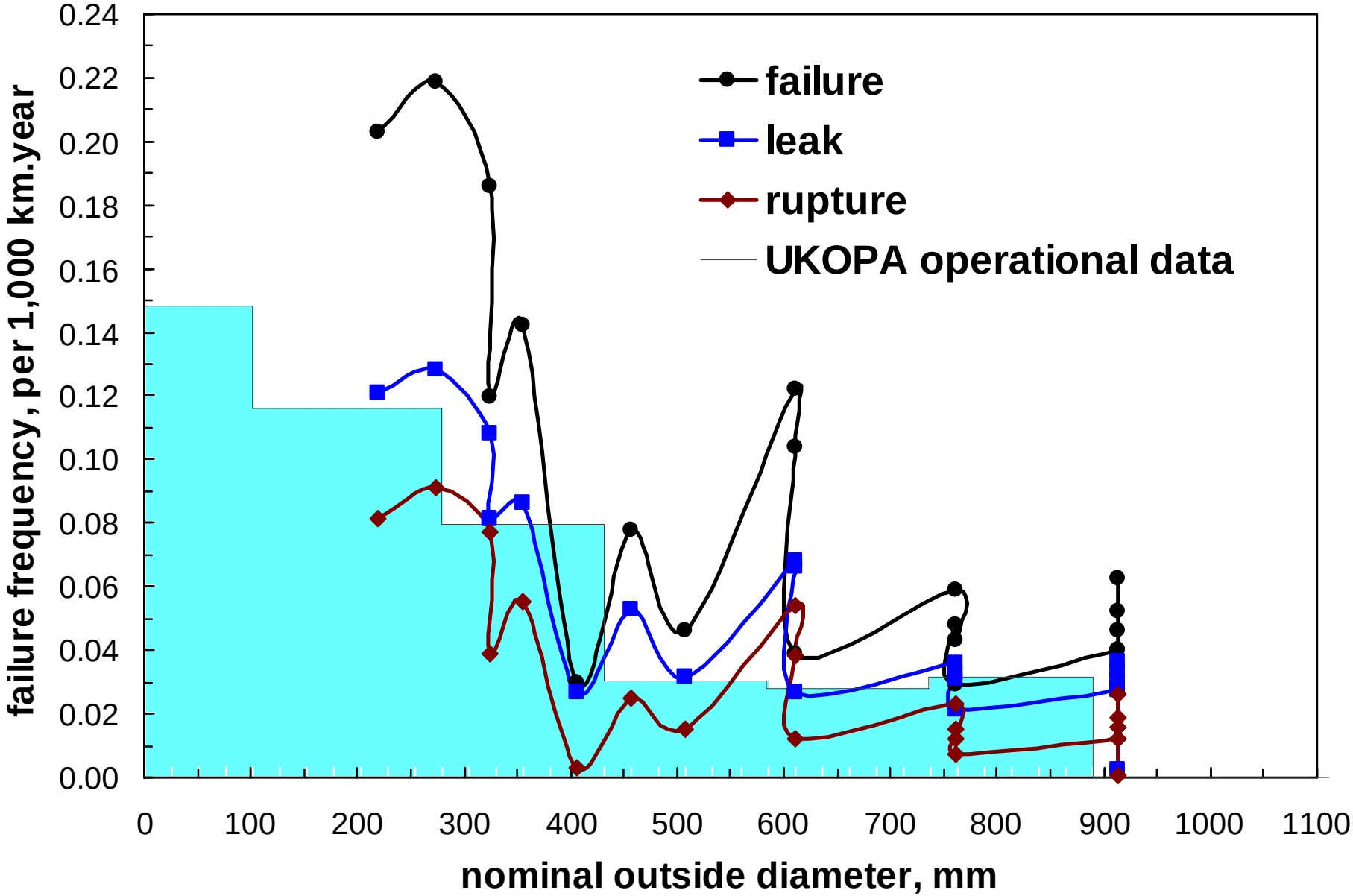
Probability of Failure



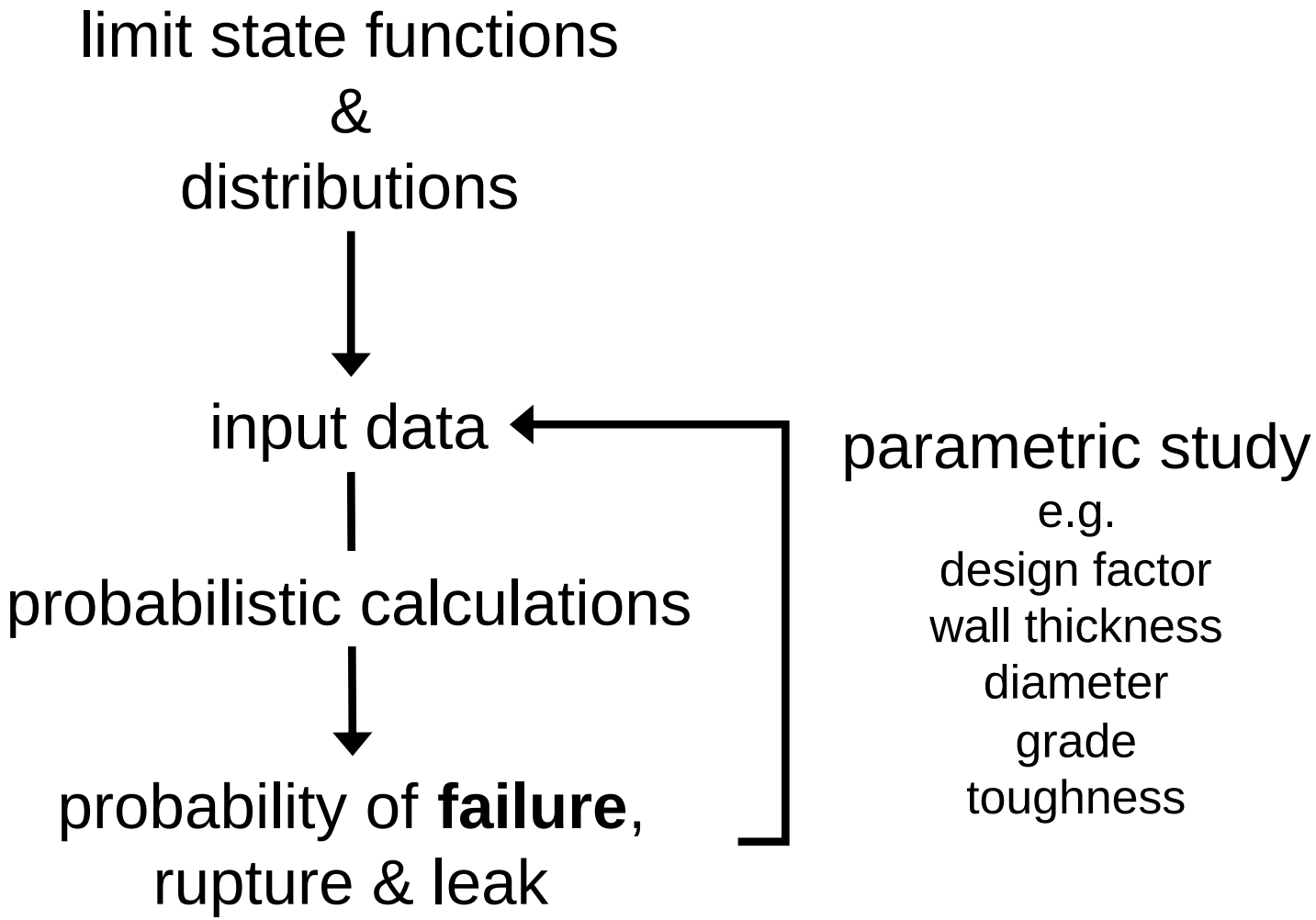
(100,000,000 simulations)



Failure Frequency



Probabilistic Parametric Study



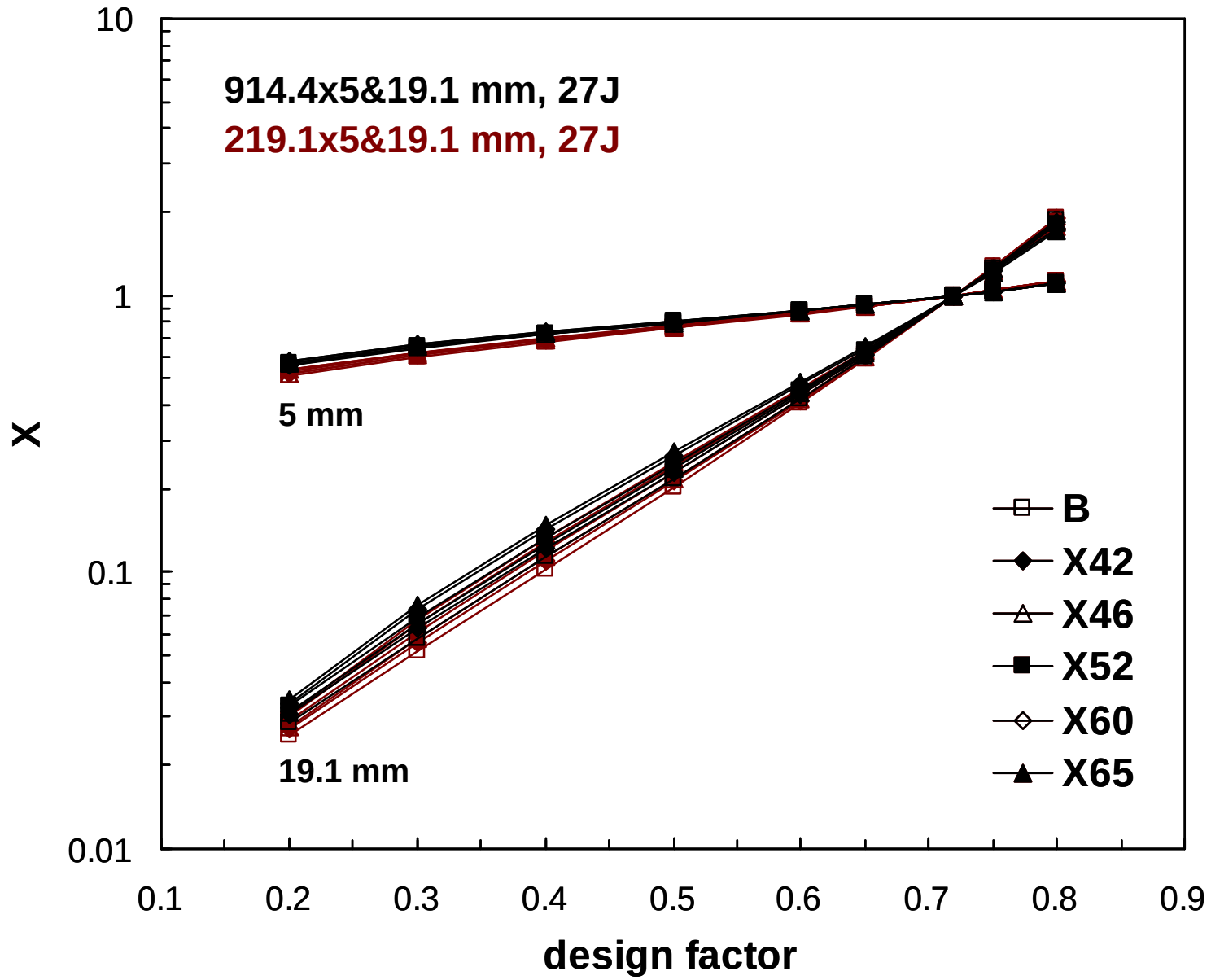
Range of Parameters

- diameter 219.1 to 914.4 mm
- wall thickness **5.0** to 19.1 mm
- grade API 5L B to X65
- design factor 0.2 to 0.8 (inc. 0.3, 0.5 & **0.72**)
- toughness 10 to 100 J (inc. 22, 24 & **27**J)

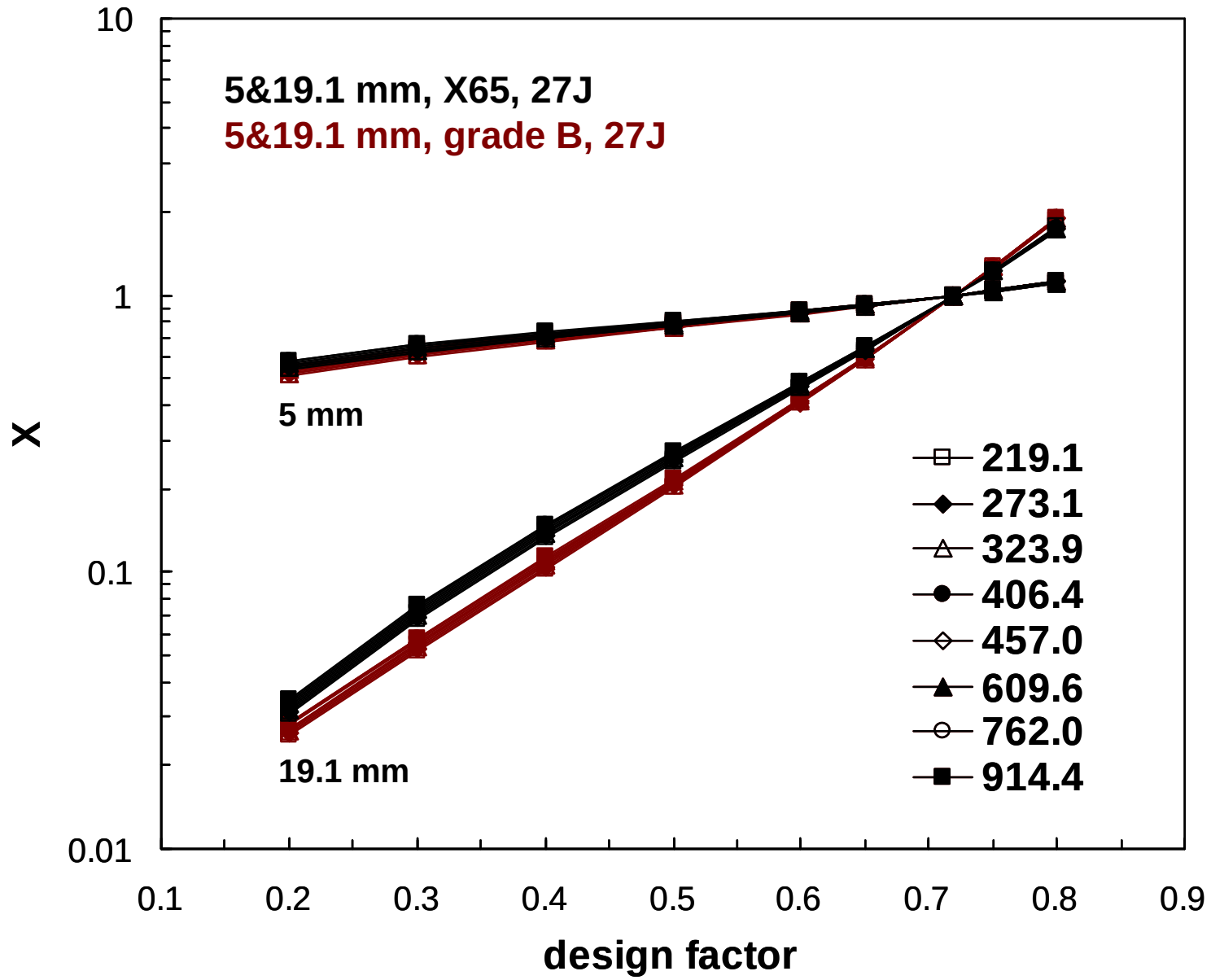
Based upon the requirements quoted in:

- DAT6 (1994)
- GBE/LX1, 4 & 5 (1993)
- IGE/TD/1, Edition 4

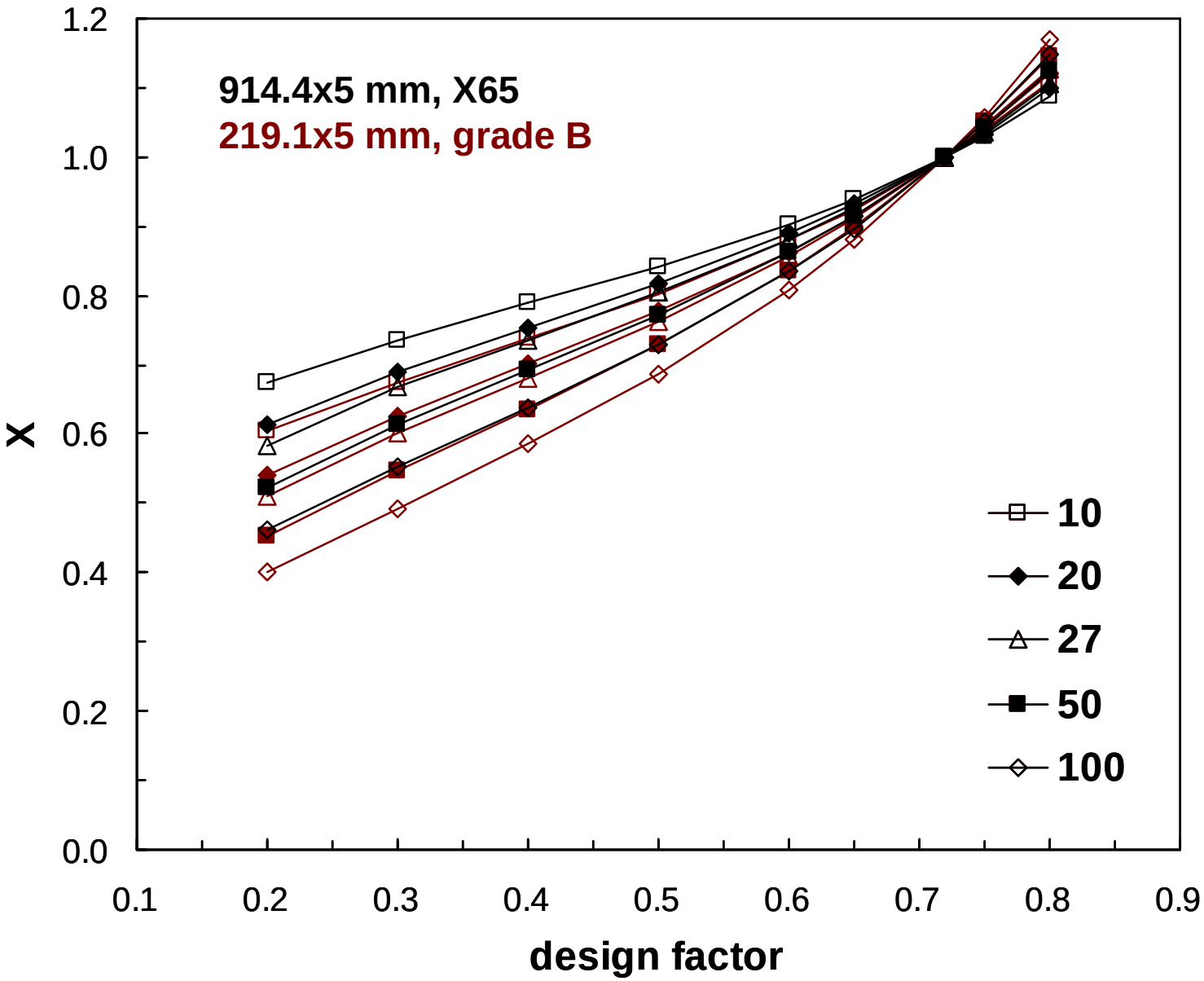
Design Factor and Grade



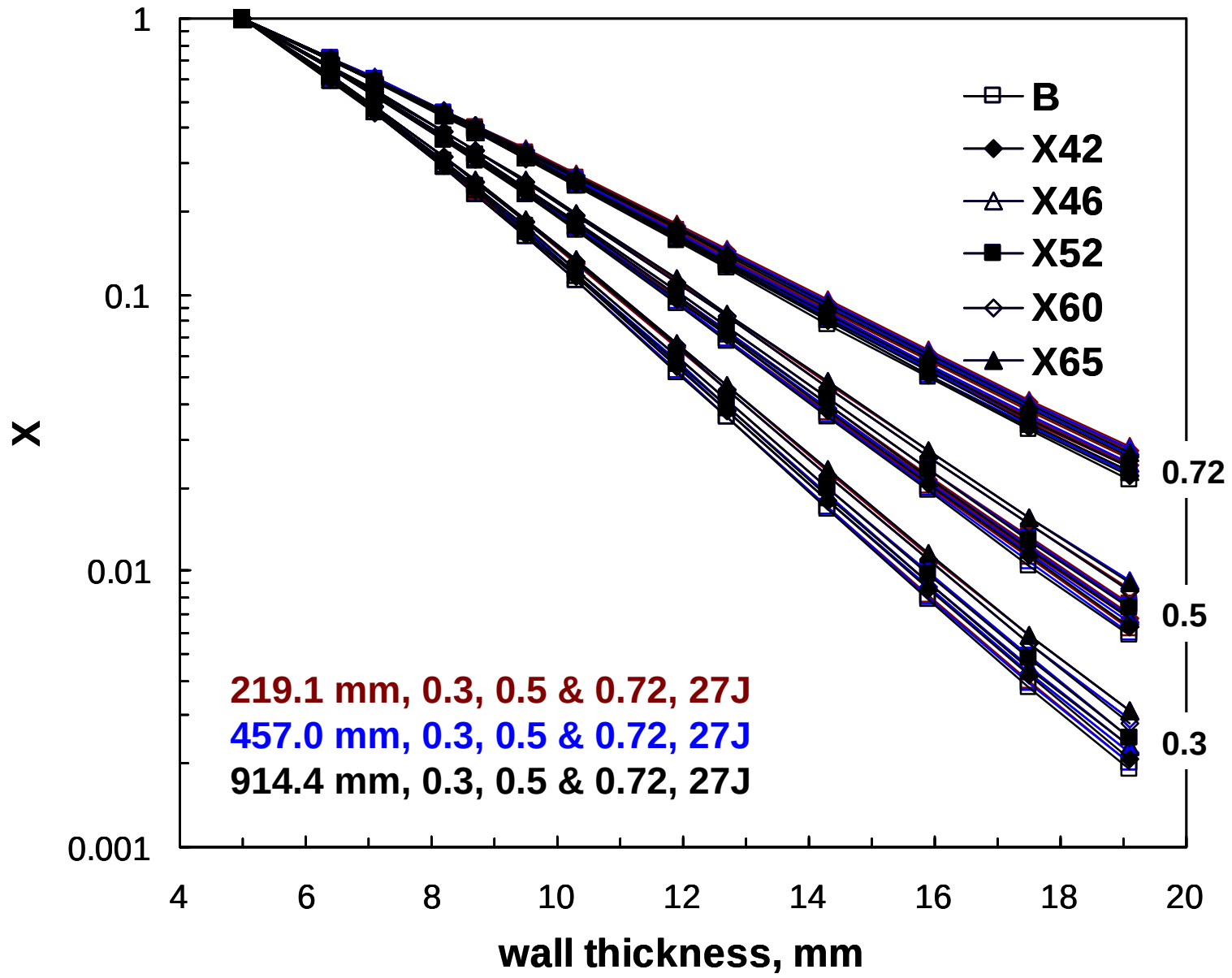
Design Factor and Diameter



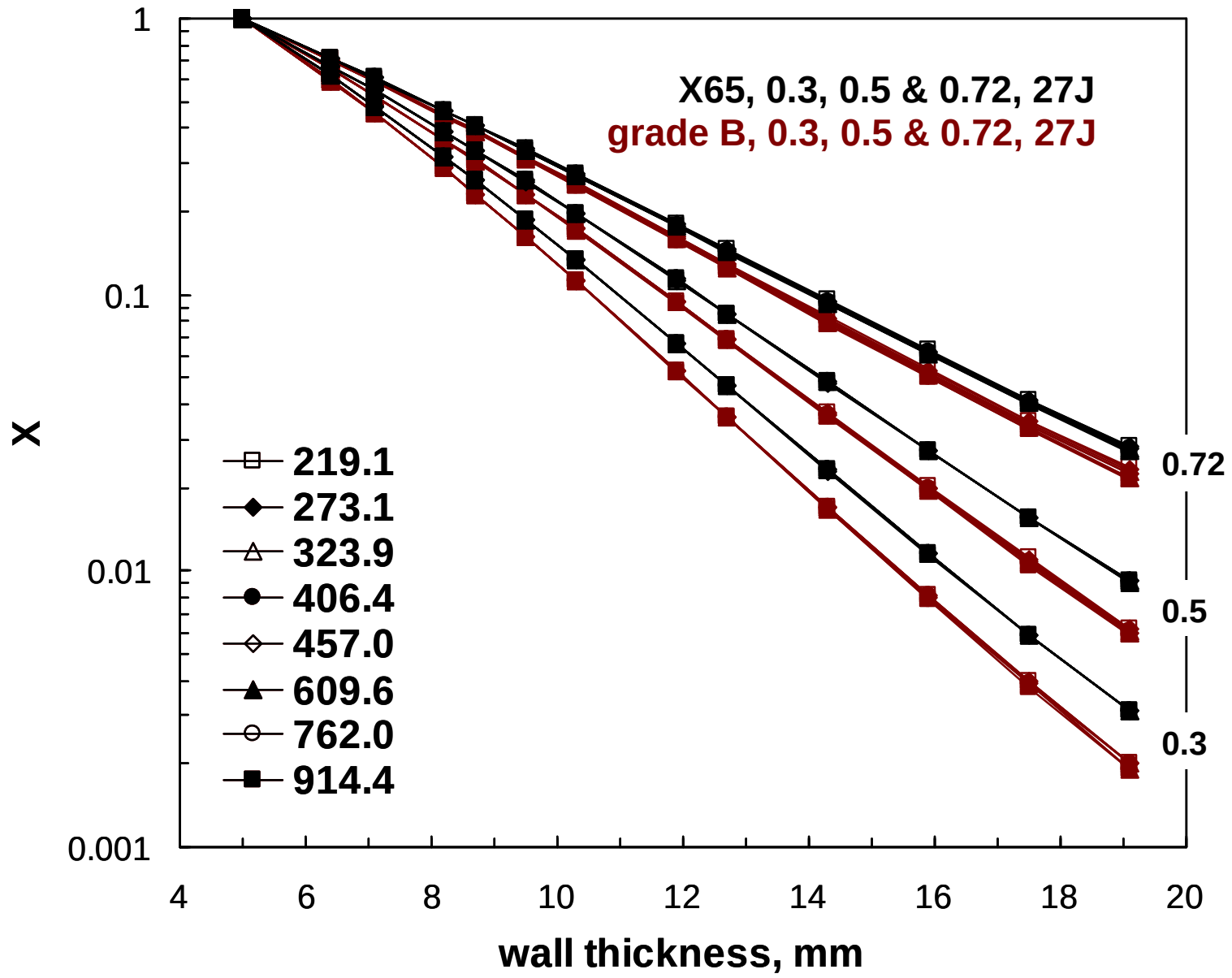
Design Factor and Toughness



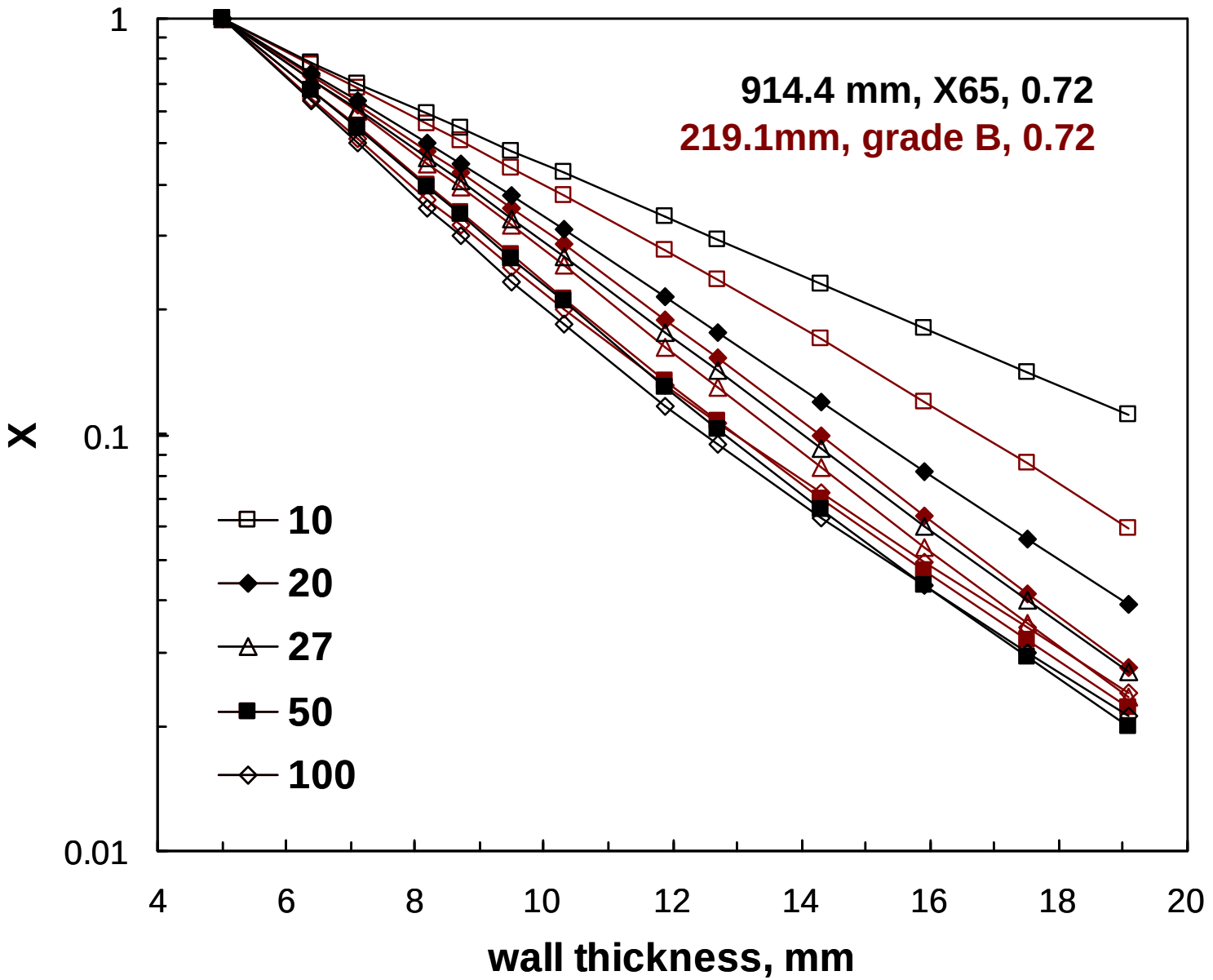
Wall Thickness and Grade



Wall Thickness and Diameter



Wall Thickness and Toughness



Reduction Factors

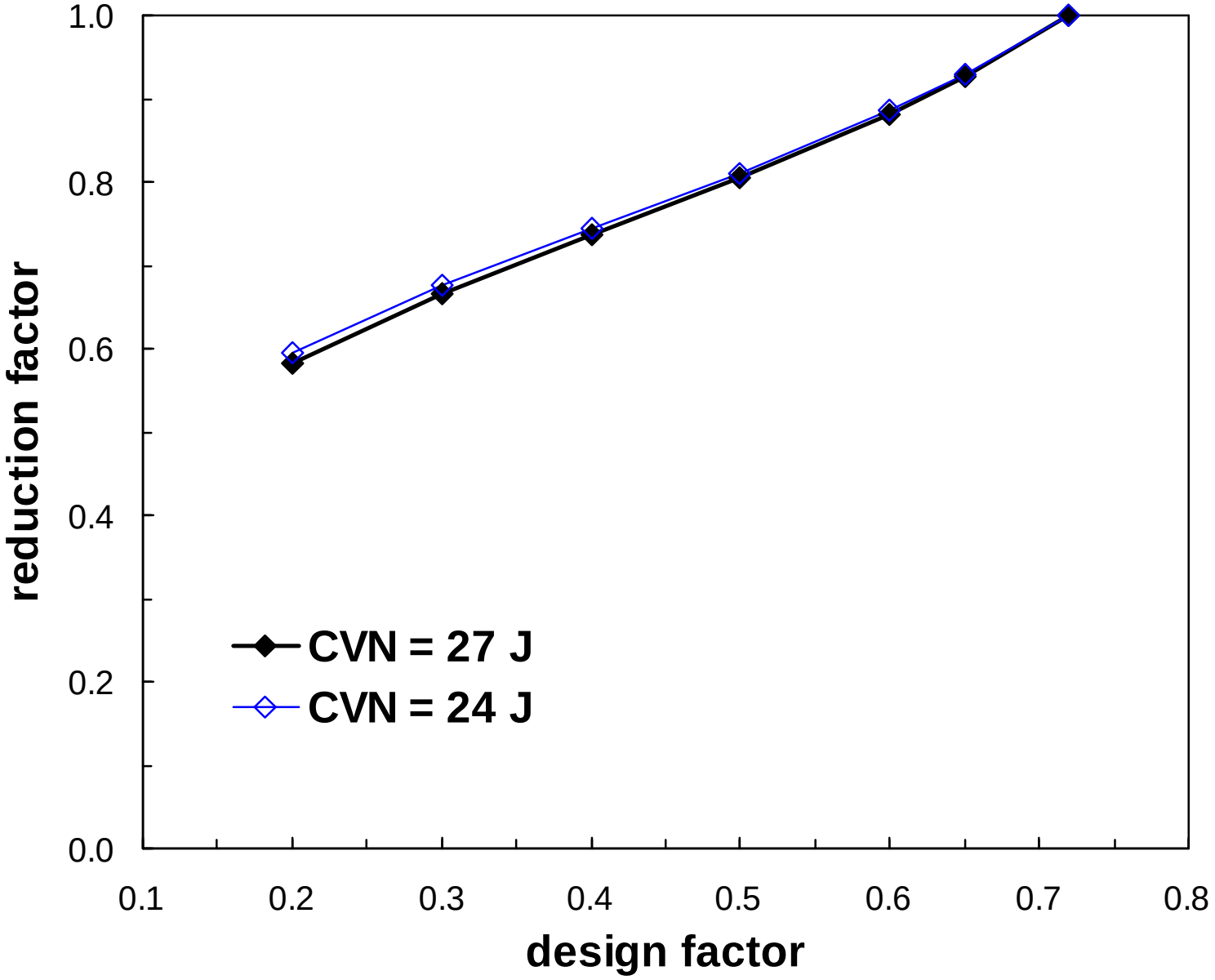
- design factor
- wall thickness

} **only two factors**

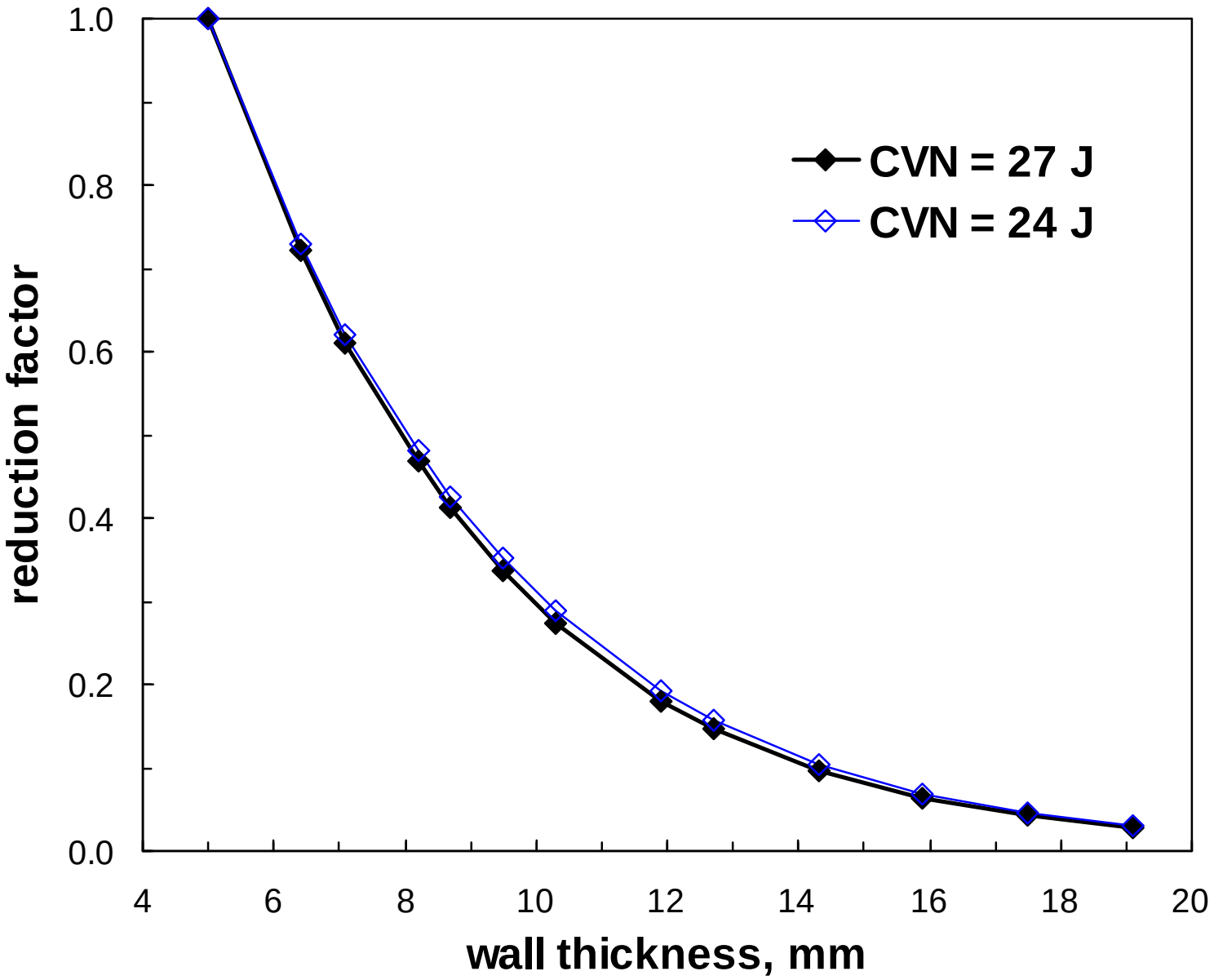
- diameter and grade are secondary

- toughness has a significant effect – **but** assuming a low toughness is conservative

Reduction Factor for Design Factor



Reduction Factor for Wall Thickness



Verification of Reduction Factors

- verification cases
  - 8 diameters, 13 wall thicknesses, 6 grades, 3 design factors, 4 toughnesses
  - 1872x4 (= 7488) cases

- DAT6 cases
  - DAT6 geometries and grades, GBE/LX1 toughnesses, 3 design factors
  - 26x3 (=78) cases

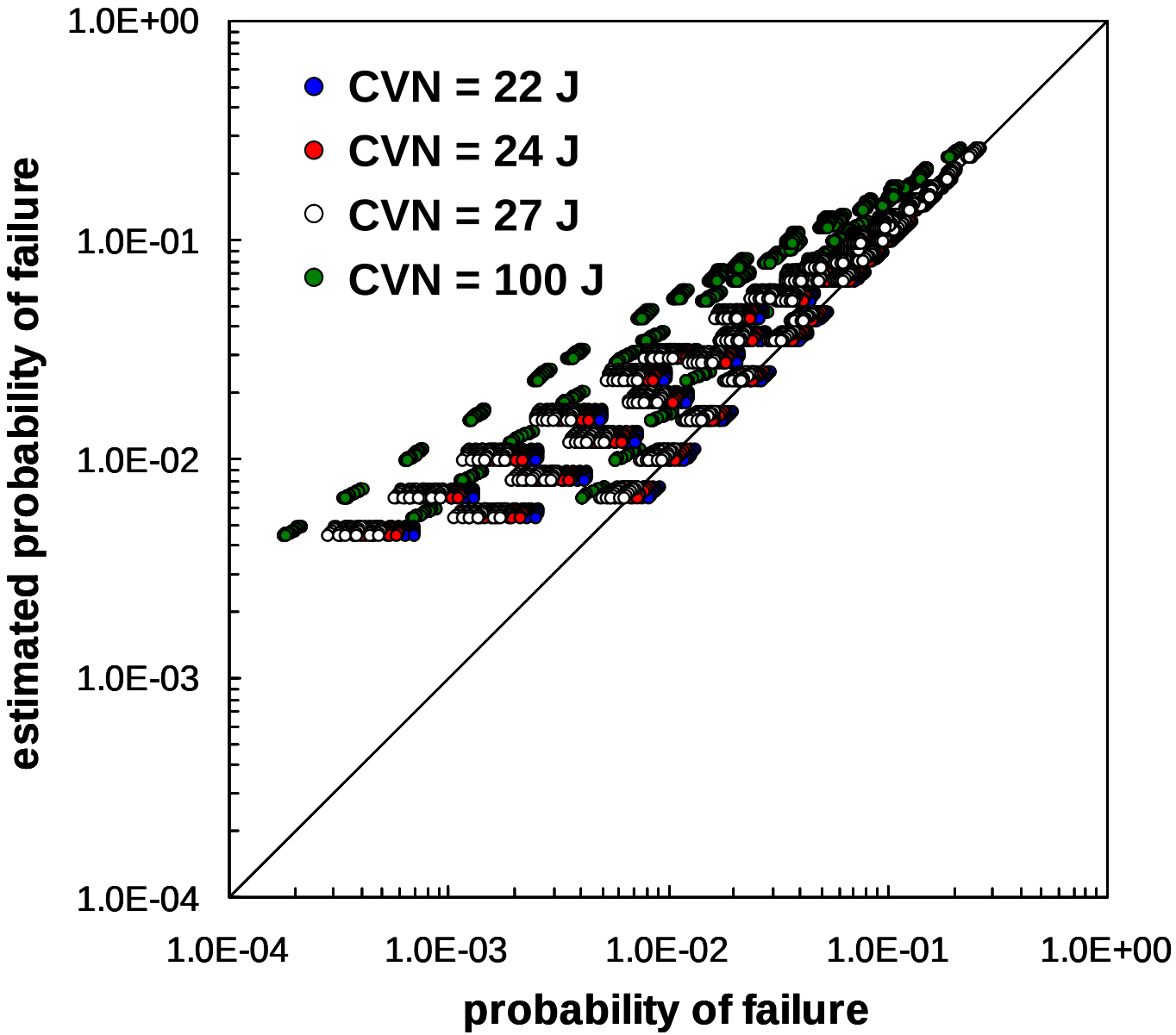
Estimating the Failure Probability using Reduction Factors

failure probability = ‘base’ failure probability x ‘reduction factors’

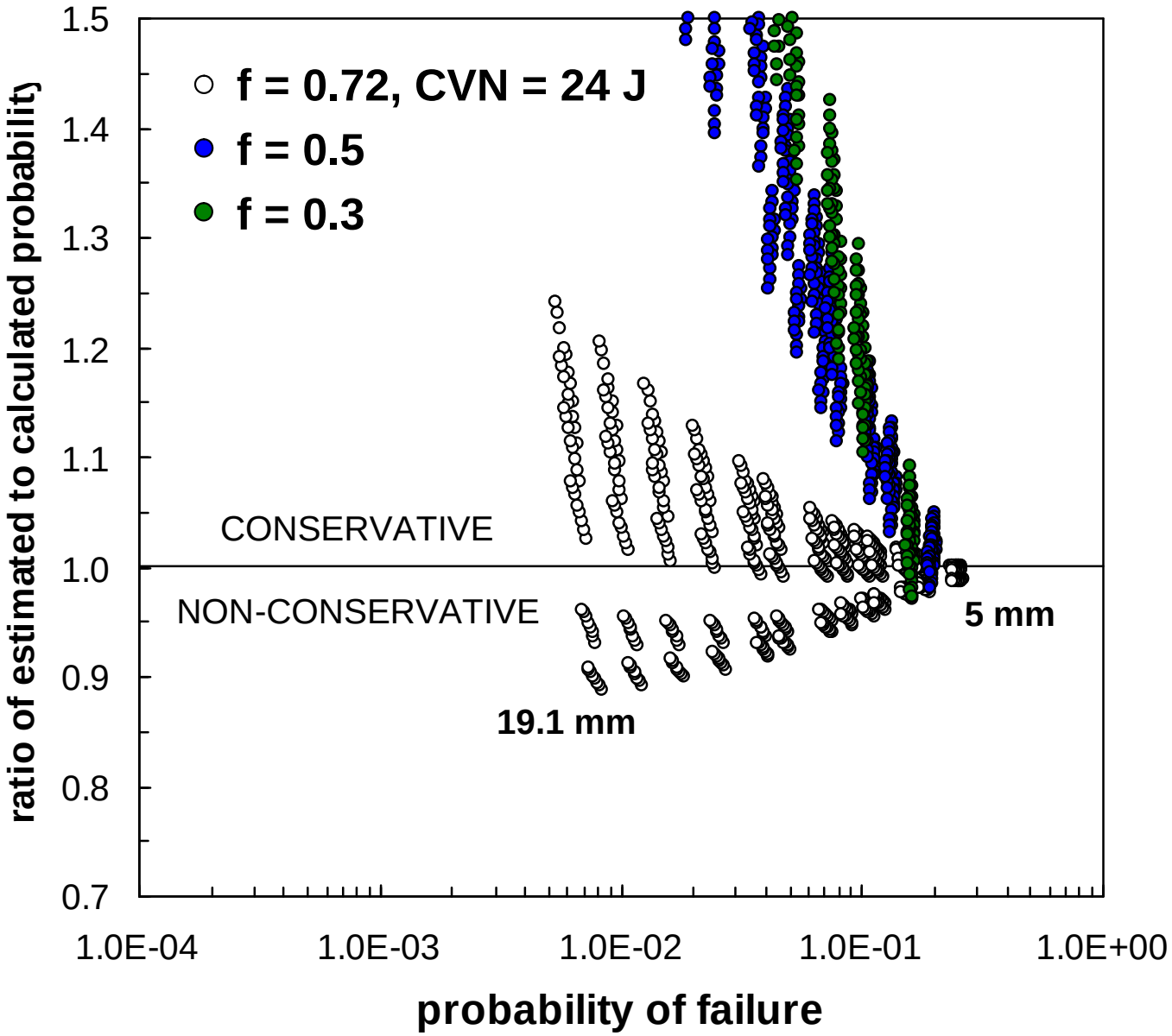
e.g.
wall thickness
design factor

diameter	219.1 to 914.4 mm
wall thickness	5.0 mm
grade	X65
design factor	0.72
toughness	27 J

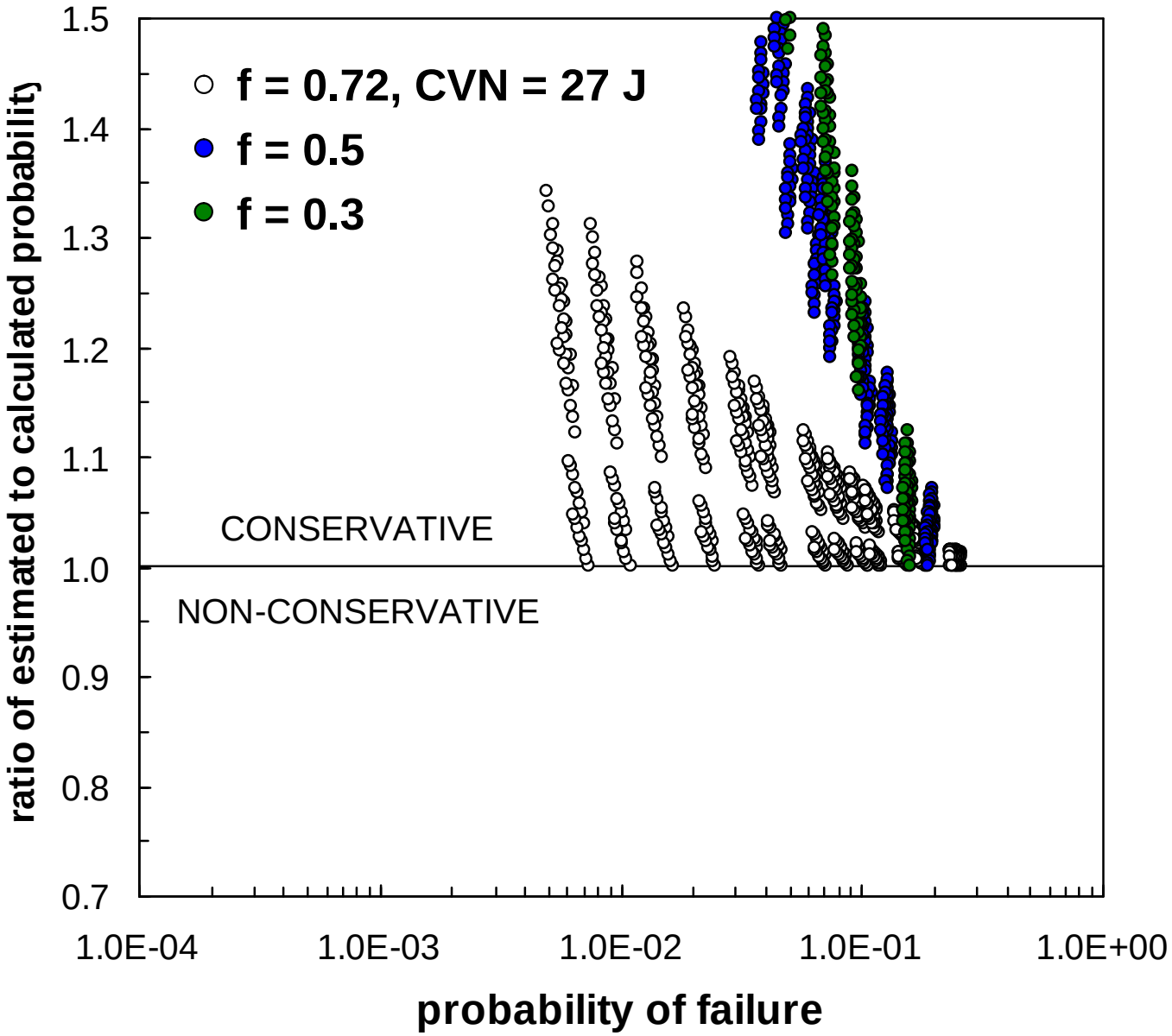
Verification Cases, Probabilities



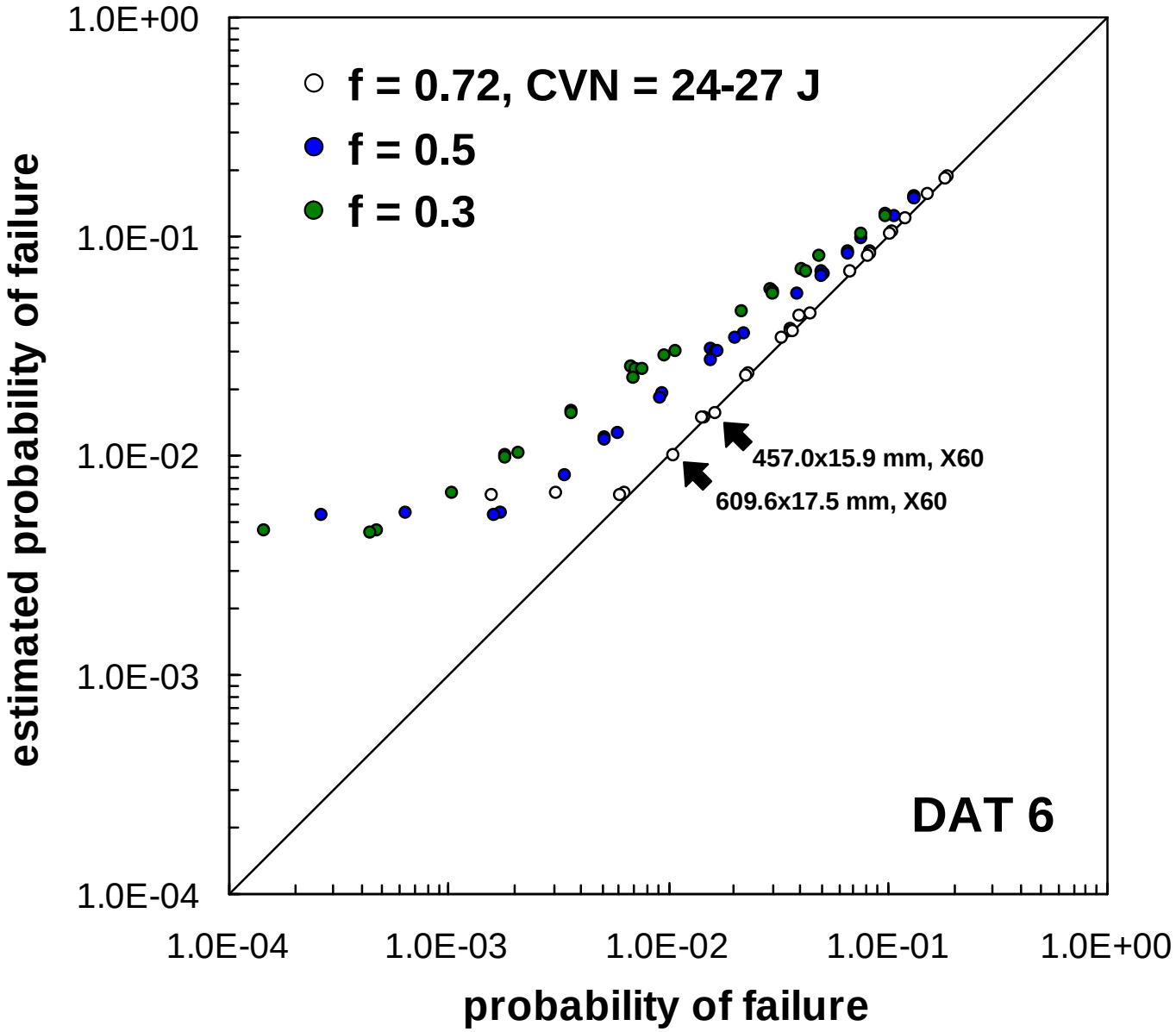
Verification Cases, Ratios



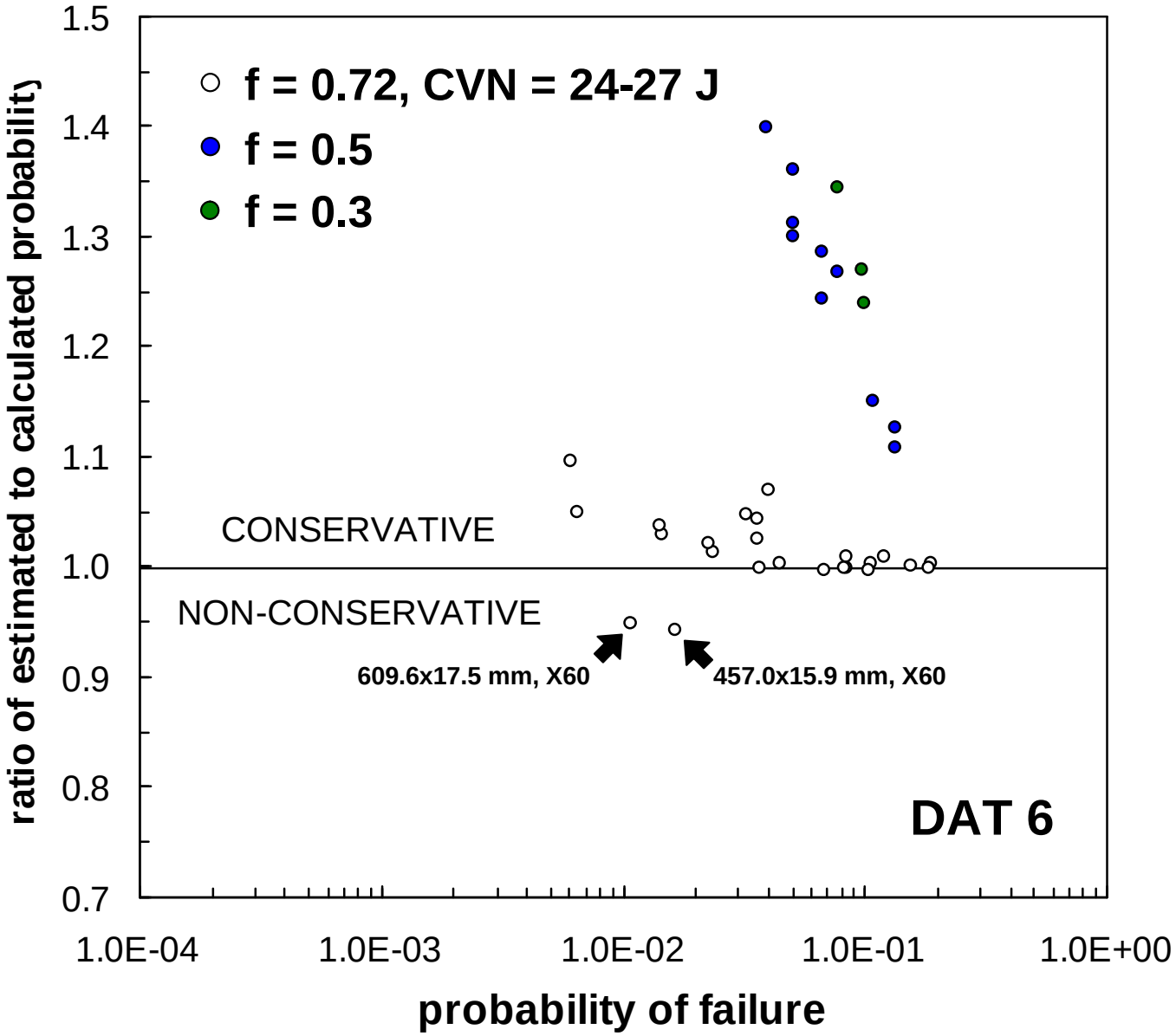
Verification Cases, Ratios



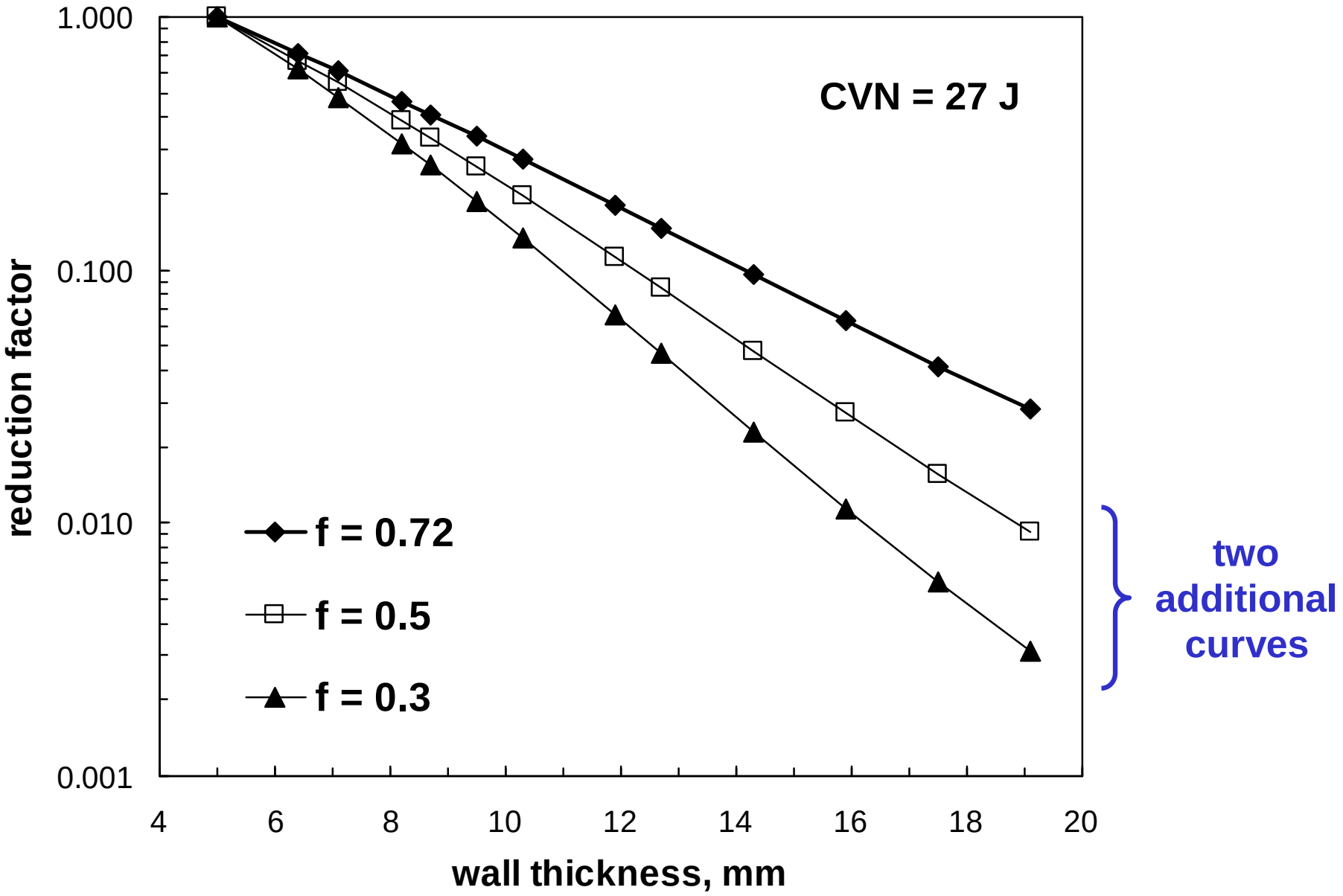
DAT6 Cases, Probabilities



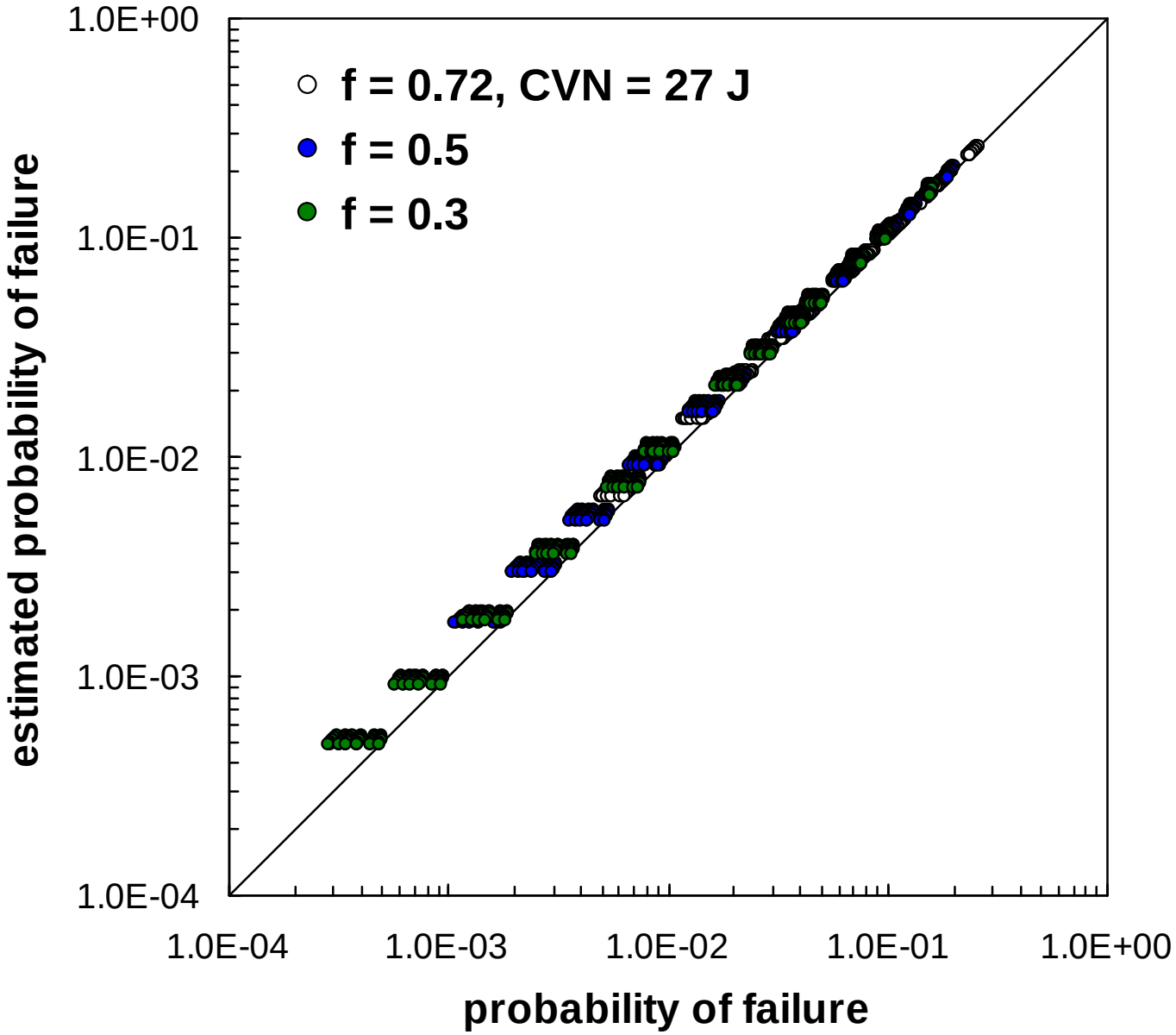
DAT6 Cases, Ratios



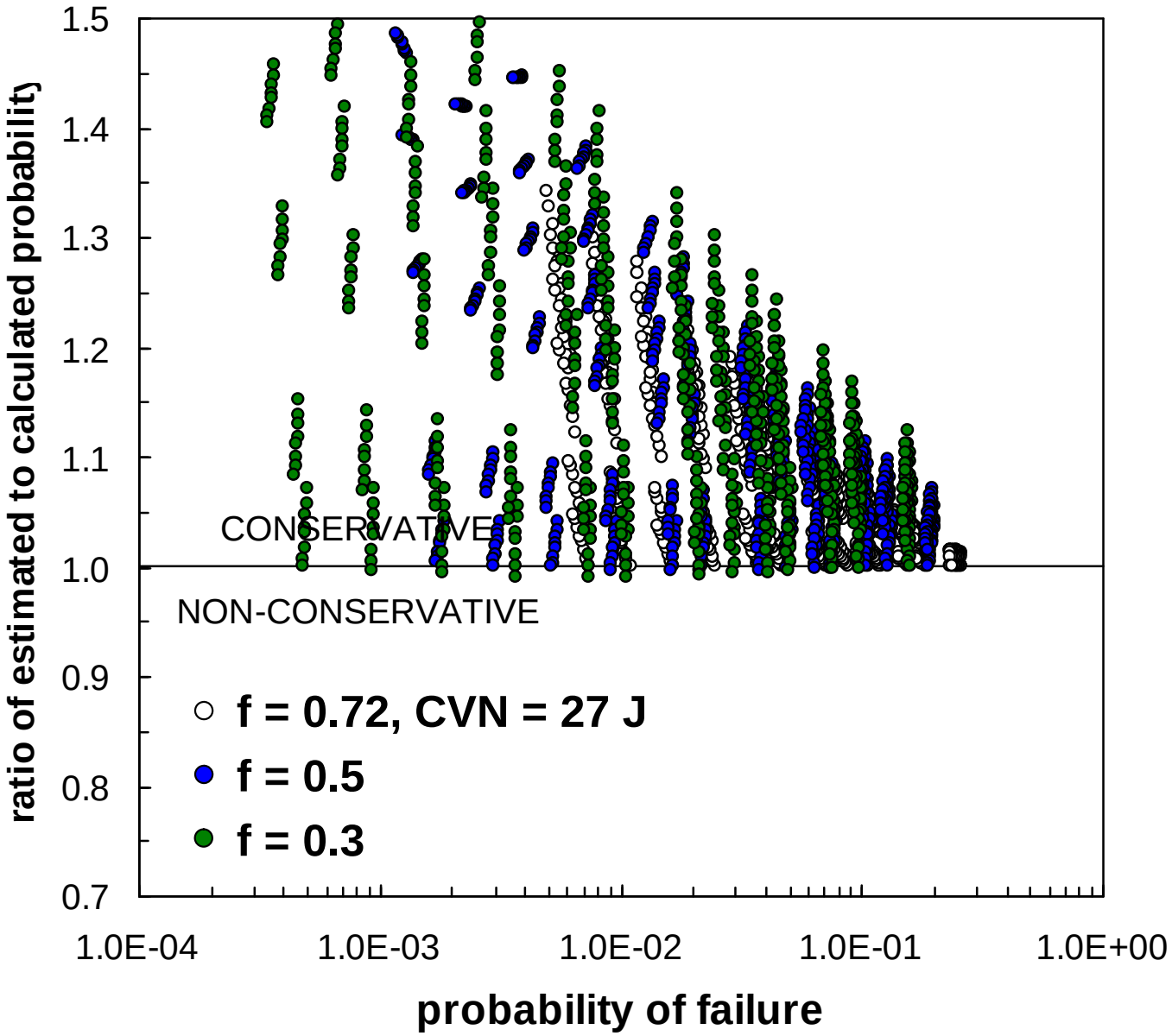
Reduction Factor for Wall Thickness



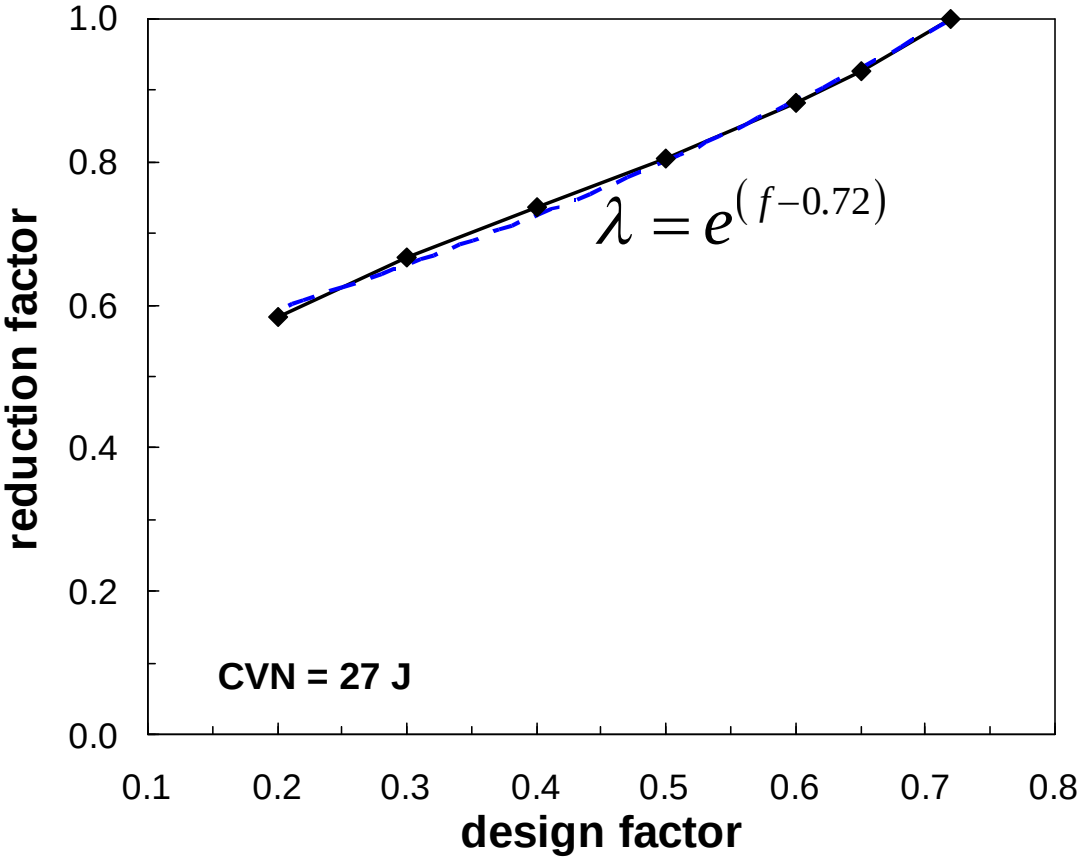
Verification Cases, Probabilities

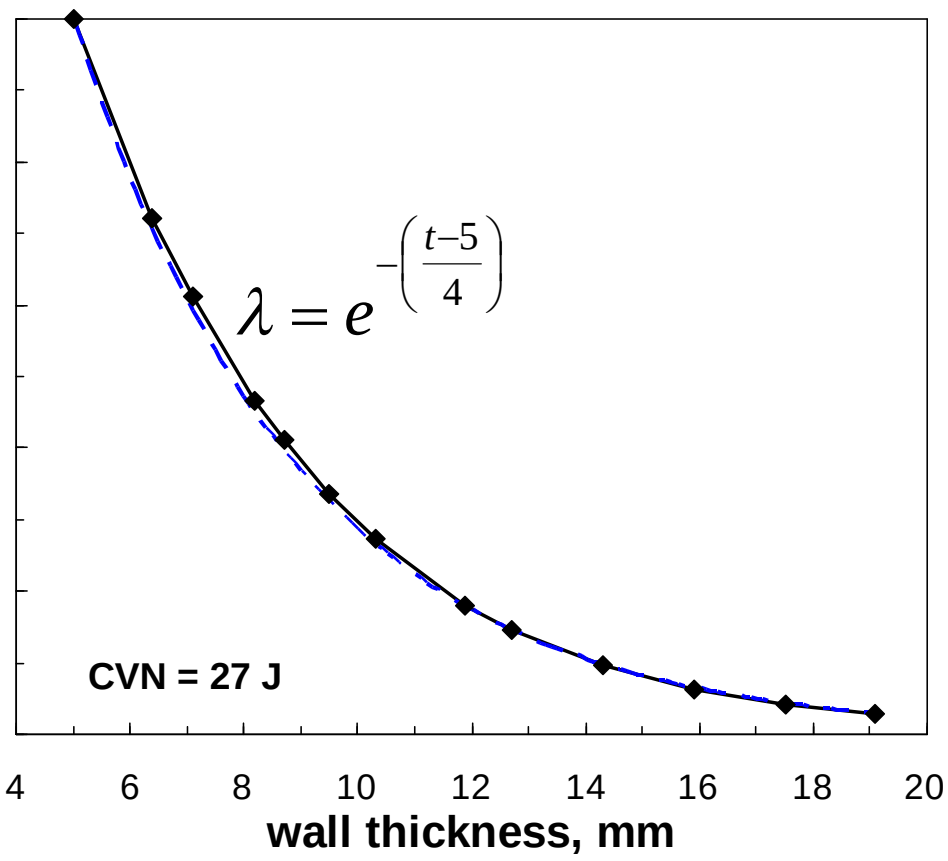


Verification Cases, Ratios



Reduction Factors





Range of Applicability

diameter	219.1 mm to 914.4 mm
wall thickness	greater than or equal to 5.0 mm
grade	less than or equal to X65
design factor	less than or equal to 0.72
toughness	minimum average CVN impact energy greater than or equal to 24 J *

GBE/LX1: 24-27 J, average (22-24 J minimum), diameters of 406.4 to 914.4 mm

GBE/LX4: 27 J, average (19 J minimum), diameter of 323.9 mm or greater, with a wall thickness of 12.7 mm or greater

GBE/LX5: no specified CVN impact energy

Issues to be considered:

- Toughness used to calculated reduction factors?
- Range of applicability of reduction factors, particularly the minimum toughness?

- Multiple curves for the reduction factor for wall thickness, e.g. 0.3, 0.5 and 0.72?

- ‘Base’ failure probabilities based on calculations and/or ‘base’ failure frequencies based on historical failure data?