Monte Carlo Simulation for a quantitative assessment of the likelihood of predicted strength, or molecular weight, changes with explosive age.

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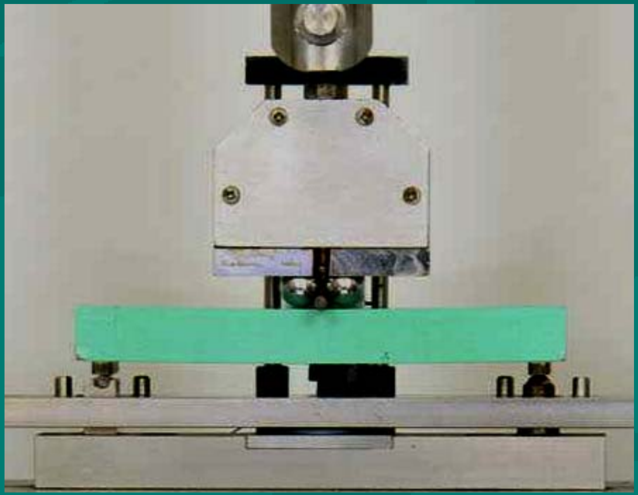
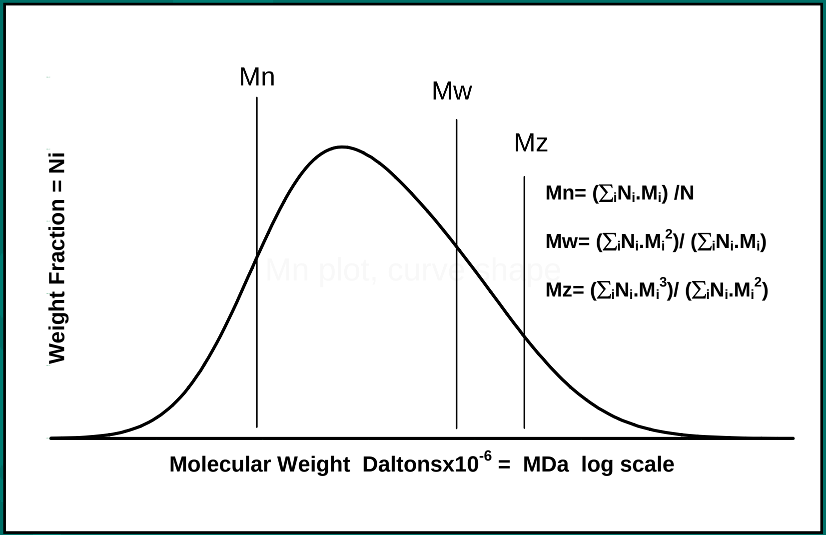
AWE. Explosive Materials

Development of Ageing Model

Nitrocellulose based energetic material

- Number Average Molecular Weight
- Flexure Strength





- Samples – unaged, thermally aged and real-time aged

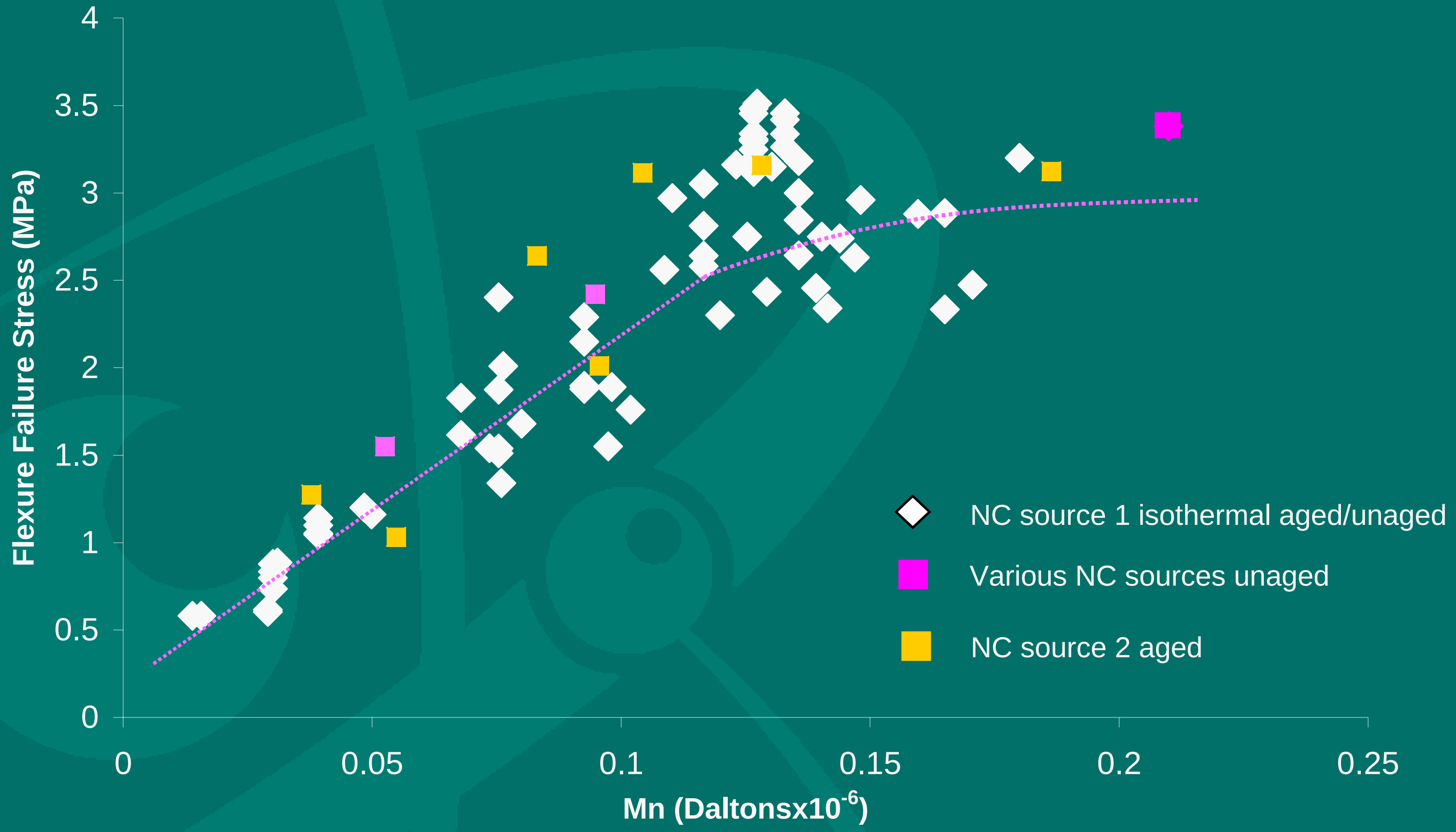
•Deacon, Leppard, Powell, Development of a Mechanical Properties Kinetic Model for ageing of a UK PBX, Proc 35th Int Ann Conf Energe. Mat. ICT. 2004

Mechanical Capabilities

- Mechanical tester

- Compression ('squashing')
- Tension ('pulling')
- Flexure ('bending')
- Creep testing
- Compression to Tension
- Fracture testing
- High strain rate testing
- Ultrasonic testing
- Extensometery

Relationship between Mn and flexure strength



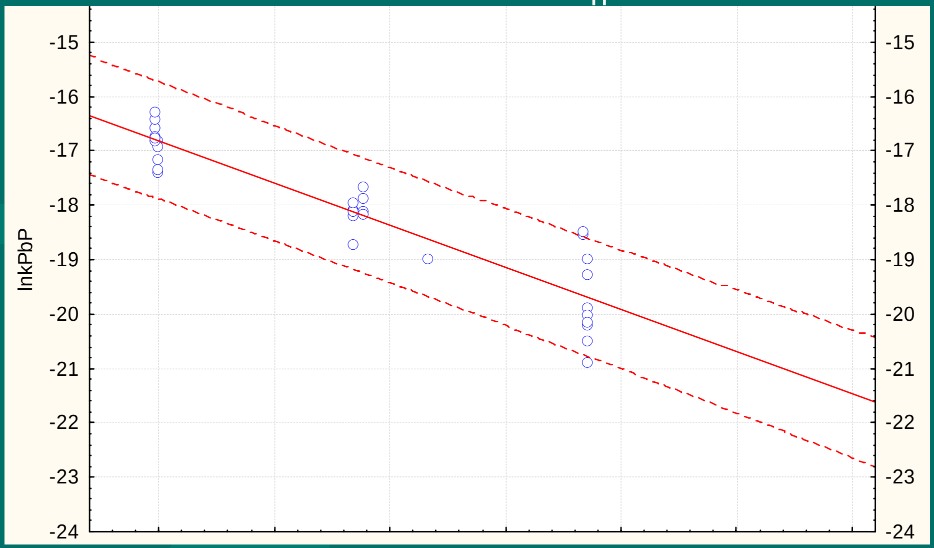
Ageing Model Development

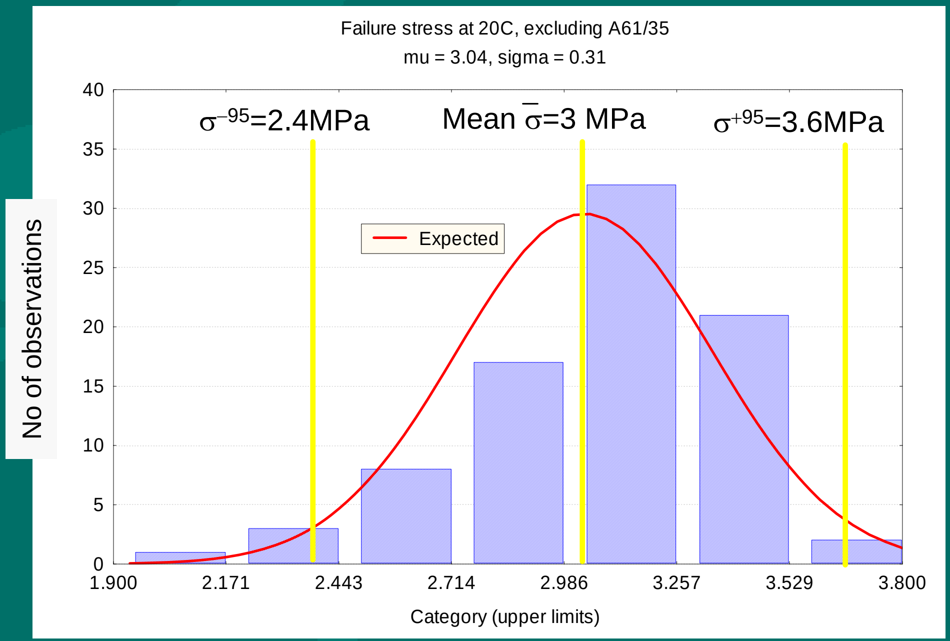
$$\ln k = \ln A - \frac{E}{RT}$$

$$\frac{1}{P_t} = \frac{1}{P_0} + k.t$$

Where P is property, M_n or flexure strength

ln k versus 1/T for M_n data





Mean Rate of Degradation

Knowing

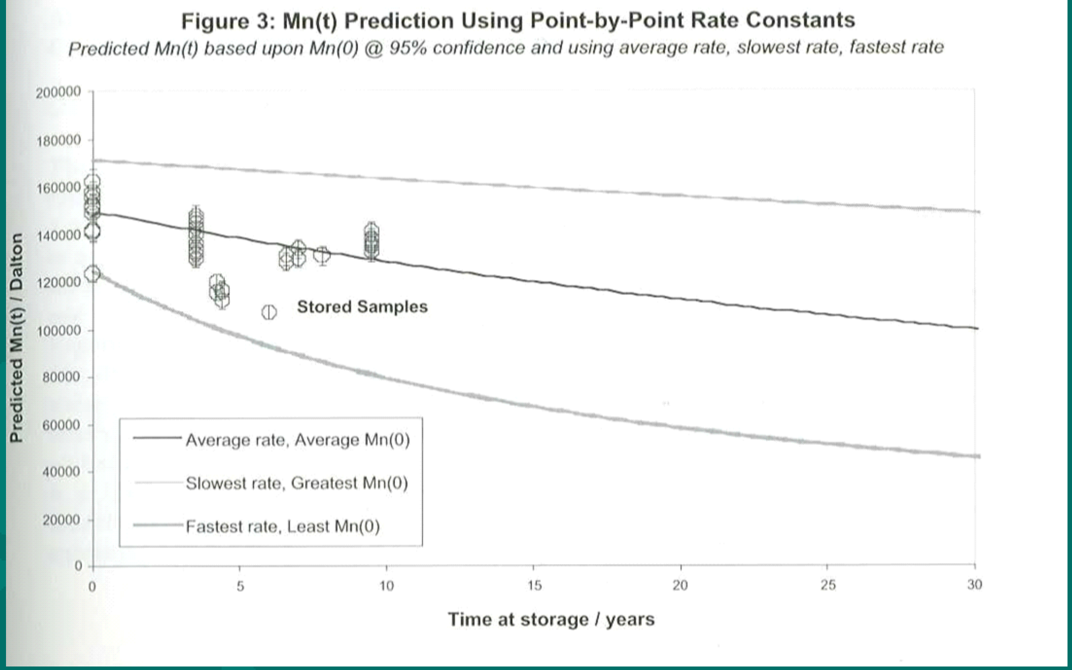
1) the rate constant k,

at a given temperature

2) the unaged, or starting position

$$\frac{1}{P_t} = \frac{1}{P_0} + k.t$$

•Deacon, Leppard, Powell, Energetic Materials, 35th Int Annual Conference of ICT Proceedings, 2004, P141.



- Mean rate of degradation
- Outer limits not strictly correct

Monte Carlo Simulation

- No simple mathematical solution to generate the PDF for property, P versus time, t
- Use a statistical sampling method to combine the PDFs for P_o and lnk
- Two independent analyses carried out

MC - Random Numbers

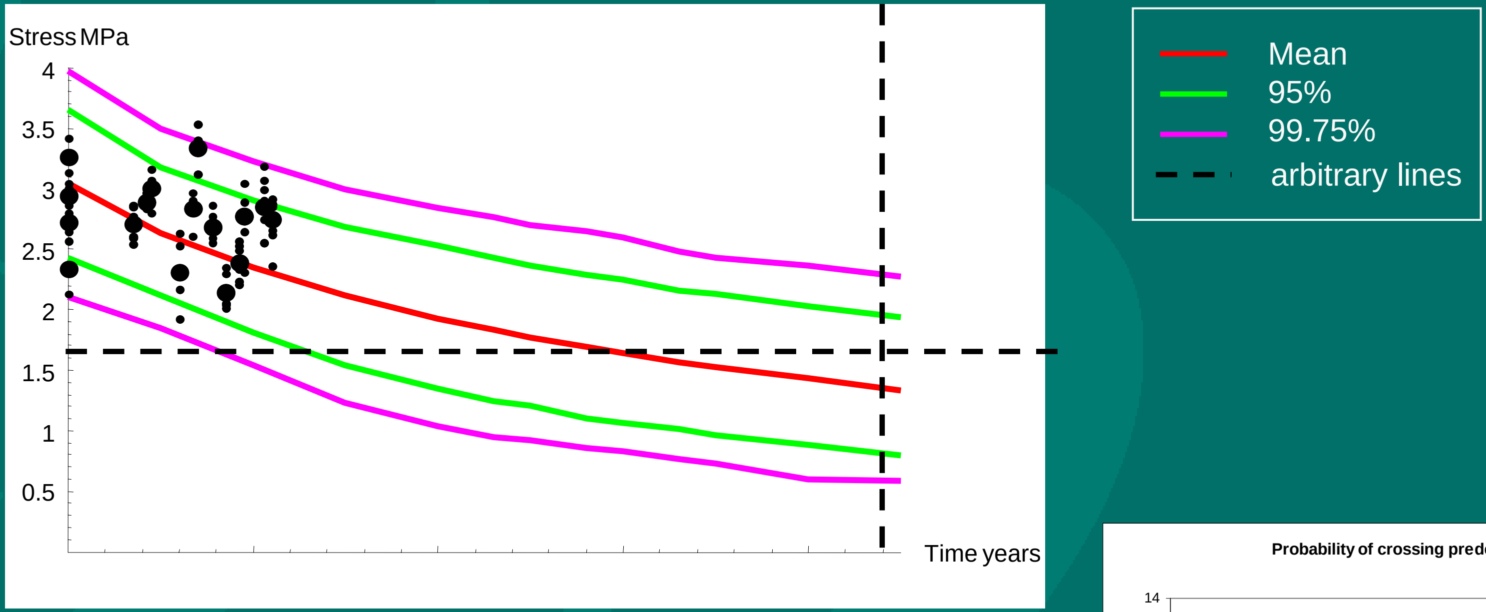
- Random number generation for P_o, from the given mean and s.dev (assumed normal distribution).
- Random number generation for P_o, from raw data
- Random number generation for ln k, from mean lnk and s.dev, converted to k.

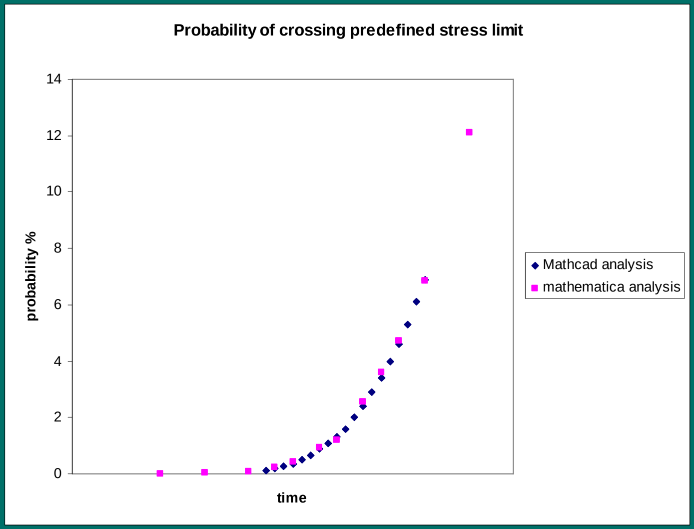
$$\ln k = \ln A - E/RT$$

$$1/P_t = 1/P_0 + k.t$$

- Product is a set of random numbers for P_t versus t. Statistical software allows the PDF to be described.

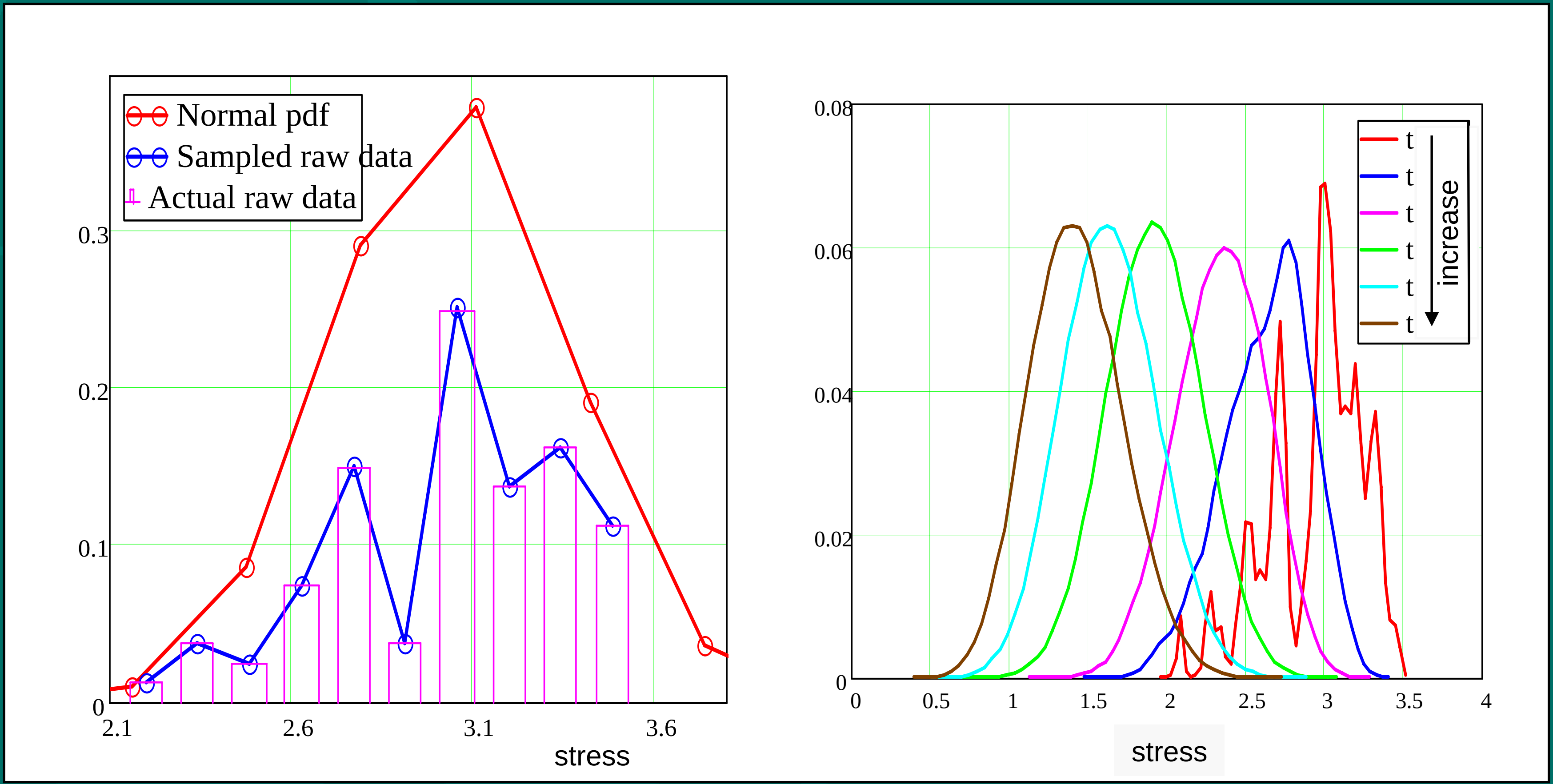
Monte Carlo - Results





- Comparing 2 independent analyses

Monte Carlo - Results



•Unaged flexure strength PDF and a fitted normal distn.

•PDF changes with age – initial signature is lost with time

Conclusions

- Monte Carlo simulation has provided a quantitative assessment of the likelihood of predictions with explosive age
- The MC analysis has shown early properties are most sensitive to the unaged distribution
- At extended times the MC prediction is less sensitive to the unaged data and more sensitive to the distribution function for the rate data

Acknowledgements

- Keith Macknelly – distinguished scientist AWE
- Mechanical Properties Team AWE