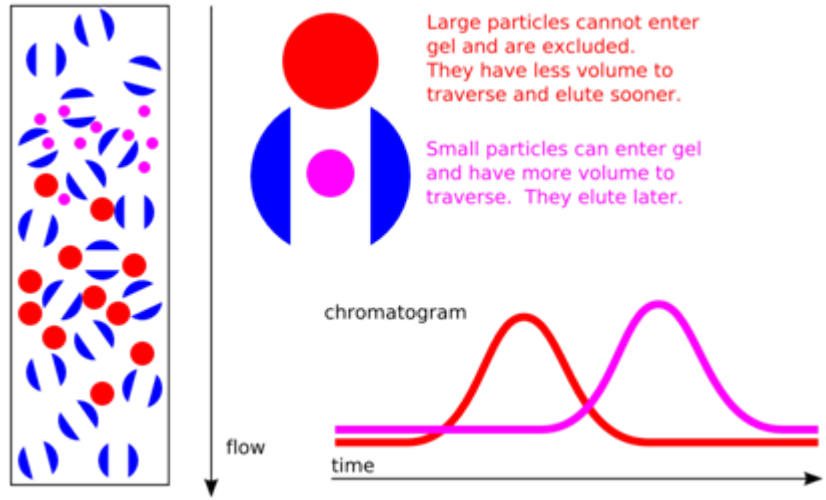
WHOLE LIFE ASSESSMENT OF NC IN PROPELLANTS

Dr Philip P Gill
Cranfield University
pgill.cu@da.mod.uk



Objectives

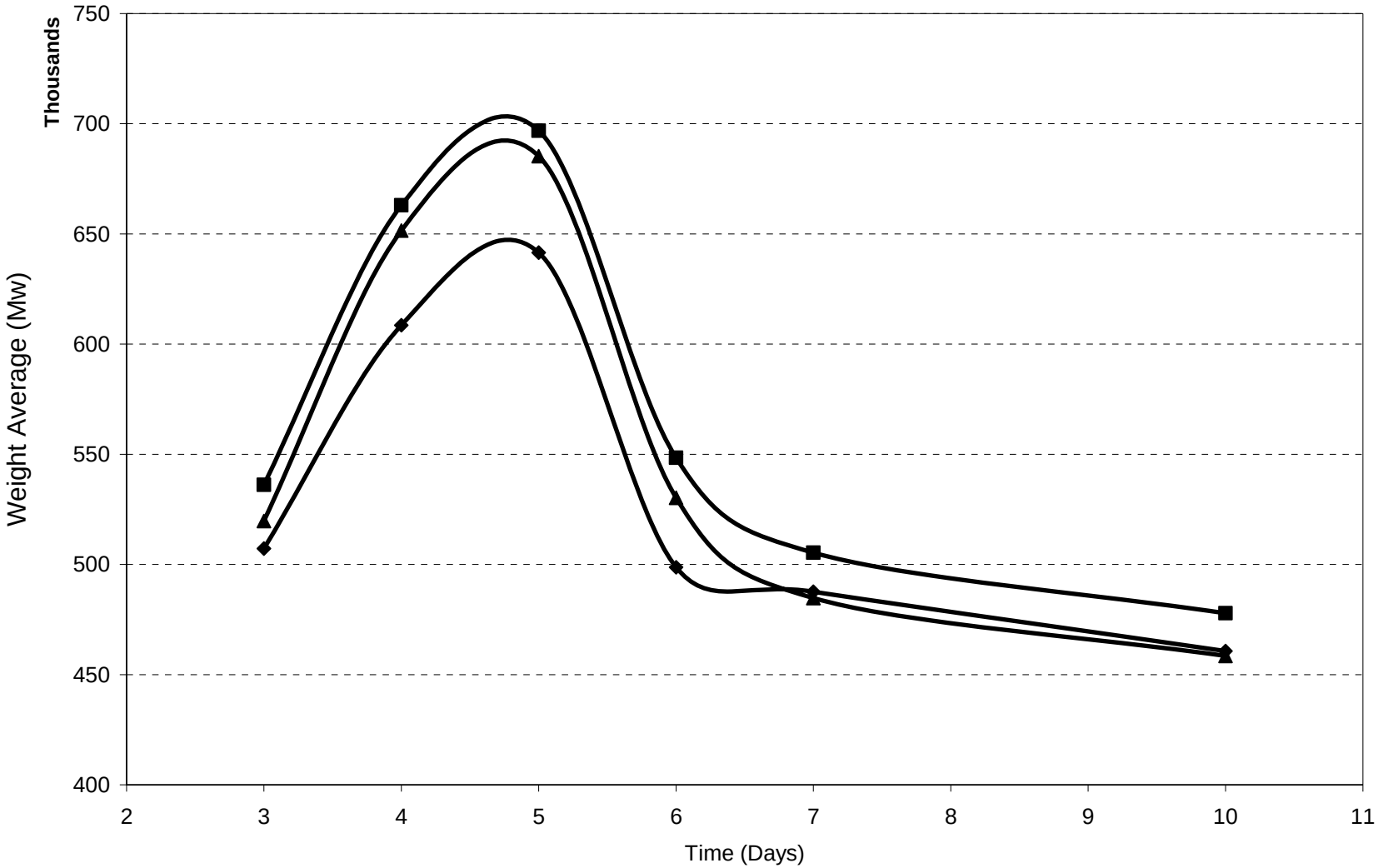
- Develop a NC surveillance method
  - Extraction technique of NC from Propellants
    - Accelerated aged and real time aged propellants
    - GPC, HPLC, DMA/Nano-identation
  - Nitrocellulose Thin Films
    - Accelerated aged and real time aged propellants
    - GPC, HPLC, DMA/Nano-identation
- Develop a predictive method for final product properties
  - Nitrocellulose Thin Films
    - Accelerated aged and real time aged propellants
    - GPC, HPLC, DMA/Nano-identation

Extraction Method

- Do as little to the sample as possible!

- Any mechanical work or time in solution will alter the structure of Nitrocellulose in solution

Solvation effects



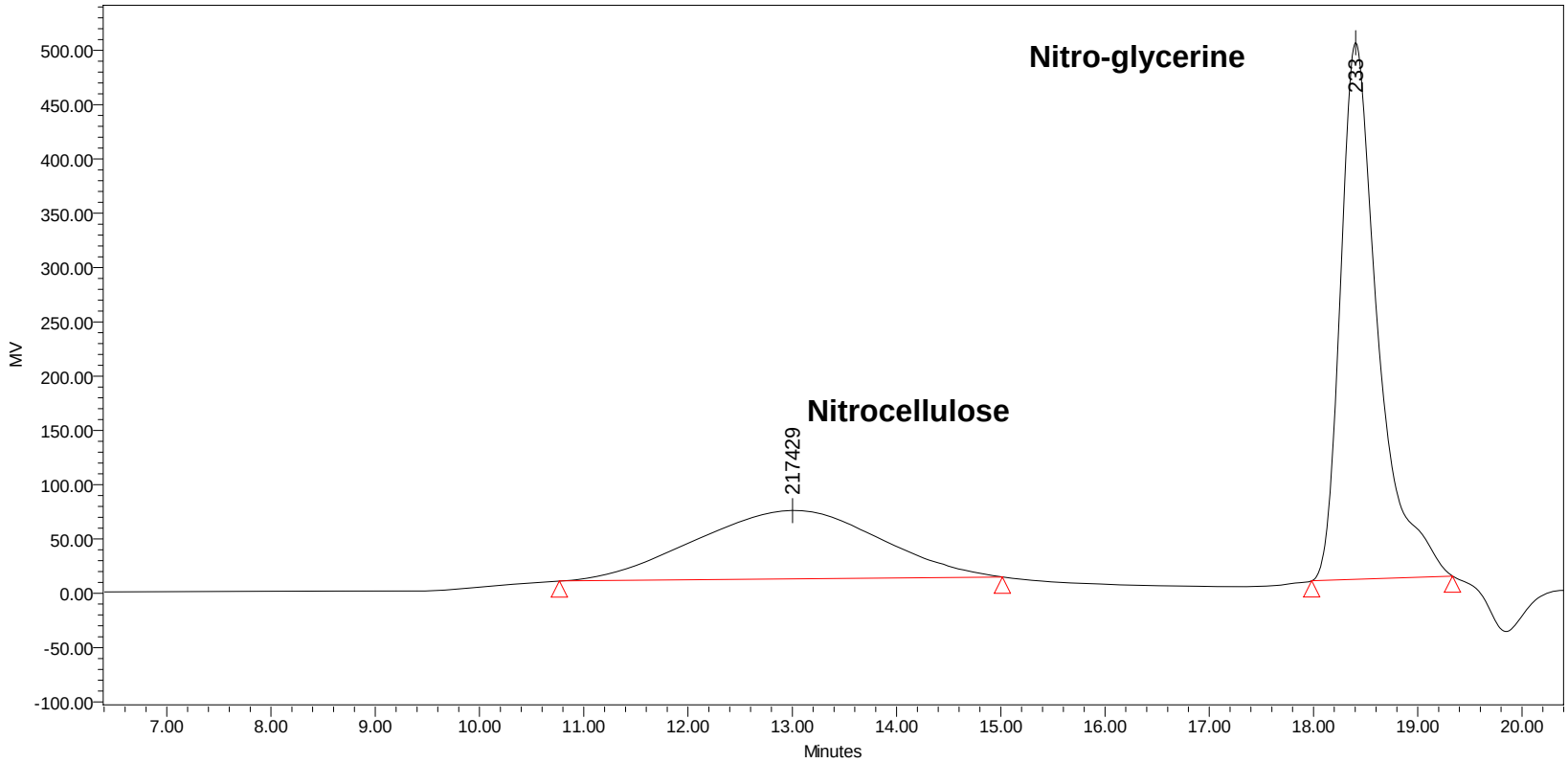
Extraction Method

- Do as little to the sample as possible!
- Any mechanical work or time in solution will alter the structure of Nitrocellulose in solution
- Use one standard concentration
  - Currently 1.5mg of NC/ml of THF

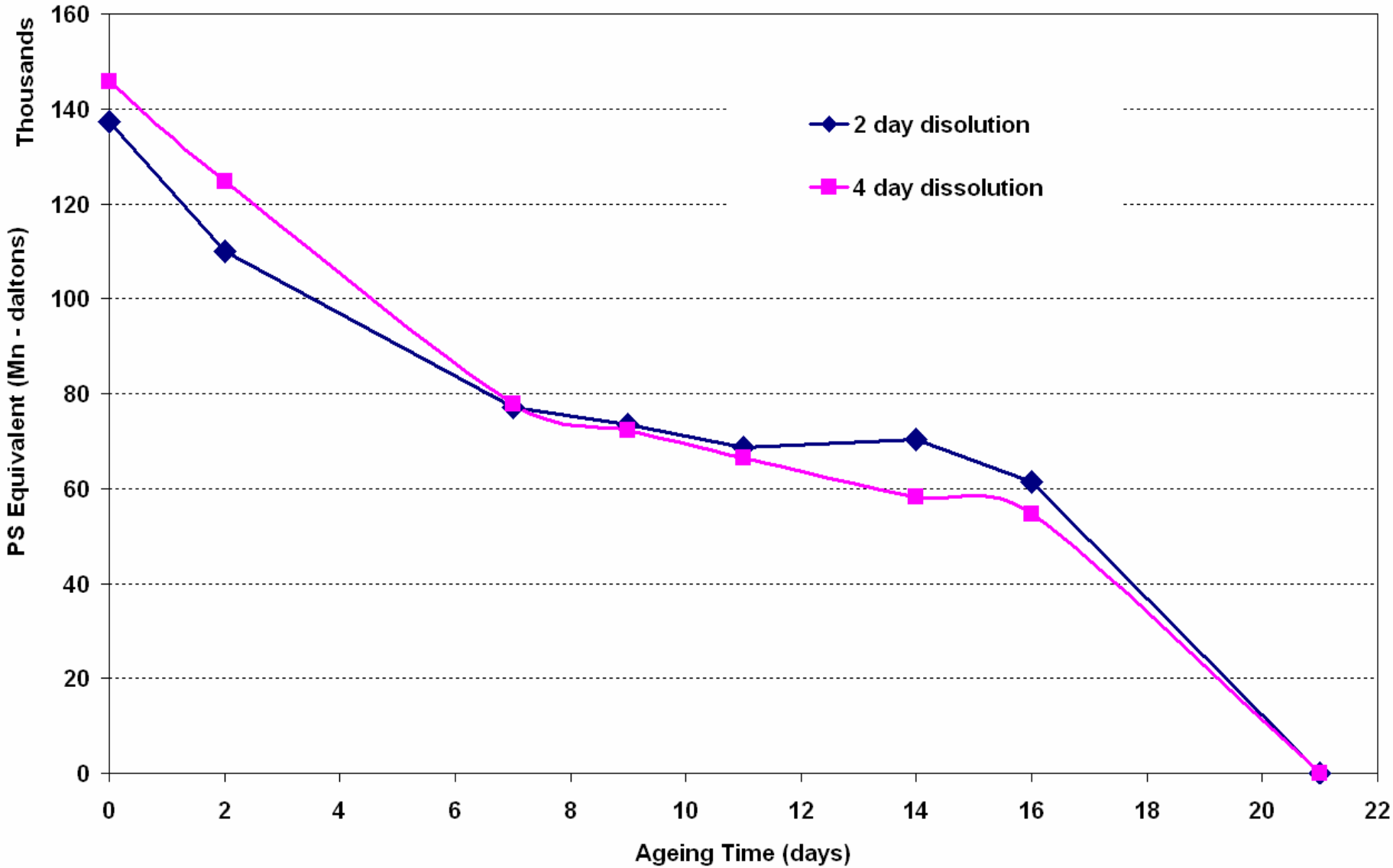
DB Rocket Propellant

- DB Rocket Motor
  - 34.3% Nitrocellulose
  - ROXEL (Rocket Motors UK) Ltd
- Accelerated Ageing
  - SEC analysis
  - Stabiliser Depletion Analysis (HPLC)
  - Mechanical Properties *(Nano-Identation & DMA)*

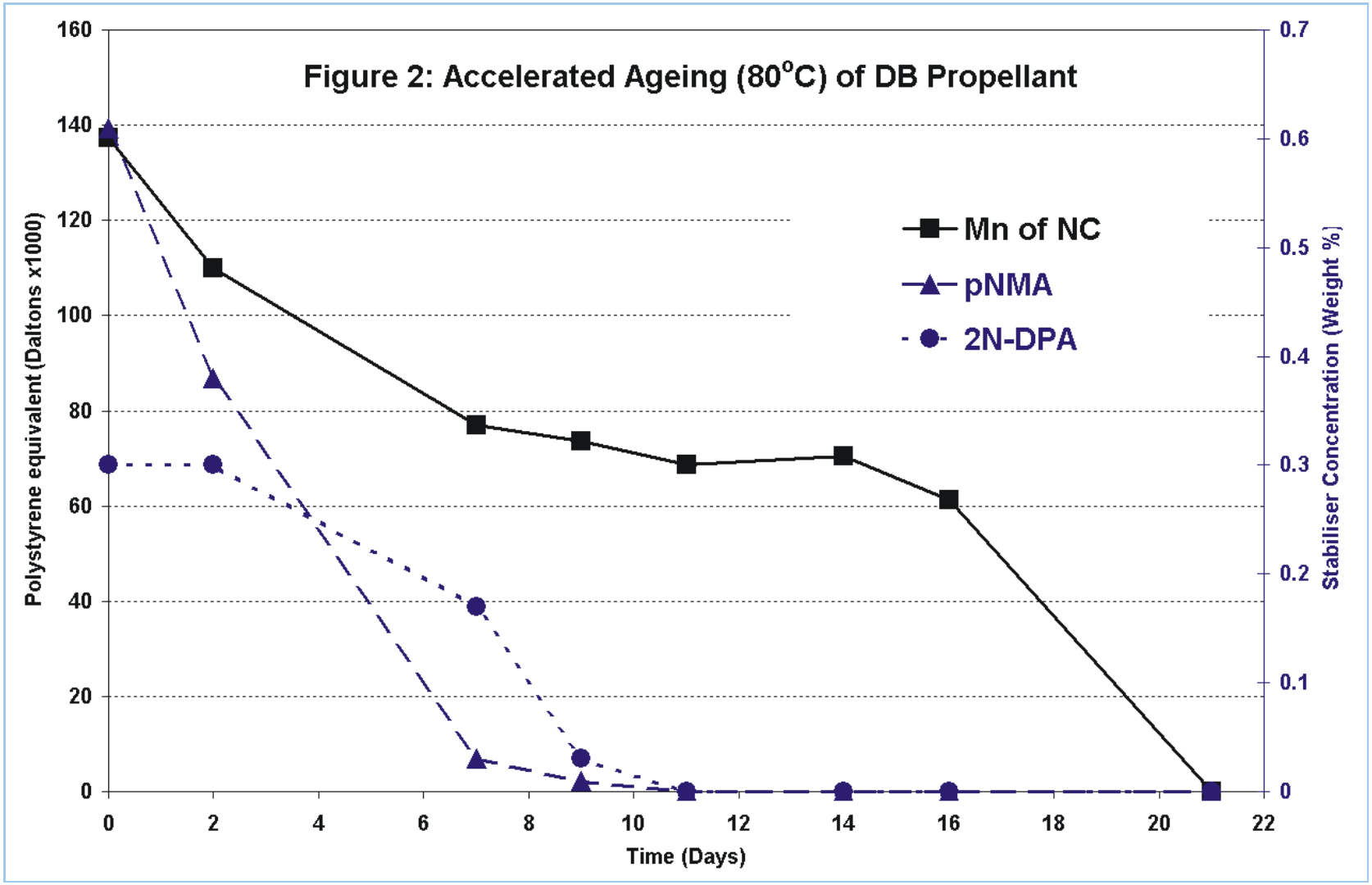
SEC of DB Propellant



DB Propellant (80°C Ageing)



DB Propellant (80°C Ageing)



Future work

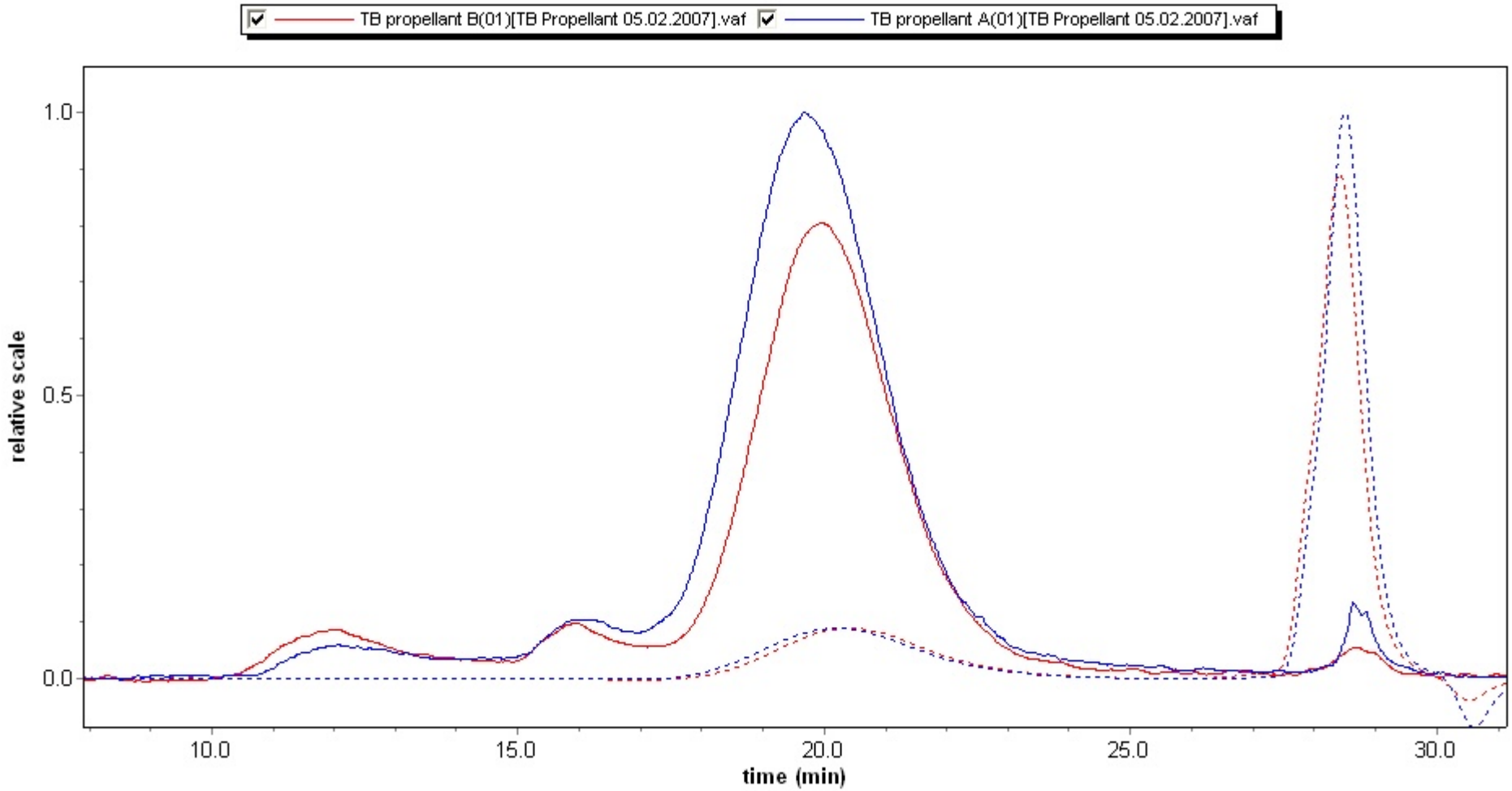
- More realistic Ageing
  - Lower Temperatures
  - Solid Loadings
- Study all Stabiliser products
- Mechanical Testing
  - DMA
  - Nano-Indentation
- Correlate SEC data with Mechanical data

TB Gun Propellant

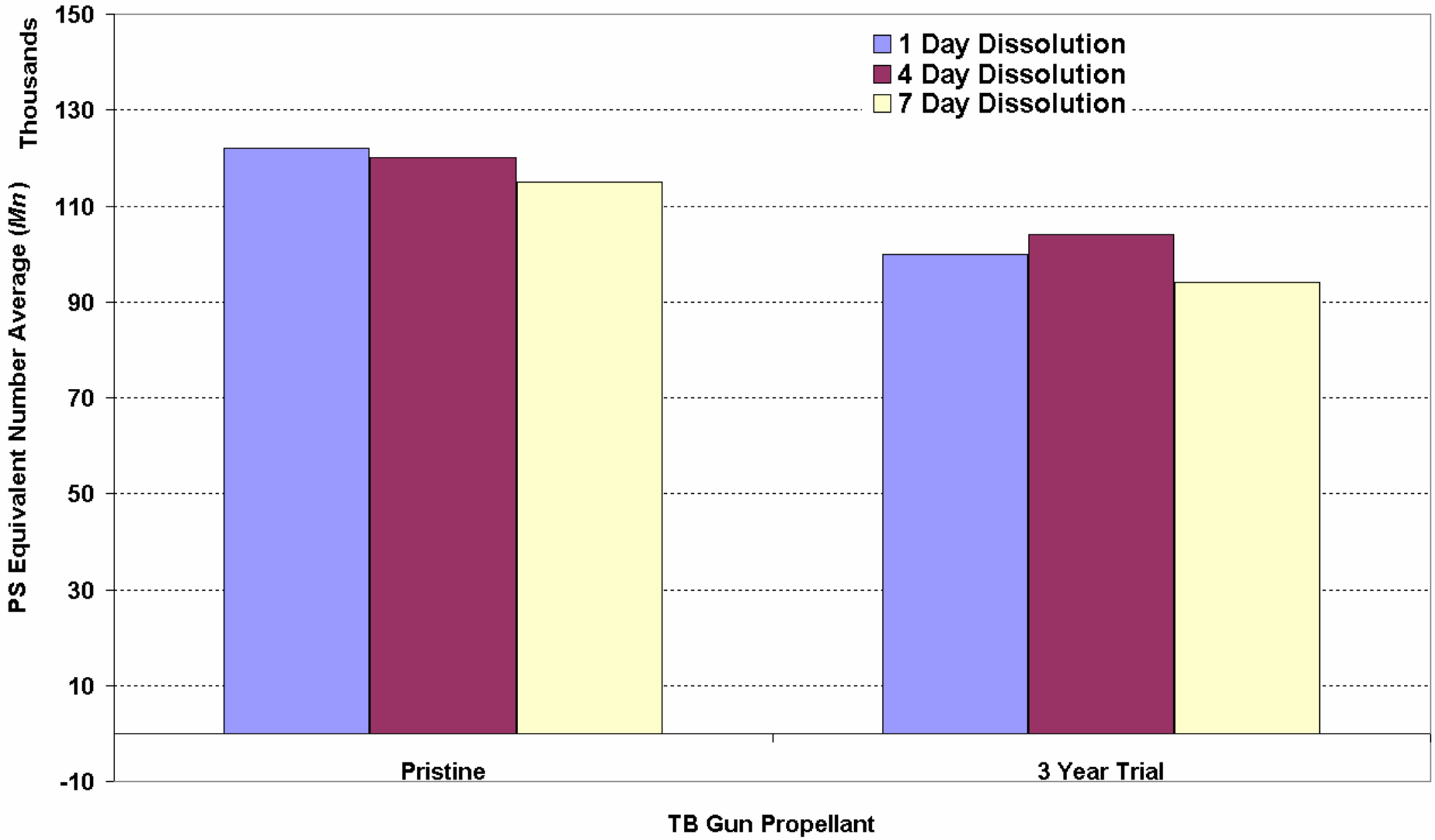
- TB Gun Propellant
  - Kindly Donated by BAE Systems
  - Rowanite 315 (16% NC, *12.6%Nitrogen*)
    - Pristine & Aged Sample (613- 3 Years)

- Accelerated Ageing
  - SEC analysis
  - Stabiliser Depletion Analysis (HPLC)
  - Mechanical Properties *(Nano-Identation & DMA)*

TB Gun Propellant



Ageing of TB Gun Propellant

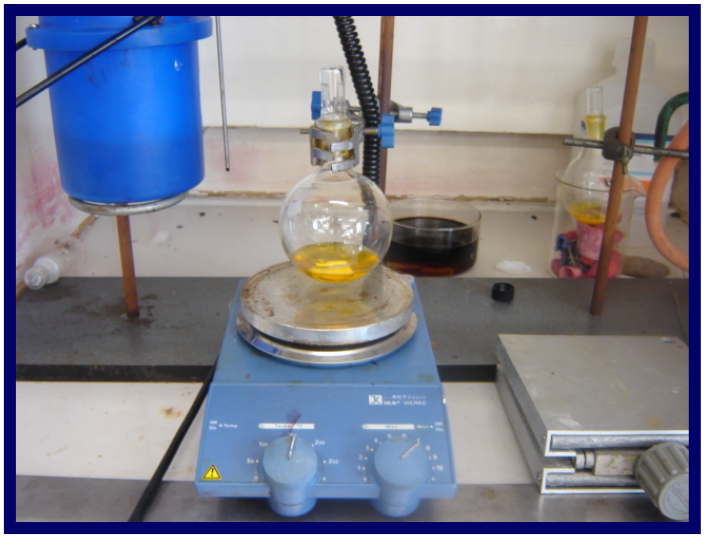


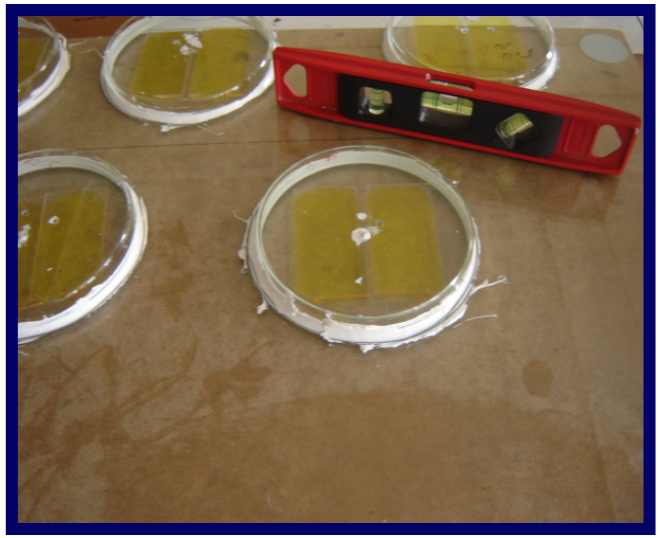
Nitrocellulose Thin Films

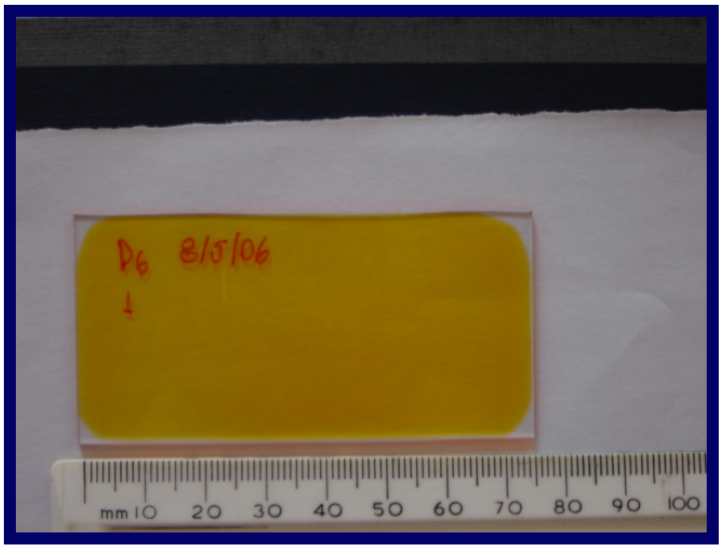
- EOE MSc project (*Jorge Perez*)
- 3 batches of NC from same supplier
  - Supplied by ROXEL (Rocket Motors UK) Ltd
  - 1 batch Problematic During Propellant Manufacture

- Thin Films from 3 different NC sources
    - Nitrocellulose, 10% DOP (plasticizer), 1% 2-NDPA (stabilizer)
  - Stabiliser Depletion (HPLC)
  - Change in *Mw* (SEC)
  - Change in Mechanical Properties (DMA)

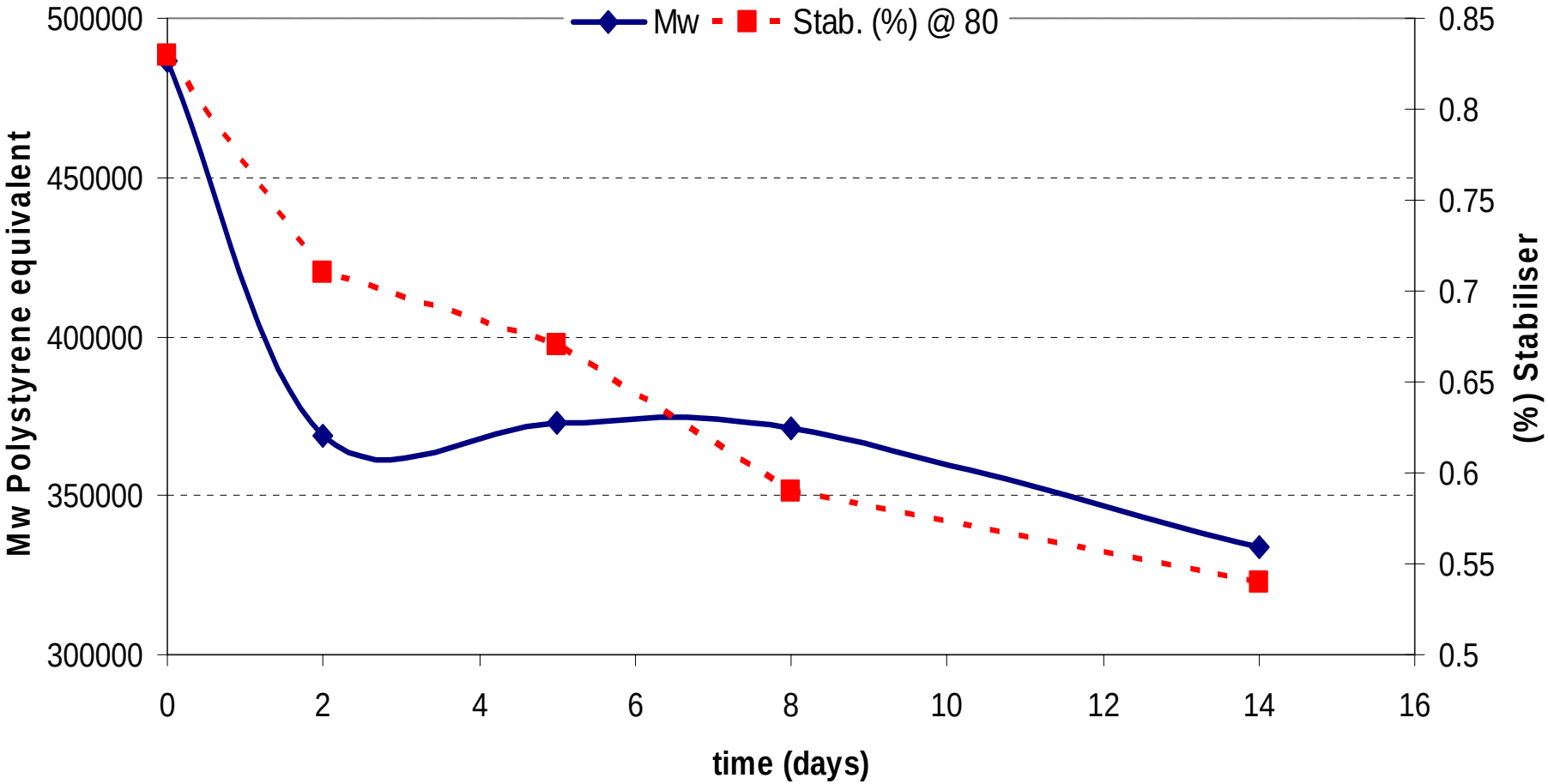
Nitrocellulose Thin Films







Effect of Ageing (D3)



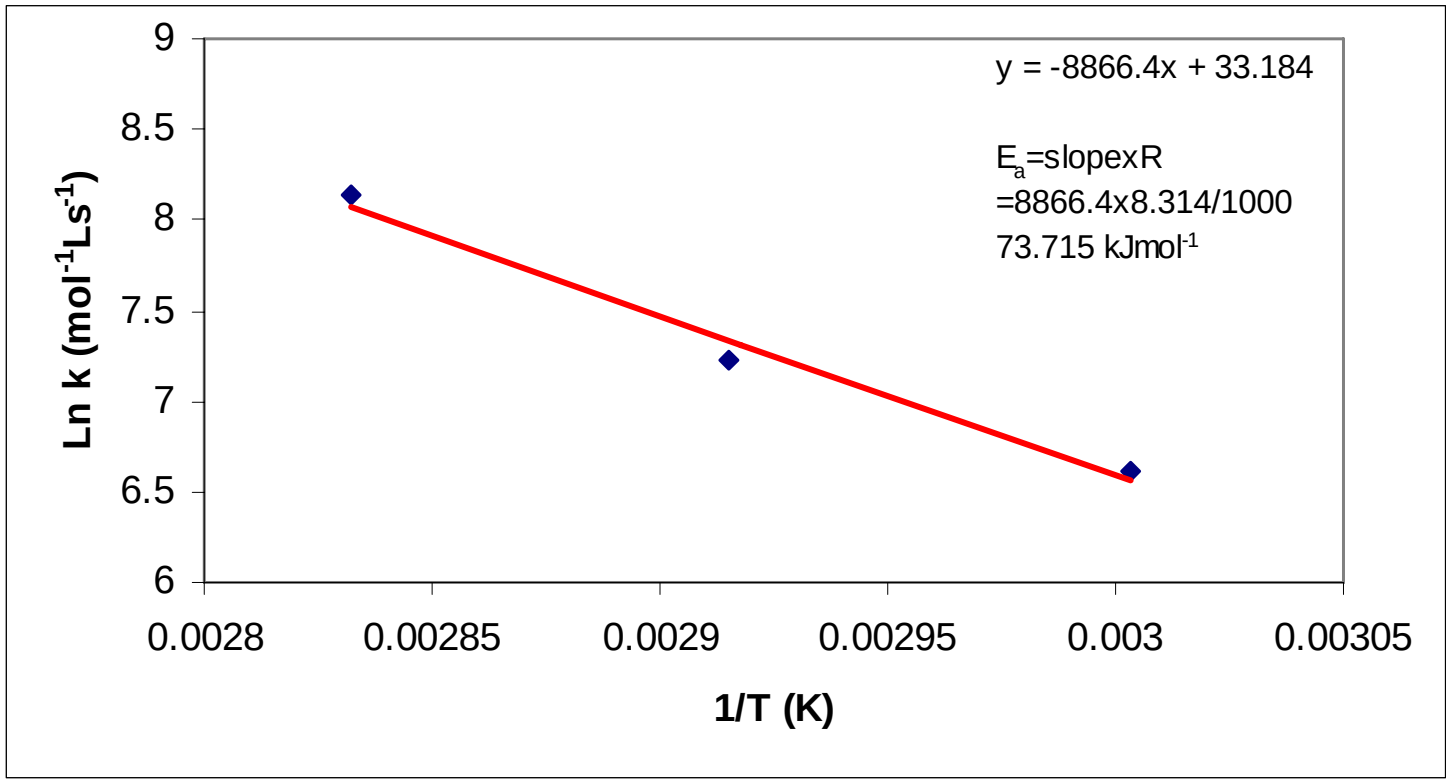
Stabiliser Depletion

Activation Energies

$Ea_{(D3)}$ = 74 kJ mol^{-1}

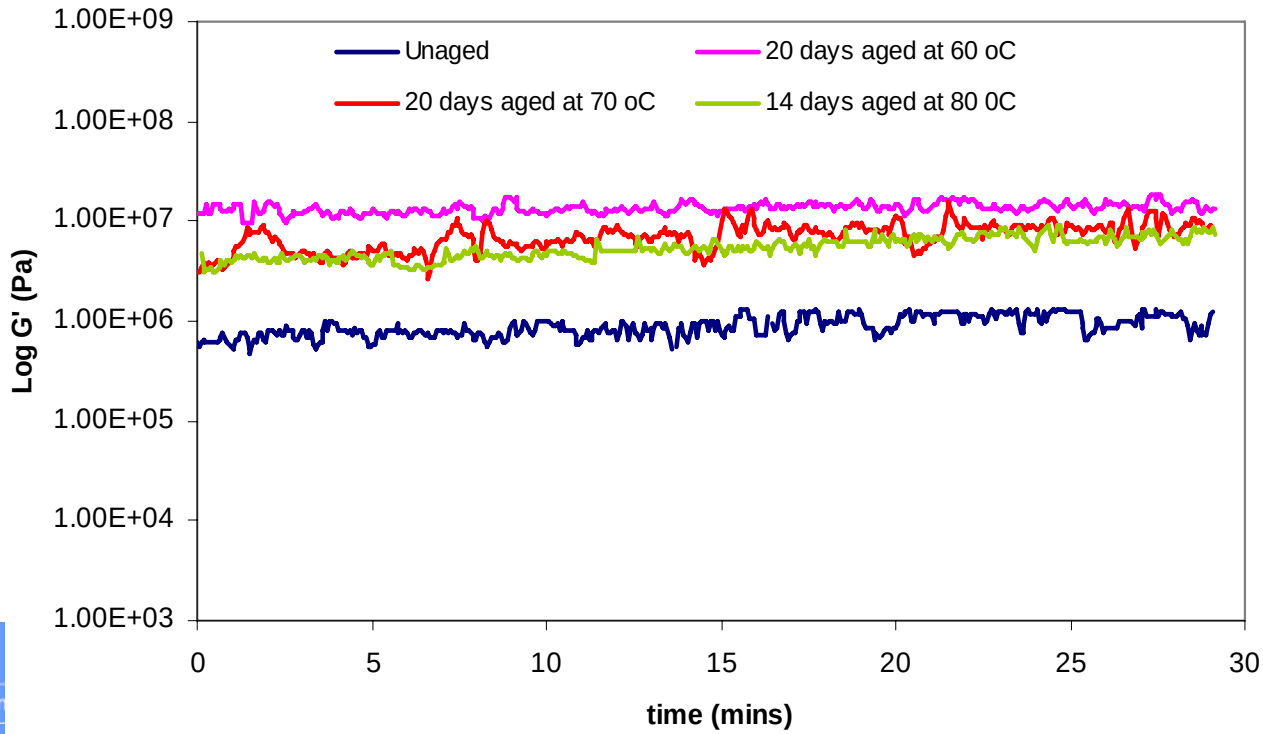
$Ea_{(D6)}$ = 93 kJ mol^{-1}

$Ea_{(D8)}$ = 74 kJ mol^{-1}



Mechanical Properties

- The storage modulus increased with ageing time which is in agreement with literature findings (the film lost its elasticity and became brittle)
- The modulus increase is related to the plasticiser depletion during aging and NC decomposition
- Decrease in Mw makes the film more brittle, justified by SEC results
- The loss of stabiliser may have some effect on the changes of the storage modulus



Thin Film Ageing

- Similar behaviour to Real Propellants
  - Many different variables
    - Can make films with no stabiliser or plasticiser

- Difference between 3 NC batches from same manufacturer
  - Problematic NC batch during batch shows different Thin Film ageing behaviour

Future Work

- Ageing at more temperatures
  - Activation Energy Calculation
- Follow all the stabiliser products
  - What is the effect on mechanical properties
- Plasticiser analysis
  - What is the effect on mechanical properties
- DMA & Nano-Identation analysis

Conclusion

- GPC analysis of extracted NC
  - relatively simple
  - Maintain constant conditions
- Correlating GPC Vs Mechanical Properties
  - Non-trivial
  - Effect of Stabiliser & Plasticiser
- Thin films
  - Reduce number of variables
  - Predictive tool for processability?

Acknowledgements

- AWE – *Deacon, Macdonald, Garman*
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- ROXEL – *Sloan, Fossey*
- BAE Systems – *Hugh, Mackenzie*
- Cranfield University – *Bellerby, Moniruzzaman, Reid, Perez, Agha*