# DOSG Nitrocellulose: Rocket Propellant Qualification Requirements

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  - Recent Nitrate Ester Source Changes
- Nitrocellulose as a  Rocket Propellant Bonding Agent
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  - Assessment of non-UK Propellant for Naval Use
  - Conclusions

# UK MoD Requirement

- Continuity of Supply of Nitrocellulose Propellants
- Consistency of Propellant Quality
  - Performance
  - Safety Characteristics
  - Service Life

# Cellulose/Nitrocellulose Supply 1990-2012

- Cotton Linter background since 1990:
  - Holden Vale Linters, Dumfries NC
  - Holden Vale Linters, Bishopton NC
  - Temmings Linters, Bishopton NC
  - Temmings Linters, Bishopton NC, Muiden Plant
  - Temmings Linters, Bergerac NC
  - Temmings Linters, Wimmis
  - Milouban Linters, Bergerac NC
  - Milouban Linters, Wimmis
  - *Bergerac future material/SNPE-SAFRAN uncertainty*
  - *Replacement Source Linters, Wimmis 2008*

✓ *Successfully validated for UK MoD in 2011*

# UK MoD Requirement: Background

- Gun Propellants continue to prove tolerant to source changes
- Rocket Propellant position more complex:
  - Lower Performance, cartridge load propellants re-qualifications have also been shown tolerance to source changes
  - High Performance Case-Bonded rocket motors more problematic
    - Nitrocellulose is used as the primary bonding agent in some Service UK Rocket motors

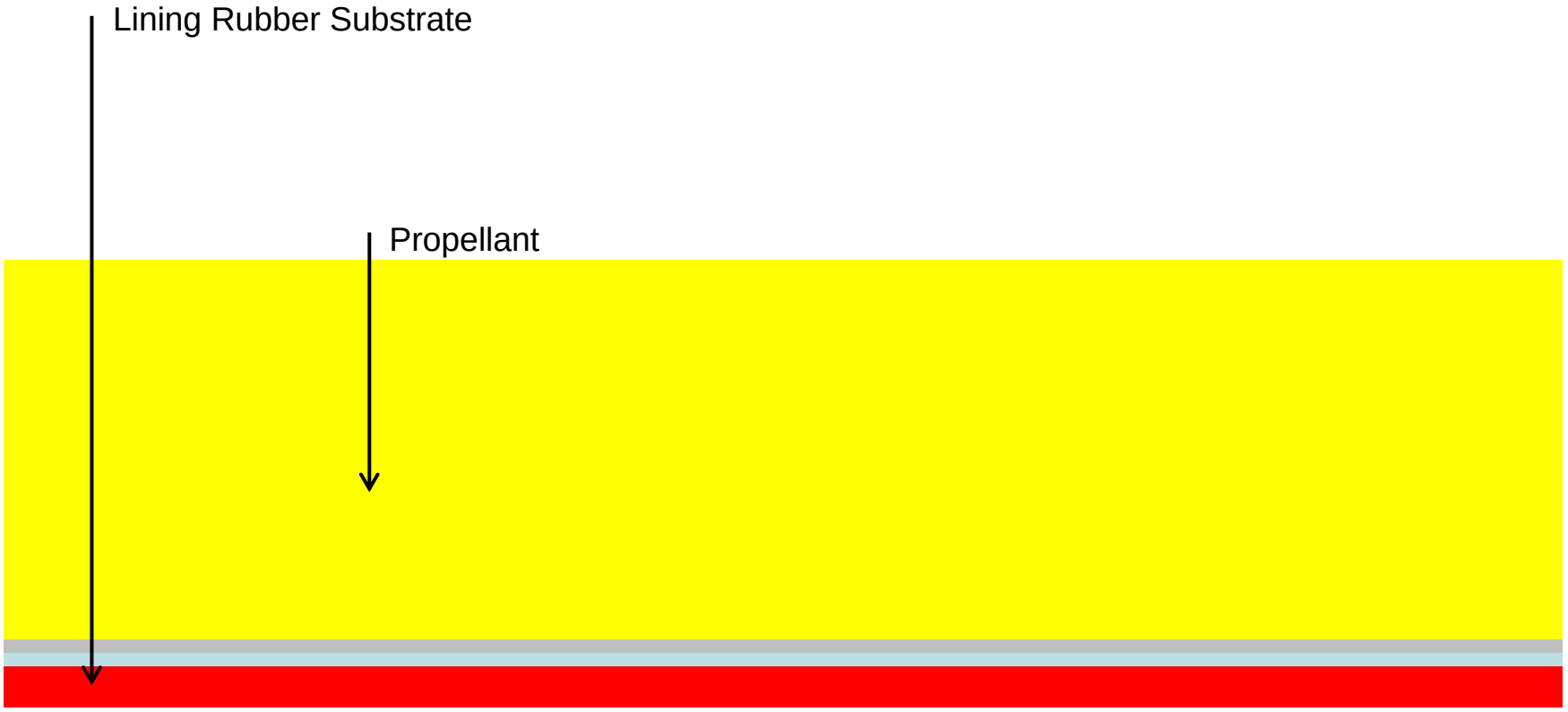
# 12 Year Service Rocket Motor

# Rocket Motor Failure: Role of NC

- Cause identified as propellant to lining rubber bondline failure
- Rocket Motor was beyond service life
- But older motors had been fired without fault

- Nitrocellulose source had changed
  - Bondline variability dates from this change
  - Service Life reduced for later batches

# Nitrocellulose: Propellant Adhesion



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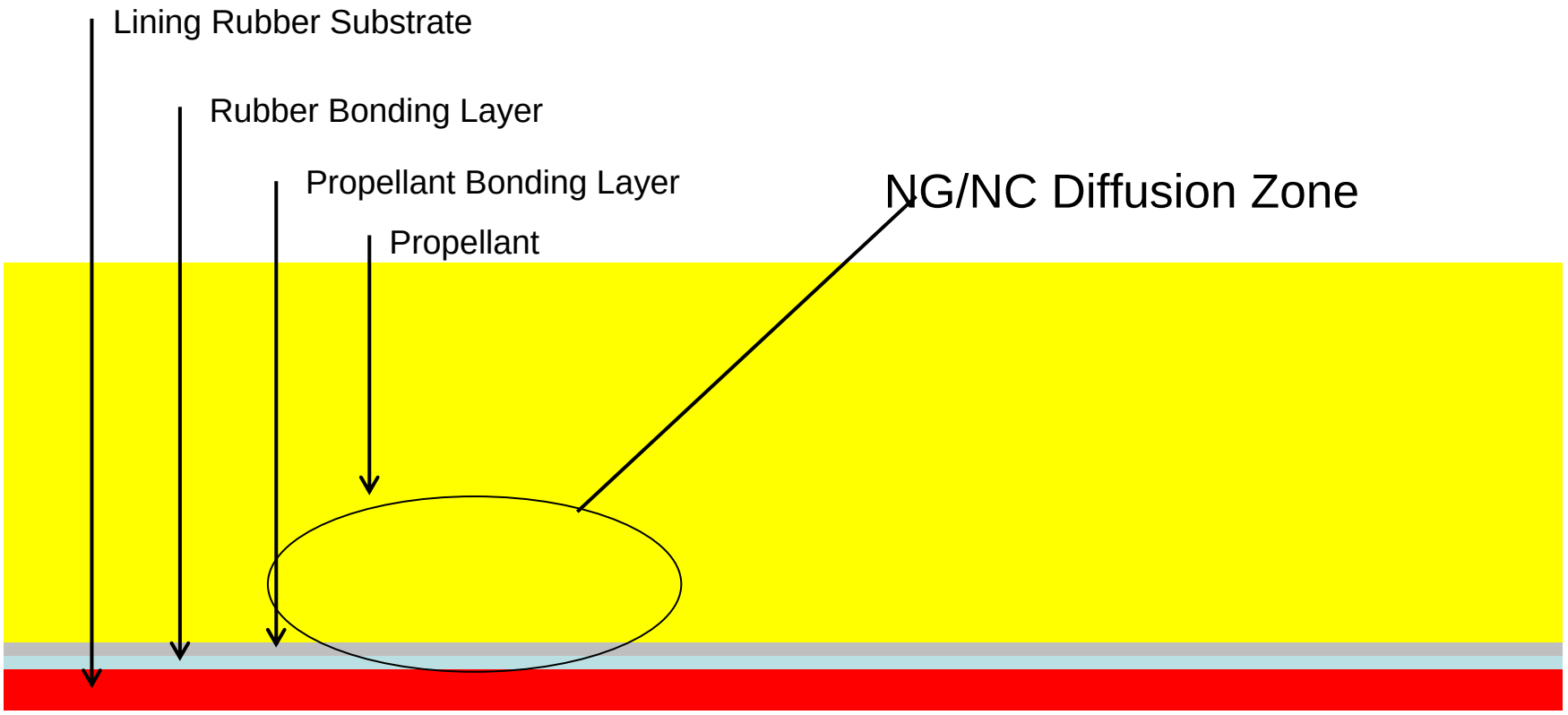

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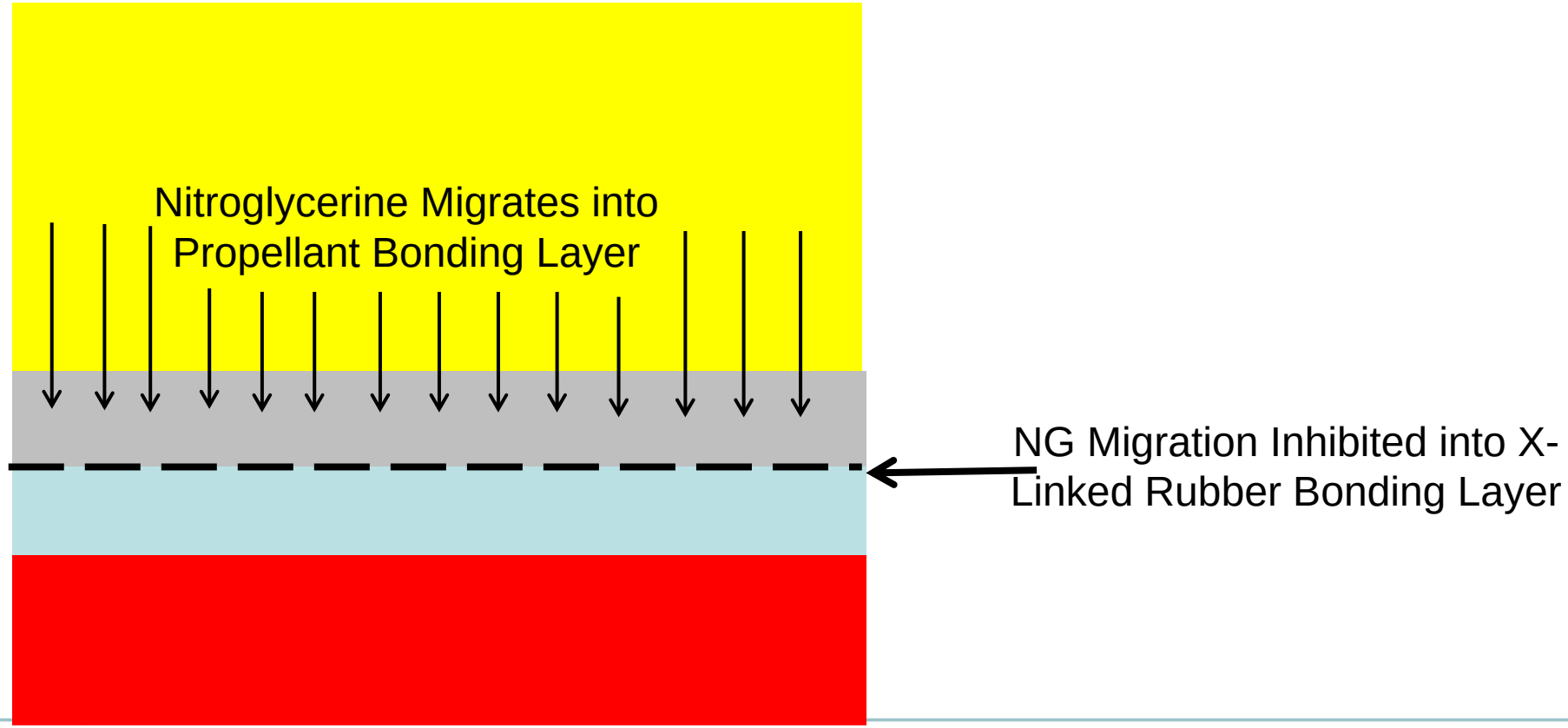

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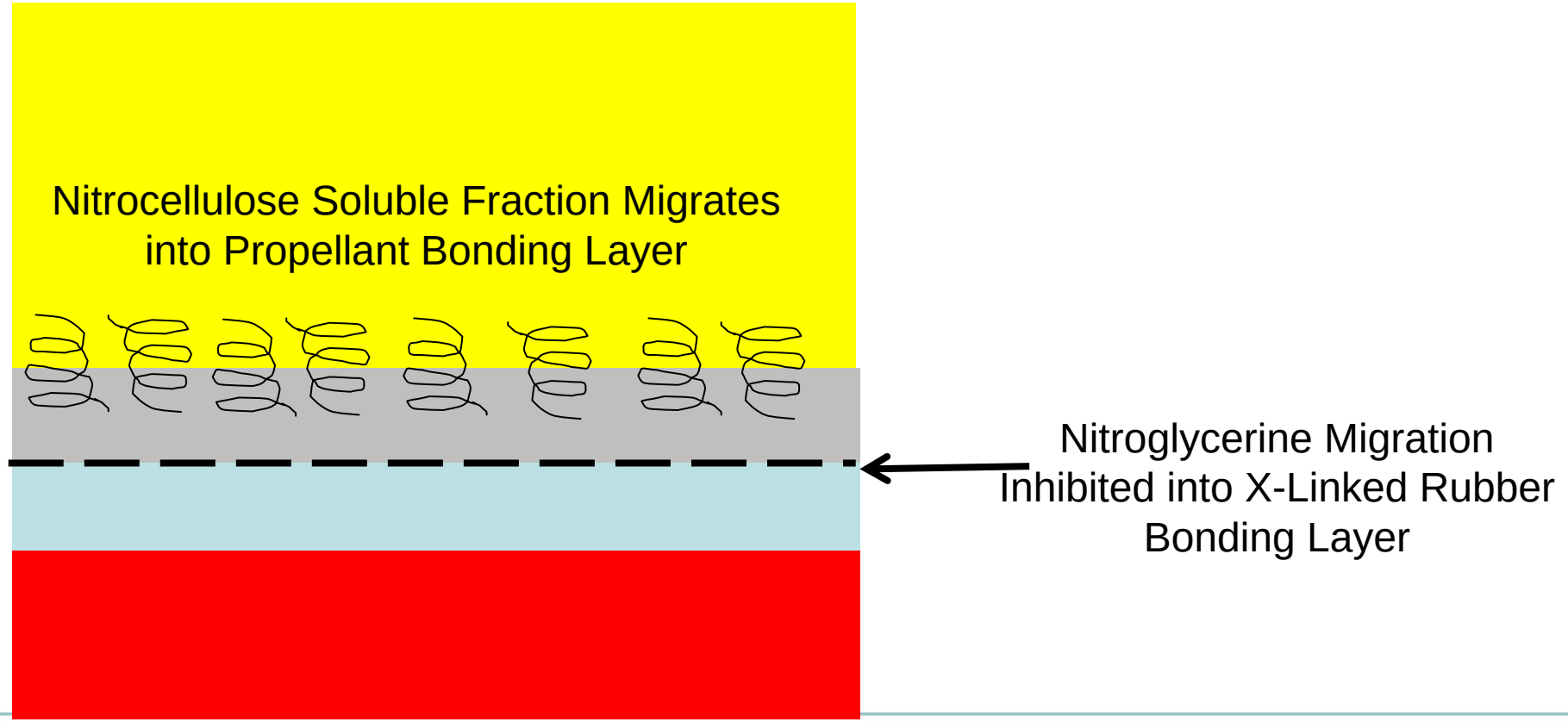
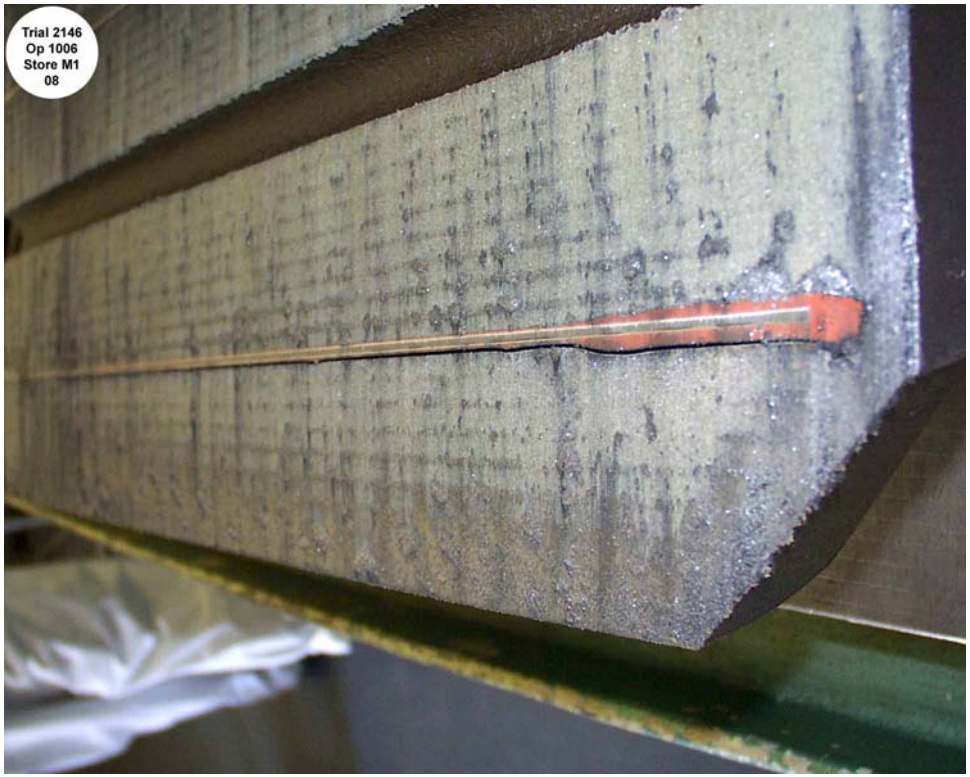


# Propellant Separation – 12 Year Service Motor



# Nitrocellulose Propellant Bonding: Key Parameters

- For propellant bonding:
  - NG diffusion rate
  - NG bonding layer equilibrium concentration
  - NC molecular weight distribution
  - NC solubility in NG and in bonding layer
  - NC gelatinisation characteristics (polarity distribution/size)
  - NC diffusion rate

- None of these parameters are adequately understood to enable bond strength prediction
- MoD funded research programme underway

# Conclusion

- The role of nitrocellulose characteristics in forming propellant bonds not adequately understood
- Basic parameters not yet quantified
- Predictive bonding model required to enable optimised service lives

# Chemical Stability of Nitrocellulose Propellants

- Historic UK Civil and Military Tests
  - Abel Heat Test
  - 80$^{O}$C Self Heating Test (originally ‘Silvered Vessel Test’)
  - 65.5$^{O}$C Chemical Stabiliser Consumption Test

- Test Requirements included in:

  JSP482 MoD Explosive Regulations

    - JSP 762 Weapons… Through Life Capability Management

- Disadvantage – UK Tests, Not Specified for Overseas Propellants

# Double Base Propellants for New UK Missile

- Naval Application – historically particularly demanding requirements in UK (BR1203)
- No Abel Heat Test or 80$^{O}$C Self Heating Test data
- Propellants in service with other Nations
  - Use a comprehensive characterisation of these propellants to establish propellants are ‘Safe and Suitable for Service’

# Test Plan for Double Base Propellants

| Test | Artificial Ageing Regime | | | | |
|---|---|---|---|---|---|
| | Fresh | 10 Days at 80°C | 4 Weeks at 60°C | 8 Weeks at 60°C | 12 Weeks at 60°C |
| **Chemical Stability** | | | | | |
| Stabiliser Content (% 2-NDPA) | Y | Y | Y | Y | Y |
| Abel Heat Test (65.5°C) | Y | N | N | N | Y |
| Vacuum Stability | Y | N | N | N | N |
| Calorific Value | Y | N | N | N | N |
| 90°C Mass Loss | Y | N | N | N | N |
| Self Heating Test | Y | N | N | N | N |
| UN Thermal Stability (3c) | Y | N | N | N | N |

Two Propellant Formulations, Sustain Type and Igniter Type

# Testing of Double Base Propellants

| Test (Conditions) | Sustain | | Igniter | |
|---|---|---|---|---|
| | Unaged | 12 Weeks @ 60°C | Unaged | 12 Weeks @ 60°C |
| Abel Heat Test (mins @ 65.5°C) | 9 | 7 | 16 | 8 |
| Self Heating Test (hours @ 80°C) | 2952 | - | 3192 | - |
| Chemical Stabiliser Content (%) [10Days @80°C] | 1.70 | 1.37 [0.96] | 1.76 | 0.74 [0.18] |
| Vacuum Stability (mls gas, 5g, 10 Days @80°C) | 6.4 | - | 3.9 | - |
| Mass Loss Test (days @ 90°C for 5% loss) | 37 (4.98%) | - | 31 (4.90%) | - |
| UN Stability Test (48 hrs. @ 75°C) | Pass | - | Pass | - |
| Temperature of Ignition (°C) | 176 | - | 162 | - |
| Calorific value (Cal/g) | 864 | - | 1130 | - |

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# Testing of Double Base Propellants: Conclusions

- Individual Tests Give Apparently Contradictory Results
- Ranking of Propellant Stability Inconsistent Between Tests
- Abel Heat Test Not Appropriate for Overseas Propellant

- DOSG Favoured Test Ranking For NC Based Propellants
  - 80°C Self Heating Test (but a UK Only Test)
  - Chemical Stabiliser Depletion
  - Vacuum Stability Test
  - 90°C Mass Loss Test

# Abel Heat Test/Self Heating Test for NC Propellants

- Abel Heat Test should not be used as the primary measure of NC based propellant stability – prefer Stabiliser Depletion Measurement
- Abel Heat Test appropriate as a Quality Test where it was used in original manufacturing specification
- DOSG will require 80°C Self Heating Test where any anomaly or marginality found in Stabiliser  Depletion, Vacuum Stability or 90°C Mass Loss Tests

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- DOSG will require 80°C Self Heating Test where any anomaly or marginality found in Stabiliser Depletion, Vacuum Stability or 90°C Mass Loss Tests
  - UK have only very limited Heat Flow Calorimetry database for nitrocellulose based rocket propellants.
  - Include HFC in future Propellant Qualification Tests

# Conclusions:

- A wide range of chemical stability tests exist
- It is rarely a case of ‘good’ and ‘bad’ tests
- Rather ‘appropriate’ and ‘inappropriate’ tests

- NC propellants are not entirely understood
- NC propellants will be required for decades to come
- Further research is essential for both safety and reliability