



Australian Government

Department of Defence

Defence Science and Technology Group

# Ageing Protocol Development to Support the Qualification of Propellant Manufactured on Australia's Modernised Mulwala Facility

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# Background

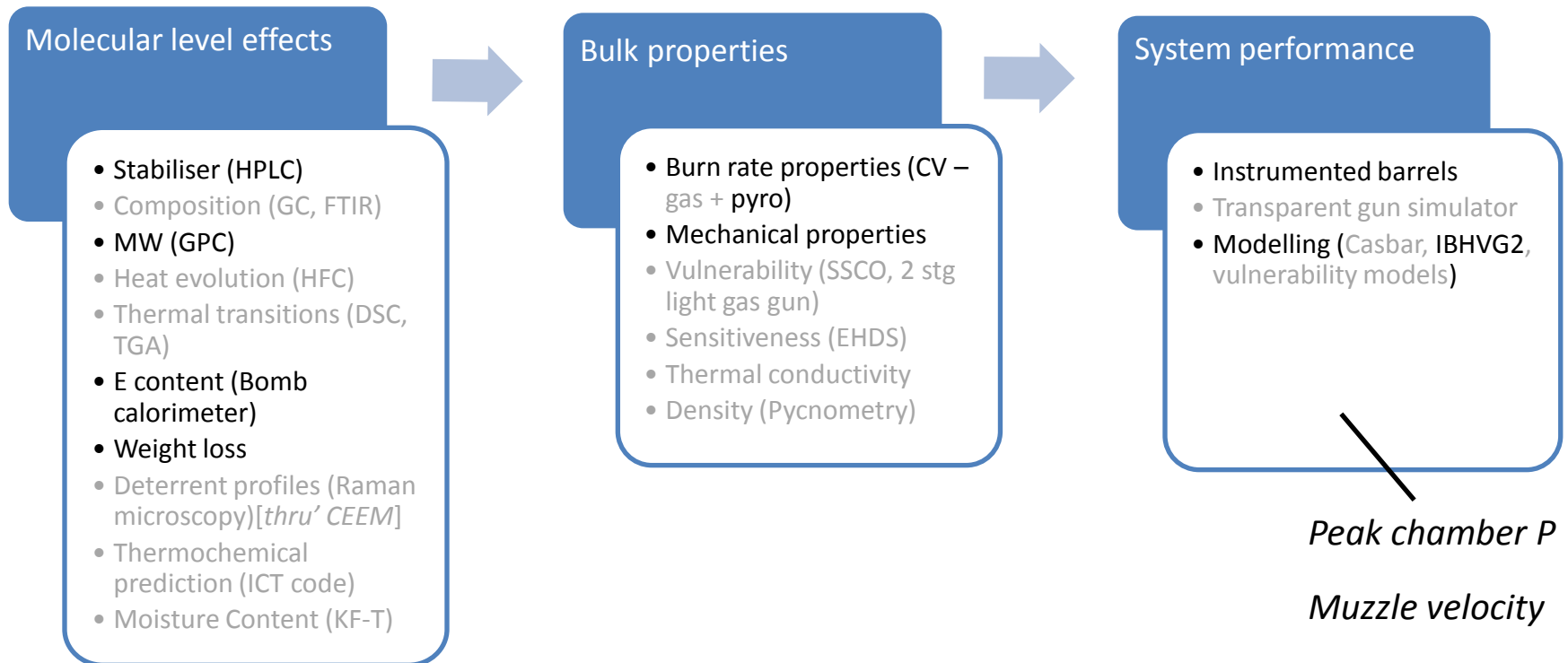
- **Modernised Mulwala Facility (MMF):**
  - SB propellant manufacturing capability
  - Enhanced production capacity; improved environmental and OH&S characteristics
- **Qualification guidelines:**
  - New propellant from new facility requires fundamental assessment of ageing characteristics and comparison with product previously demonstrated to be S3.
- **Nature specific ageing protocol development:**
  - Required ageing conditions
  - Identification of life-limiting propellant properties



# Approach

Life-Limiting Factors (safe-life/performance)

Ageing Media Equivalence



# Test Program: Comparison Propellants

Propellant	DOM	Type	Stabiliser	NC Grade	Deterrent
AR1	Oct '10	SB	DPA	C: 13.2% N	DNT
AR3	Apr '05	SB	DPA	C: 13.2% N	DNT
L2	Jun '10	SB	EC	E: 12.0% N	-

Propellant	Grain Dimensions (relative to normalised dimensions of AR1)			
	Length	Diameter	Web	Perforations
AR1	1.0	1.0	1.0	1
AR3	3.4	2.3	2.6	1
L2	16.2	8.0	3.8	7

# Test Program: Ageing

Testing	Media	Ageing Duration (days at 70°C)		
		AR1	AR3	L2
Molecular level	TAM, PCA	0-135	0-84	0-197
Bulk properties	PCA	0-84	0-84	0-197
Gun performance	PCA	0-84	-	-



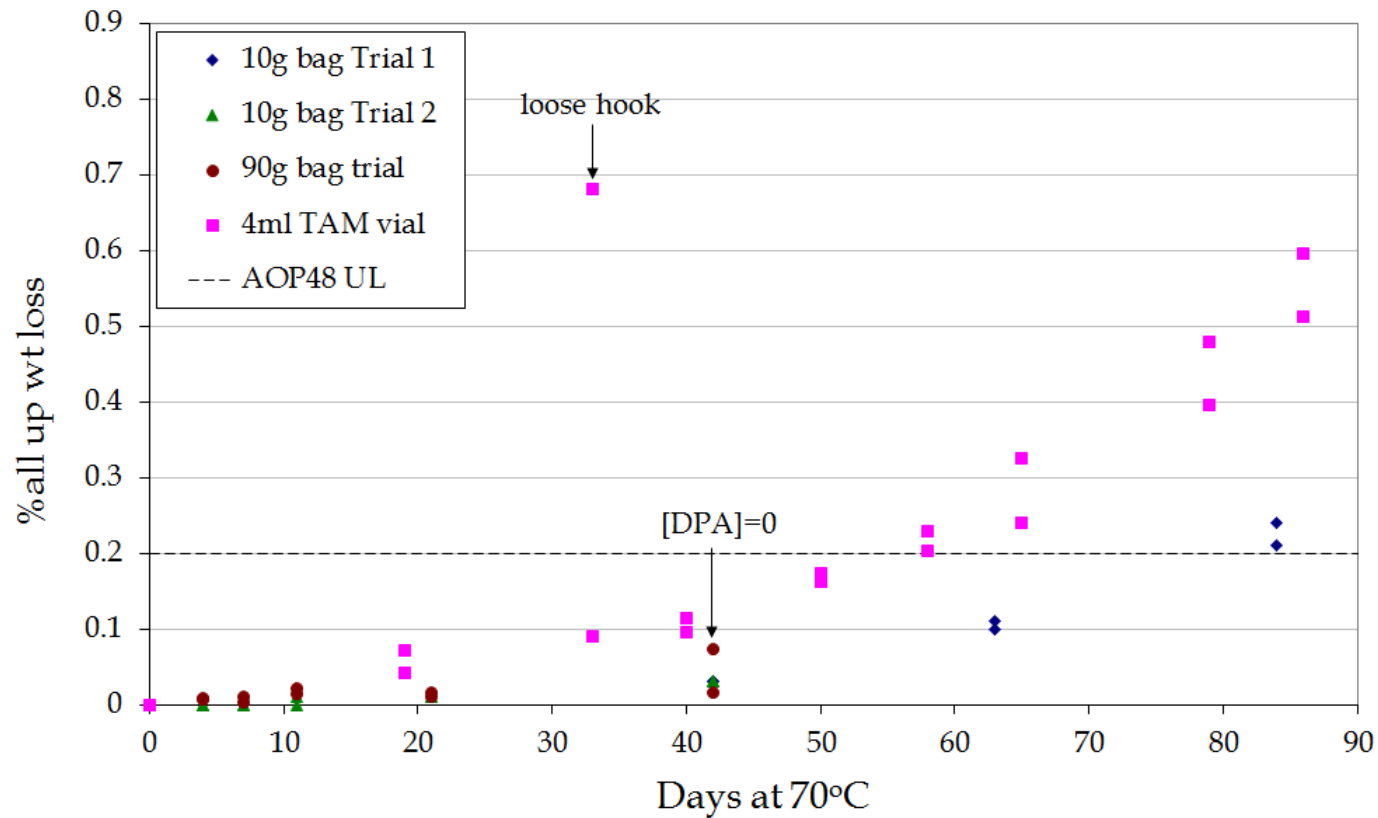
- ☒ TAM ampoules (4,20 mL)
- ☒ Wheaton vials (8 mL)
- ☒ Pharmaglass vials (21 mL)
- ☒ PCA Bags



Testing	Media	Days at 80°C
		L2
Molecular level	20ml TAM	20, 40, 60, 80
Bulk properties	20ml TAM	40, 60, 80
Gun performance <sup>^</sup>	-	40, 80

<sup>^</sup>IBHVG2 simulations

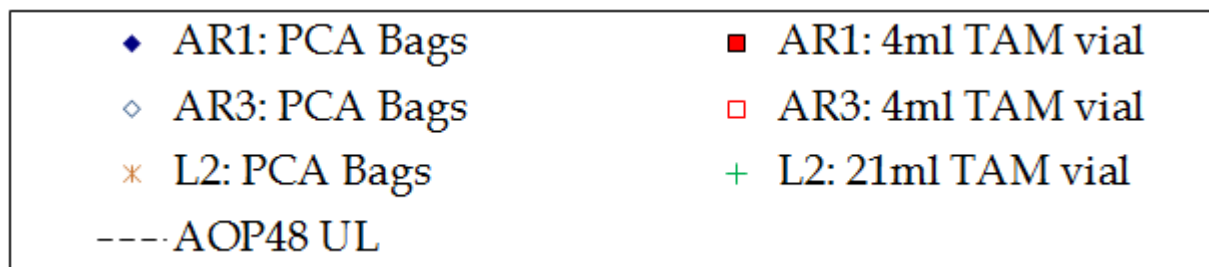
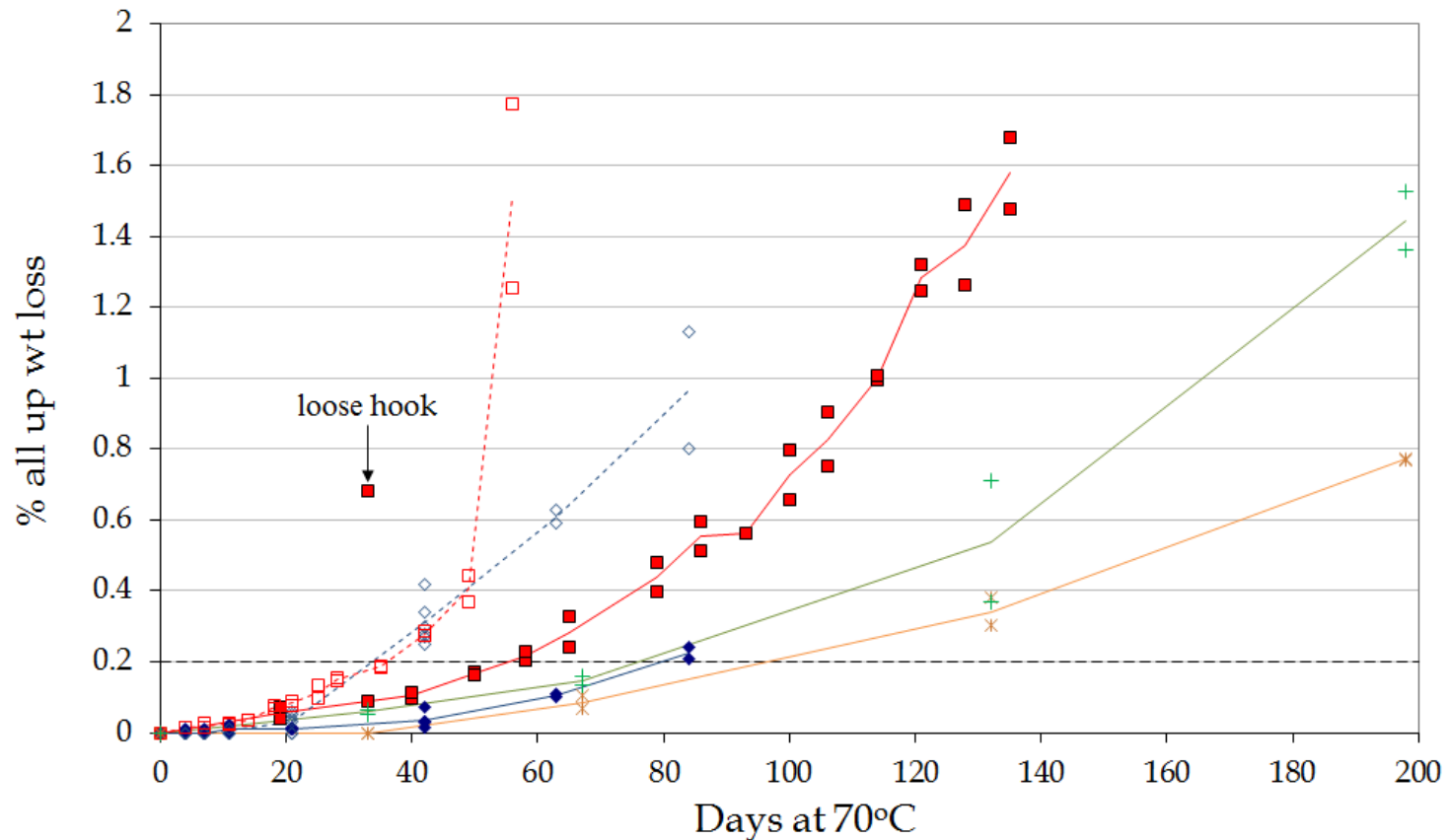
# Ageing Media Equivalence: Weight Loss – AR1



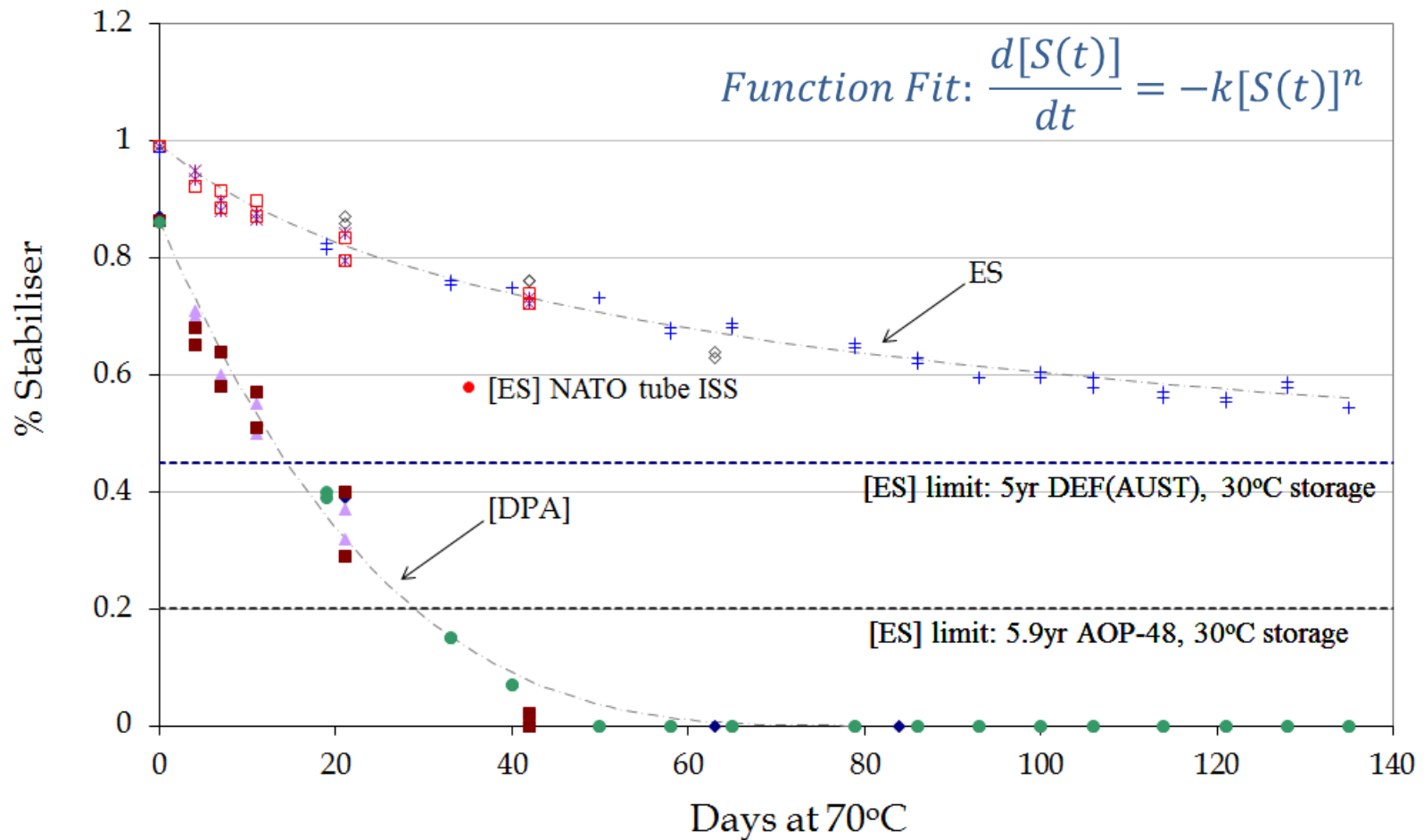
## AOP-48 guidance

Media	Wt loss%
4 ml TAM	<0.2
PCA bag	<0.1
Sealed ammo	<0.1

# Ageing Media Equivalence: Weight Loss Summary



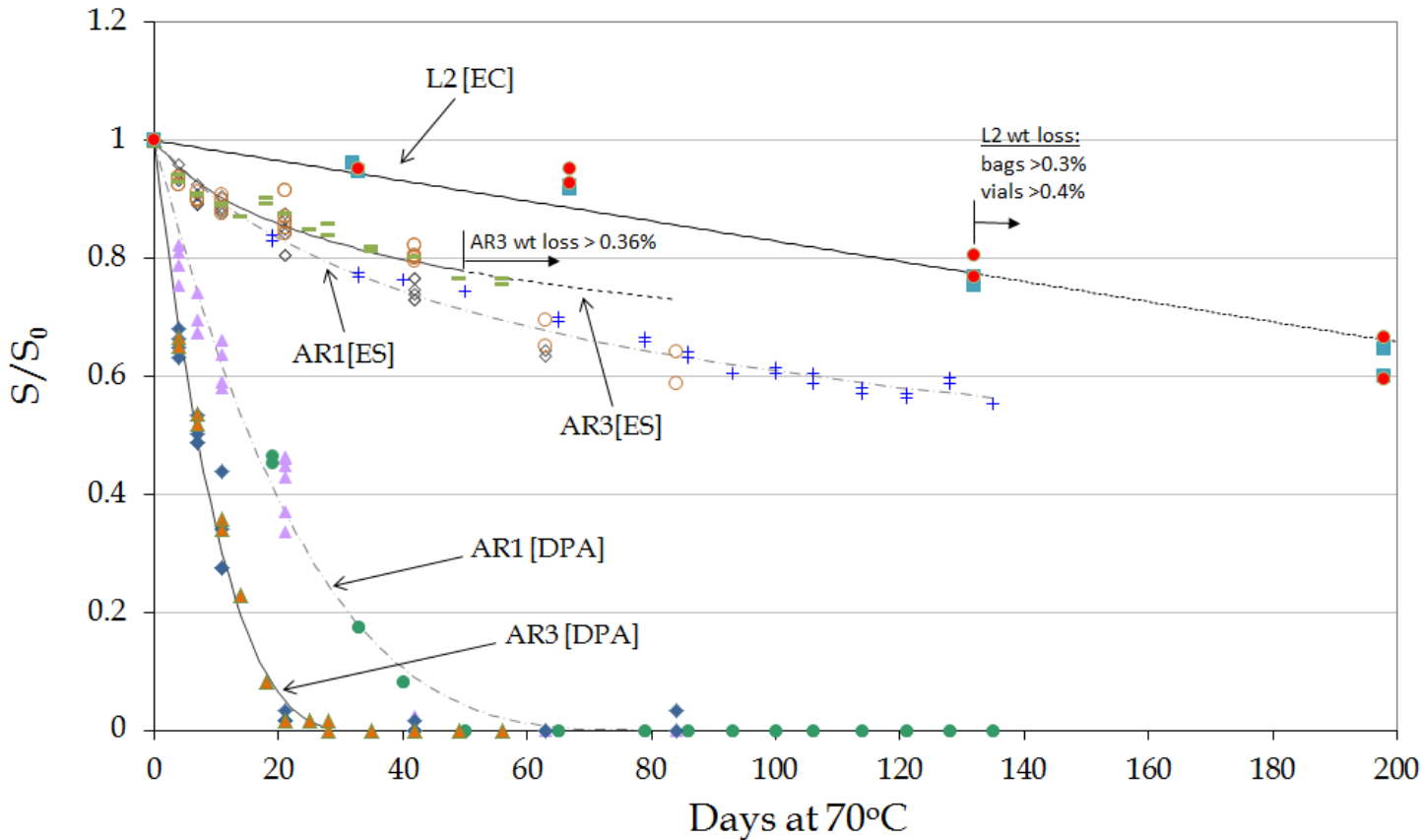
# Ageing Media Equivalence: Stabiliser loss – AR1



- ◆ [DPA] 10g bag Trial 1    ▲ [DPA] 10g bag Trial 2    ■ [DPA] 90g bag trial    ● [DPA] 4ml TAM
- ◇ [ES] 10g bag Trial 1    ✱ [ES] 10g bag Trial 2    □ [ES] 90g bag trial    + [ES] 4ml TAM



# Propellant Stabiliser Depletion - Summary



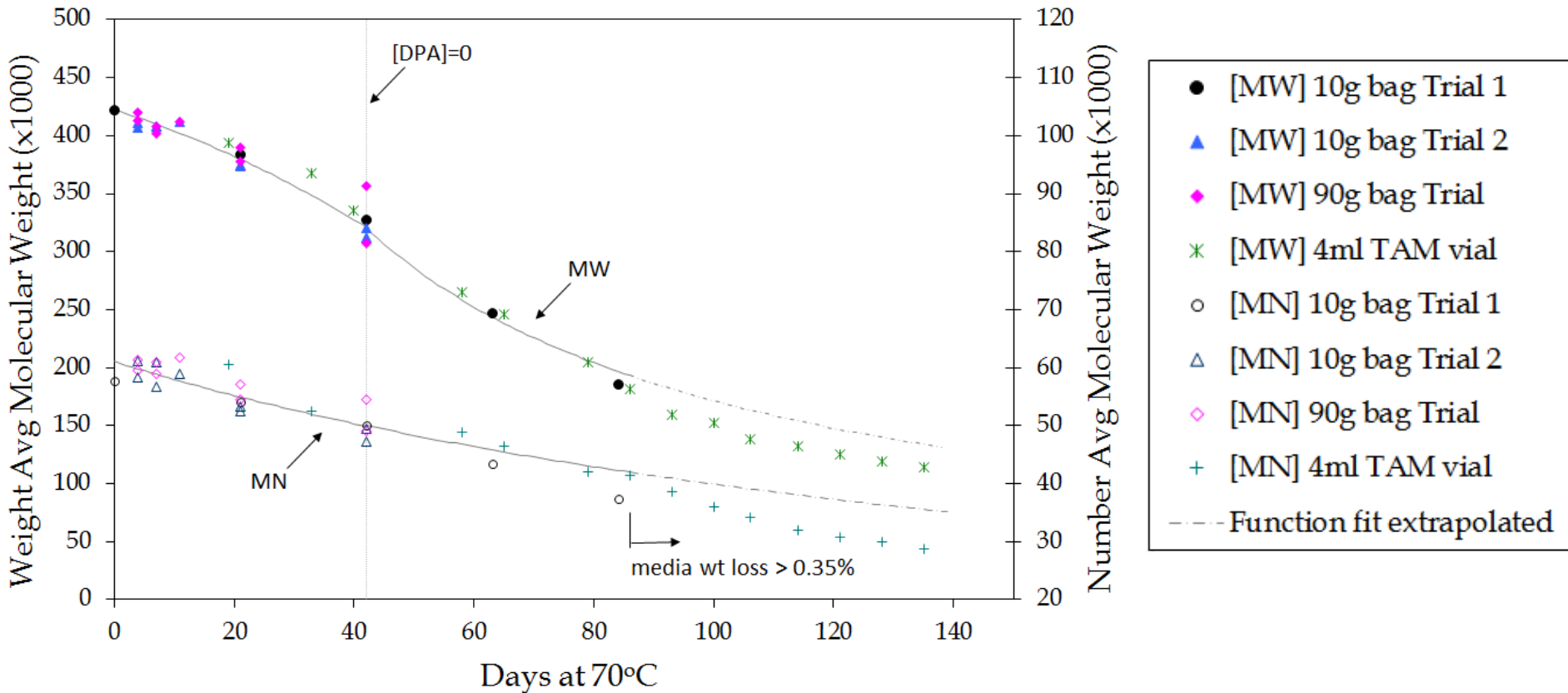
- ▲ AR1: [DPA] PCA Bag   
 ● AR1: [DPA] 4ml TAM   
 ◊ AR1: [ES] PCA Bag   
 + AR1: [ES] 4ml TAM
- ◆ AR3: [DPA] PCA Bag   
 ▲ AR3: [DPA] 4ml TAM   
 ○ AR3: [ES] PCA Bag   
 - AR3: [ES] 4ml TAM
- L2: [EC] 20ml TAM   
 ● L2: [EC] PCA Bag

$$ES = [DPA] + 0.85 [n\text{-no-DPA}]$$

DEF(AUST) 5 yr Chem Safe Life	
Propellant	$S/S_0$
AR1 [ES]	0.5
AR3 [ES]	0.5
L2 [EC]	0.6

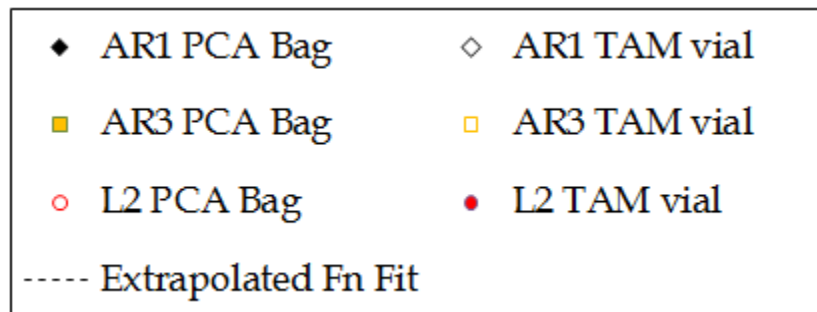
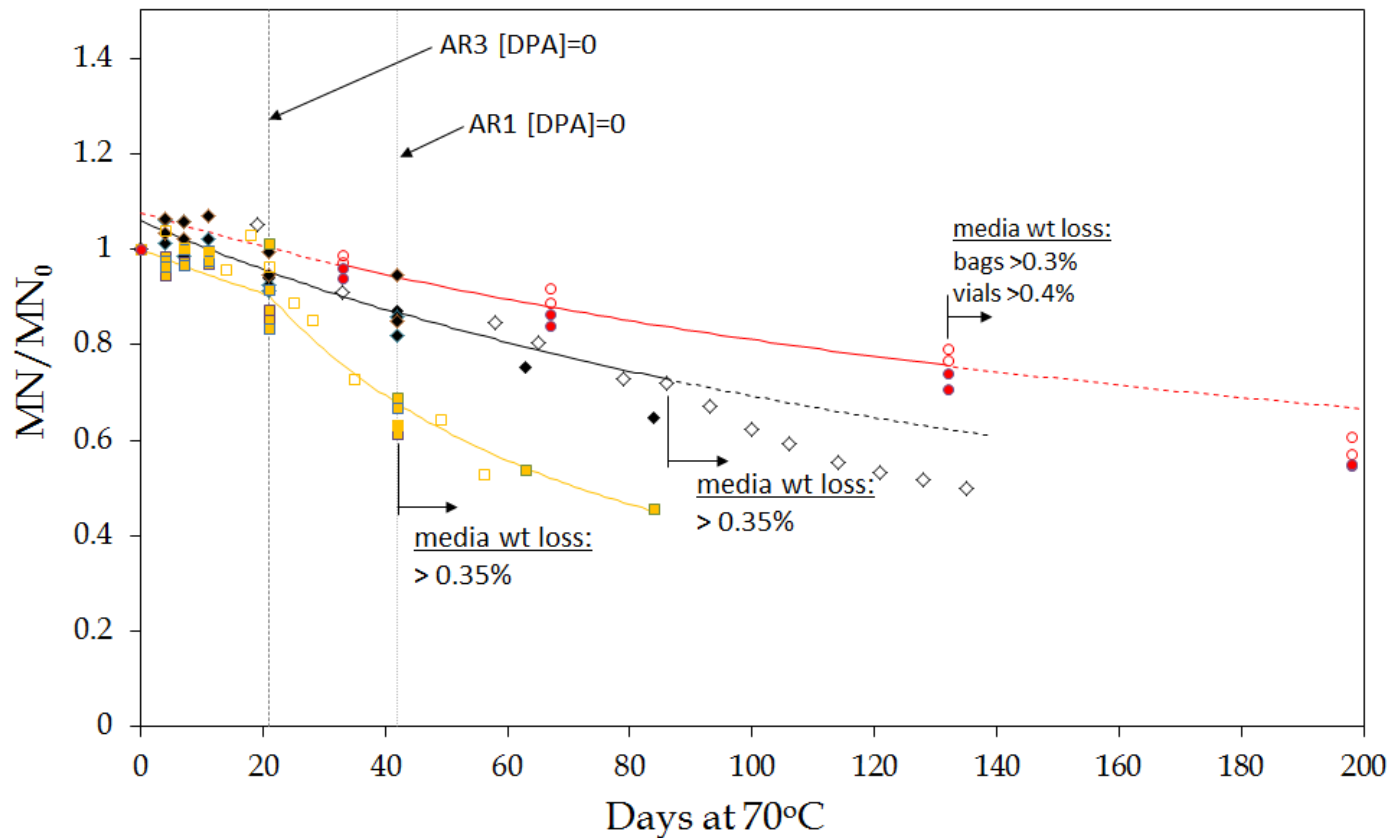


# Ageing Media Equivalence: Molecular Weight - AR1



**Function Fit:** Molecular weight reduction via monomer unit decomposition with chain recombination [Bohn, 1998]

# Propellant MN Depletion - Summary



# MN and Stabiliser Depletion - Kinetics

*MN: Reduction via Monomer Unit Decomposition ( $k_{m1}$ ) with Chain Recombination ( $k_{m2}$ )*

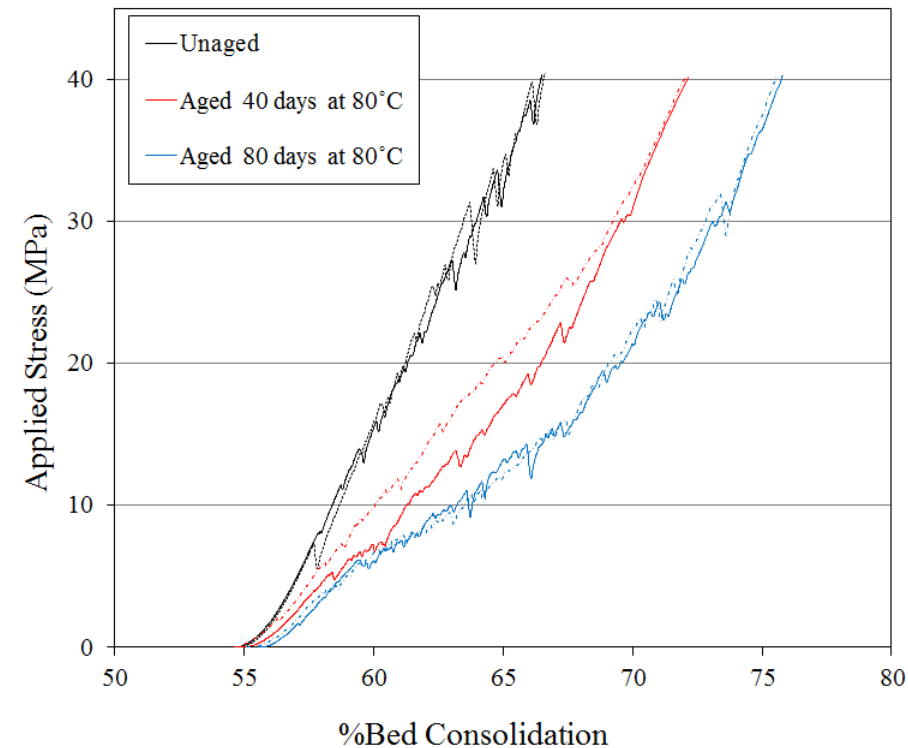
Monomer Decomposition model	[Primary Stabiliser] > 0			[Primary Stabiliser] = 0		
	$k_{m1} \times 10^{-5}$ (1/d)	$k_{m2} \times 10^{-2}$ (1/d)	$R^2$	$k_{m1} \times 10^{-5}$ (1/d)	$k_{m2} \times 10^{-2}$ (1/d)	$R^2$
AR1 (70°C)	2.6	0.0	0.4435	2.6	0.0	0.7447
AR3 (70°C)	2.6	0.0	0.5842	9.1	0.0	0.8549
L2 (70°C)	1.5	0.0	0.8832			
L2 (80°C)	11.1	2.8	0.9398			

*Stabiliser:  $n^{\text{th}}$  order decomposition [AOP-48]*

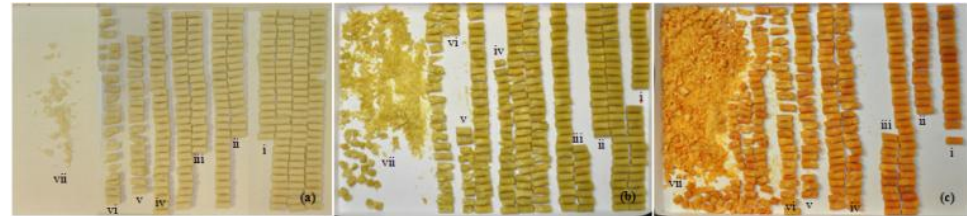
Stabiliser Depletion	$n^{\text{th}}$ order model		
	$k \times 10^{-2}$ (1/d)	n	$R^2$
AR1 (70°C)	3.9	0.7	0.9549
AR3 (70°C)	7.4	0.7	0.9668
L2 (70°C)	0.2	0.0	0.9236
L2 (80°C)	0.6	0.4	0.9822

Chem Stability  
AR3 < AR1 < L2

# Bulk Effects: Mechanical Properties - L2



Ageing Duration at 80°C



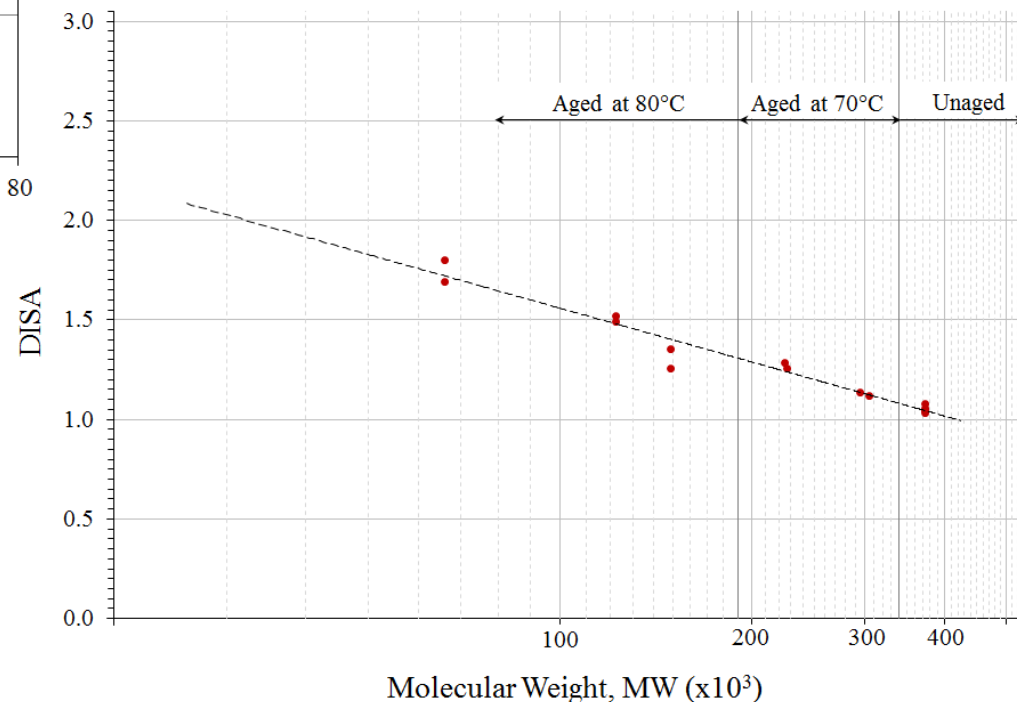
Unaged

40 days

80 days

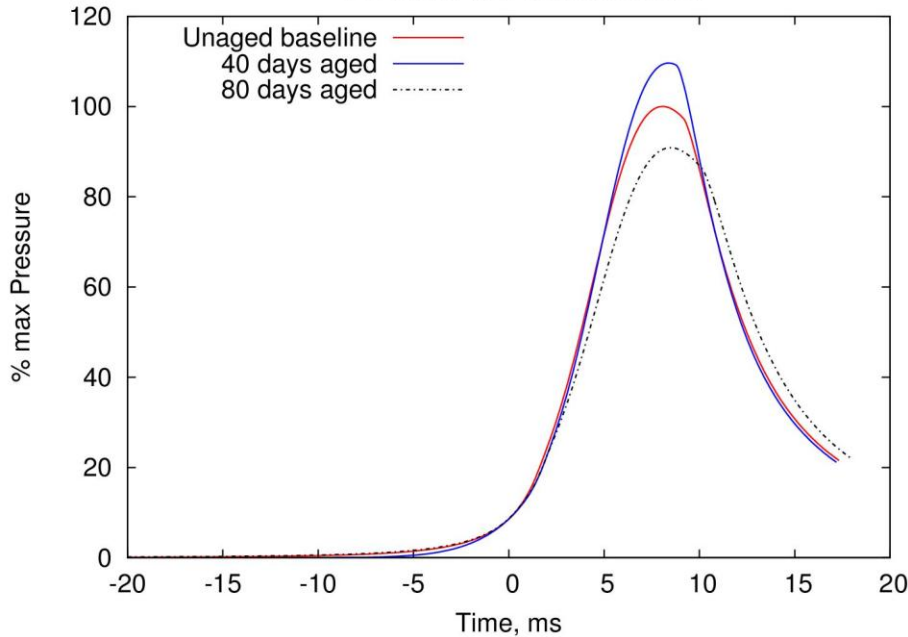
80°C Ageing

Age (days)	DISA (%)	MW (%)	PDI (%)
0	+4	0	0
40	+26	-58	-40
80	+70	-82	-50

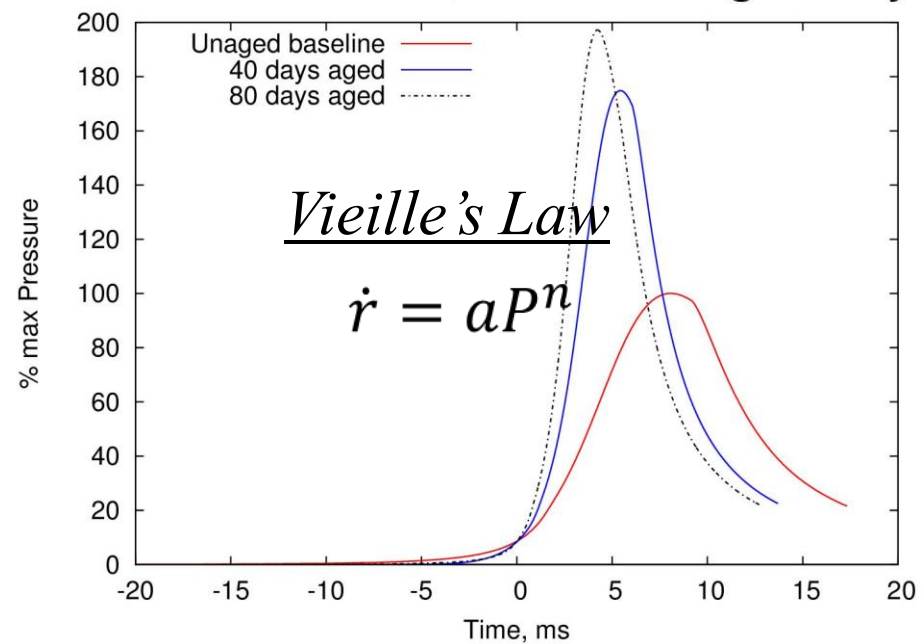


# Gun Performance: L2 (IBHVG2 modelling)

Effect of burn rate



Effect of burn rate and fractured geometry



Age (days)	a (%)	n (%)	$\dot{r}$ (100 MPa), %	Quickness (%)	E content (%)
0	0	0	0	0	0
40	-14	+4	+3	+3	0
80	-30	+6	-7	-14	-4



# Bulk Effects: Mechanical Properties - AR1 and AR3

## AR1

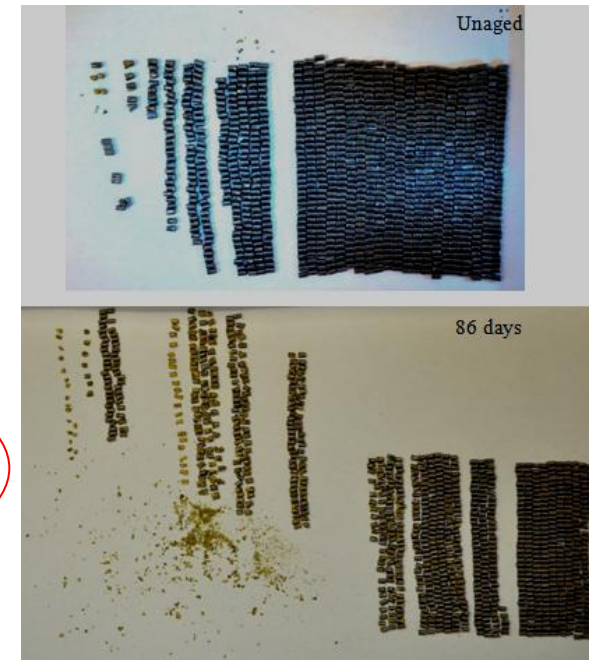
Age (days)	DISA (%)	MW (%)	PDI (%)
0	+4	0	0
42	+1	-22	-11
85	+10	-54	-33



$DISA_{deterred} = F_n(\text{physical surface area} + \text{initial burn rate enhancement})$

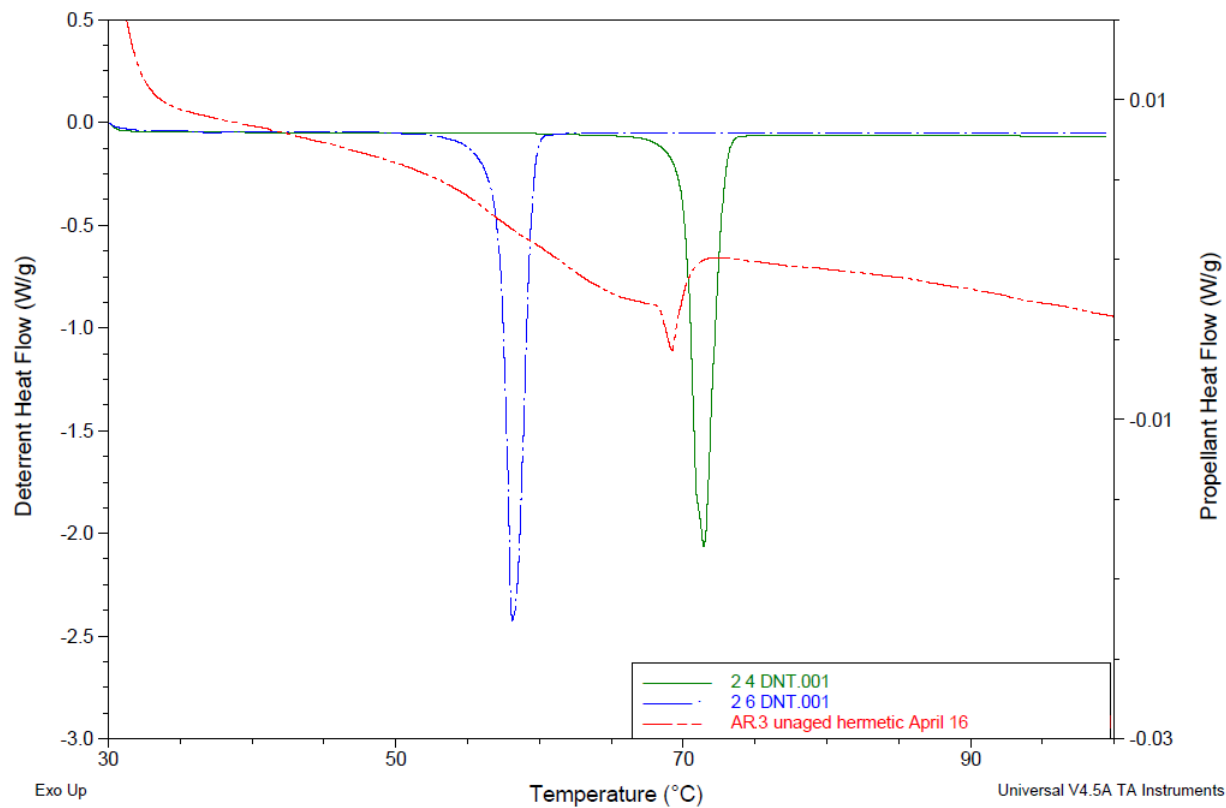
Age (days)	DISA (%)	MW (%)	PDI (%)
0	+14	0	0
42	+37	-53	-20
86	+78	-76	-52

## AR3



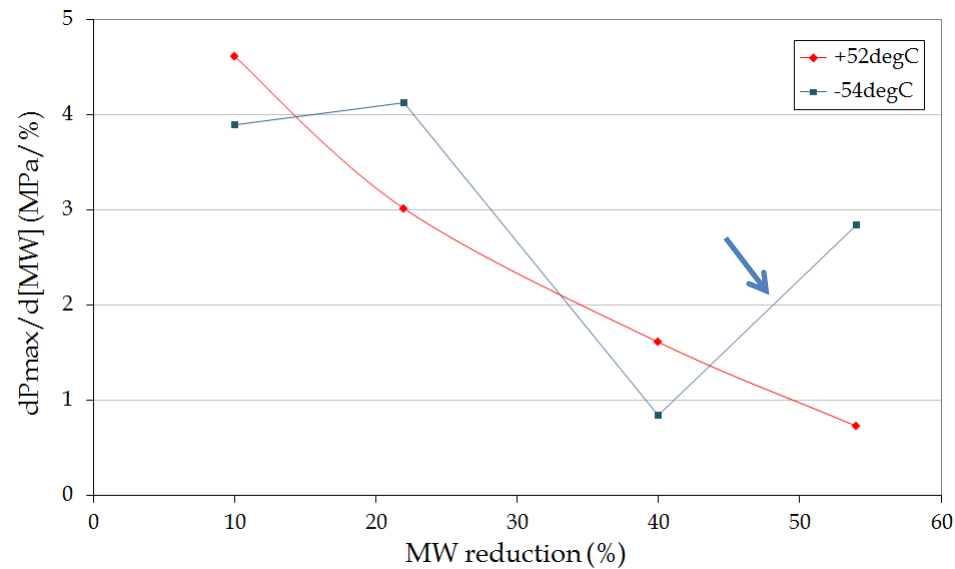
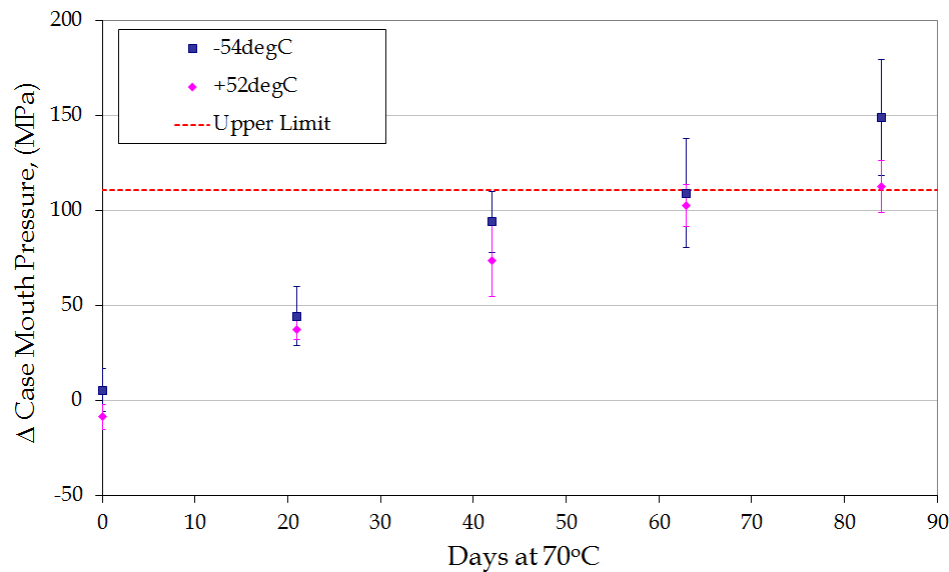
# Bulk Effects: AR1 Burn Rate

Age (days)	$\dot{r}$ (16 MPa), %	$\dot{r}$ (120 MPa), %	Pmax (%)	Quickness (%)
21	+8	+4	0	+4
42	+15	+1	0	0
85	+15	-4	-2	-8





# Gun Performance: AR1 (inst. firing)



Age (days)	$\dot{r}$ (16 MPa), %	DISA (%)	MW (%)	PDI (%)
0	0	+4	0	0
21	+8		-10	-4
42	+15	+1	-22	-11
63			-40	-24
85	+15	+10	-54	-33

# Conclusions

## ■ Ageing Media:

- PCA bags offered improved sealing efficacy over TAM vials.
- Propellant ageing in PCA bags and 4 and 20ml TAM vials gave acceptable agreement whilst adequate sealing integrity was maintained.

## ■ Ageing Protocol:

- For all propellants represented, at the ageing temperatures considered, functional performance rather than safe-life will be life-limiting.
- For the AR propellants, a 55°C ageing temperature would be more appropriate owing to DNT-loss at the 70°C condition.

Propellant	5yr Chem Safe Life	Functional Life	Life Limiting Factor
AR1	>135d at 70°C equiv.	63d at 70°C equiv.	Deterrent induced burn rate changes.
AR3	>84d at 70°C equiv.	42d at 70°C equiv.	Deterrent induced burn rate changes and (possibly) loss in structural integrity.
L2	~60d at 80°C equiv.	<40d at 80°C equiv.	Loss in structural integrity.



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