Rocket Propellant Characteristics as Influenced by Cellulose Type and Source

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Roxel
Propulsion systems

Nitrocellulose – Roxel's Most Critical Material

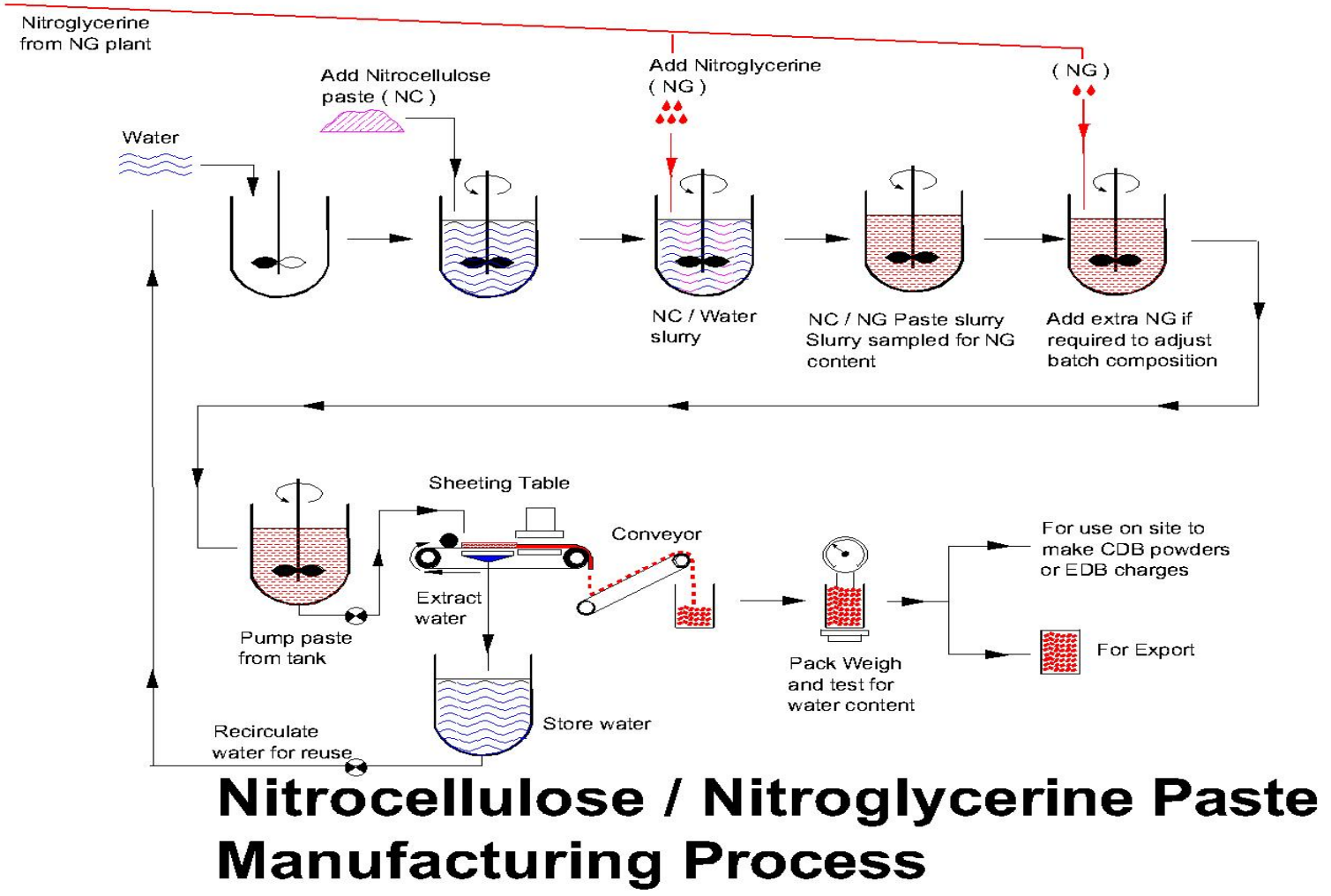
- Roxel is a world leader in the design and manufacture of insensitive munitions requiring solid rocket propulsion systems for tactical missiles. It is the third largest global supplier of rocket motors for tactical missiles, with 20 per cent of the world market and 60 per cent of Europe's.
- Roxel has supplied > 90 % of the rocket motors used in UK developed missiles and is active in all aspects of the propulsion life cycle, from initial concept through to disposal.
- Rocker Motors for:
  - Rapier
  - Sea Wolf
  - Starstreak
  - 2.75"
  - PAAMS

Nitrocellulose Usage at Roxel:

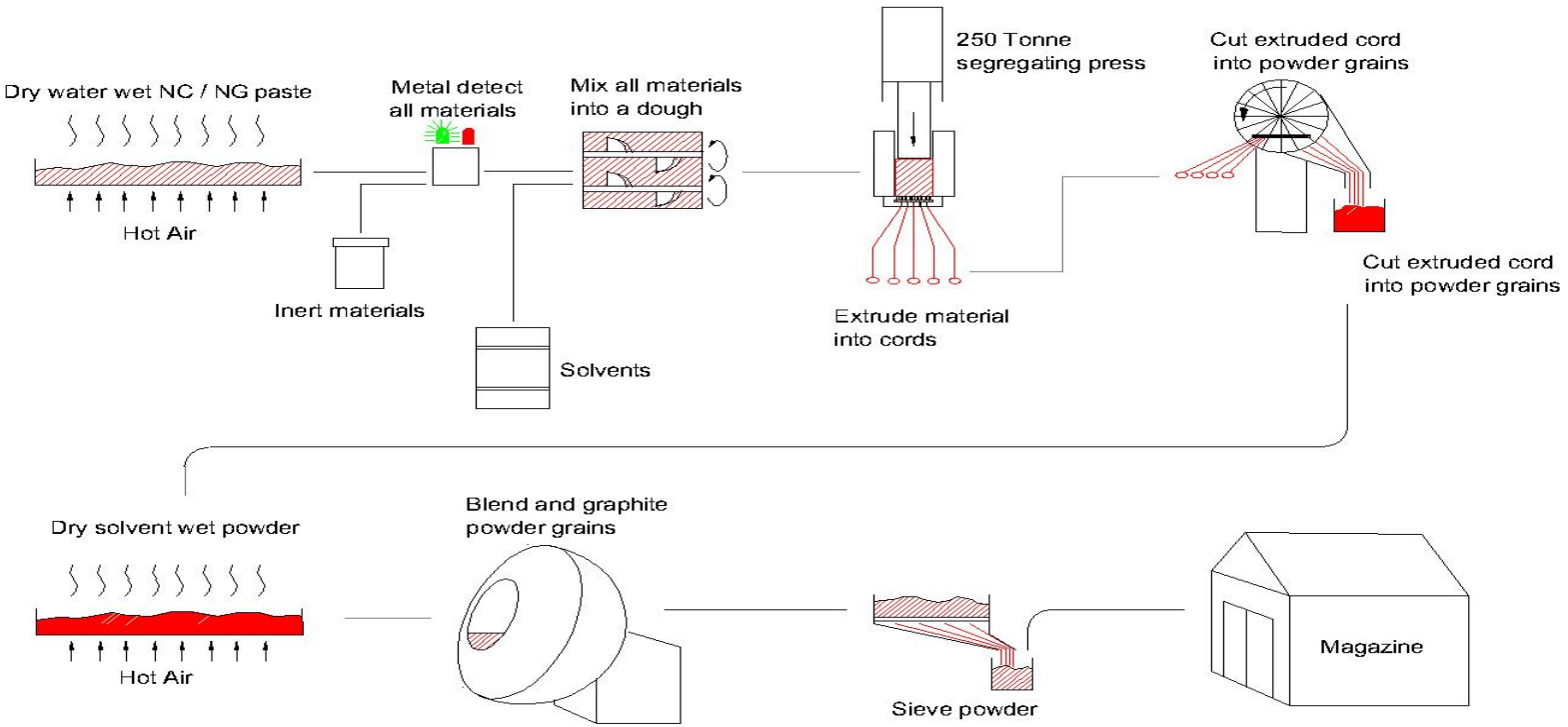
- Constitutes 30 to 80% of Double Base Propellants

- Nitrocellulose determines propellant properties:
  - Ballistic Performance
    - Burning Rate
    - Temperature Coefficient
    - Energy
  - Chemical Stability – Service life
  - Mechanical Properties – Safety over temperature range
  - Bonding – NC bonds propellant to motor case

How do Roxel Process NC?: 1



How do Roxel Process NC?: 2



Powder Manufacturing Process

Nitrocellulose Obsolescence

- Historically identified that apparently minor changes in cellulose properties could have major influence in propellant properties.
  - Example - ‘Minor’ change in bleach process at cellulose supplier prevented gelation at propellant charge level.
- Roxel very cautious on NC obsolescence issues.
- Carried out successful requalifications but these have further established our sensitivity to aspects of NC performance.
  - Processing characteristics particularly NC sensitive
  - Only a limited predictive capability has evolved.

NC Obsolescence – Continuing Issues

- NC Requalifications experienced by Summerfield (1990 -)
  - Holden Vale Linters, Dumfries NC
  - Holden Vale Linters, Bishopton NC
  - V20 Temmings Linters, Bishopton NC
  - V20 Temmings Linters, Bishopton NC, Muiden Plant
  - V20 Temmings Linters, Bishopton NC, Type D3
  - V45 Temmings Linters, Bergerac NC, CP2 Grade A Type 1
  - V45 Temmings Linters, Bergerac NC, CP2L16 Grade
  - V45 Temmings Linters, Wimmis, NC32 Grade
  - V45 Temmings Linters, Wimmis, NC77 Grade
  - *K70 Milouban Linters, Bergerac NC, CP2L16 Grade*
  - *N50 Milouban Linters, Wimmis, NC32 Grade*
  - *N50 Milouban Linters, Wimmis, NC77 Grade*
  - *Tartas Wood Sheet, Bergerac NC, CP2 W Grade*
  - *Cotton Sheet?*

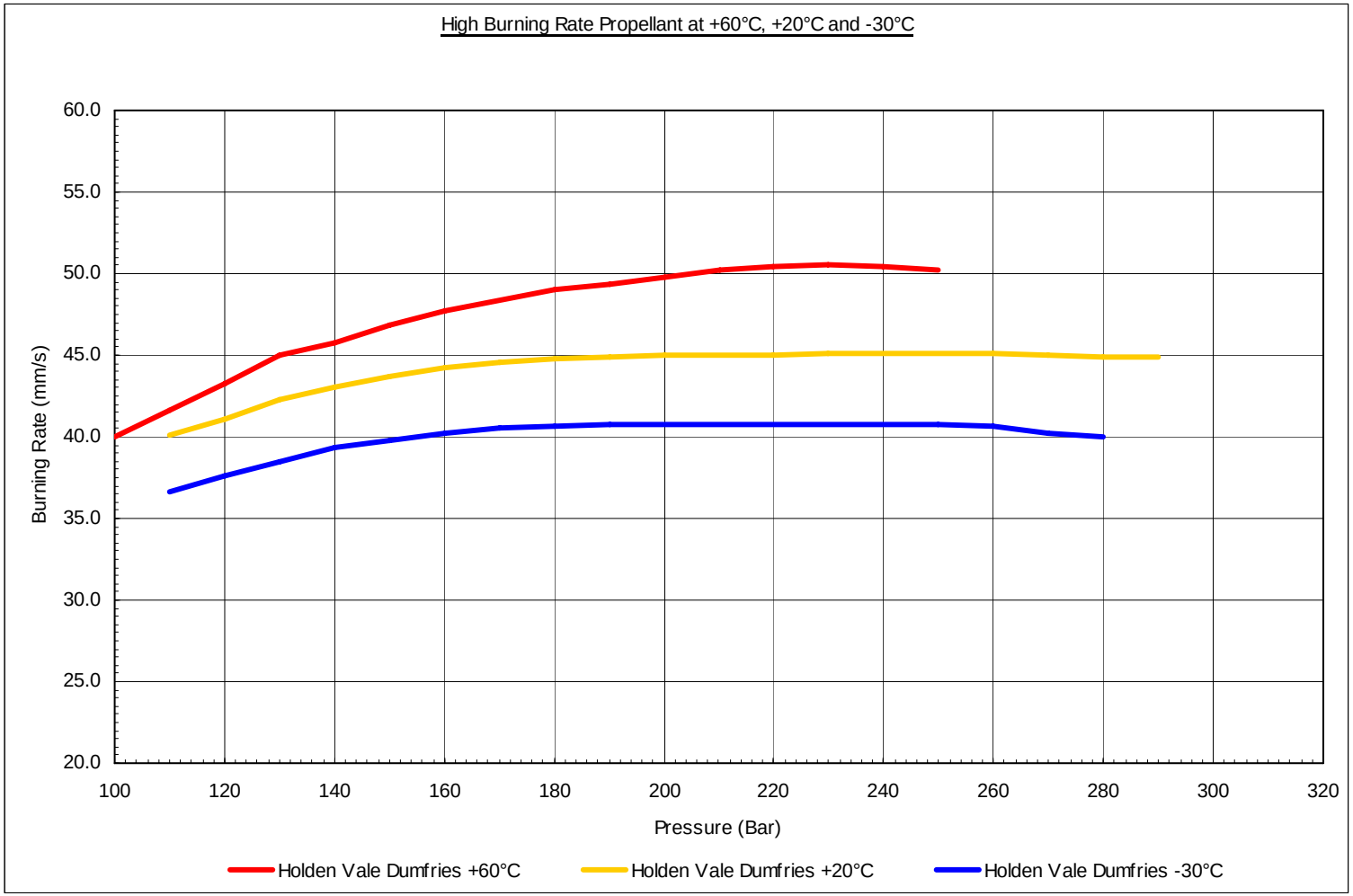
NC Properties for Double Base Propellant

- Change in NC or Cellulose Type can result in –
  - Change in Gelatinisation Properties (e.g. CP 2 Grade A from BNC)
  - Change in ‘green strength’ (also batch–batch variation)
  - Change in Die Swell and Surface Characteristics (e.g. Muiden Plant, also batch–batch variation
  - Which can all affect final propellant properties, particularly ballistics

Ballistic Spectrum (Slab) Motor

Measures Burn-Rate Across a Wide Pressure Range.

Ballistic Performance – NC/Cellulose Types



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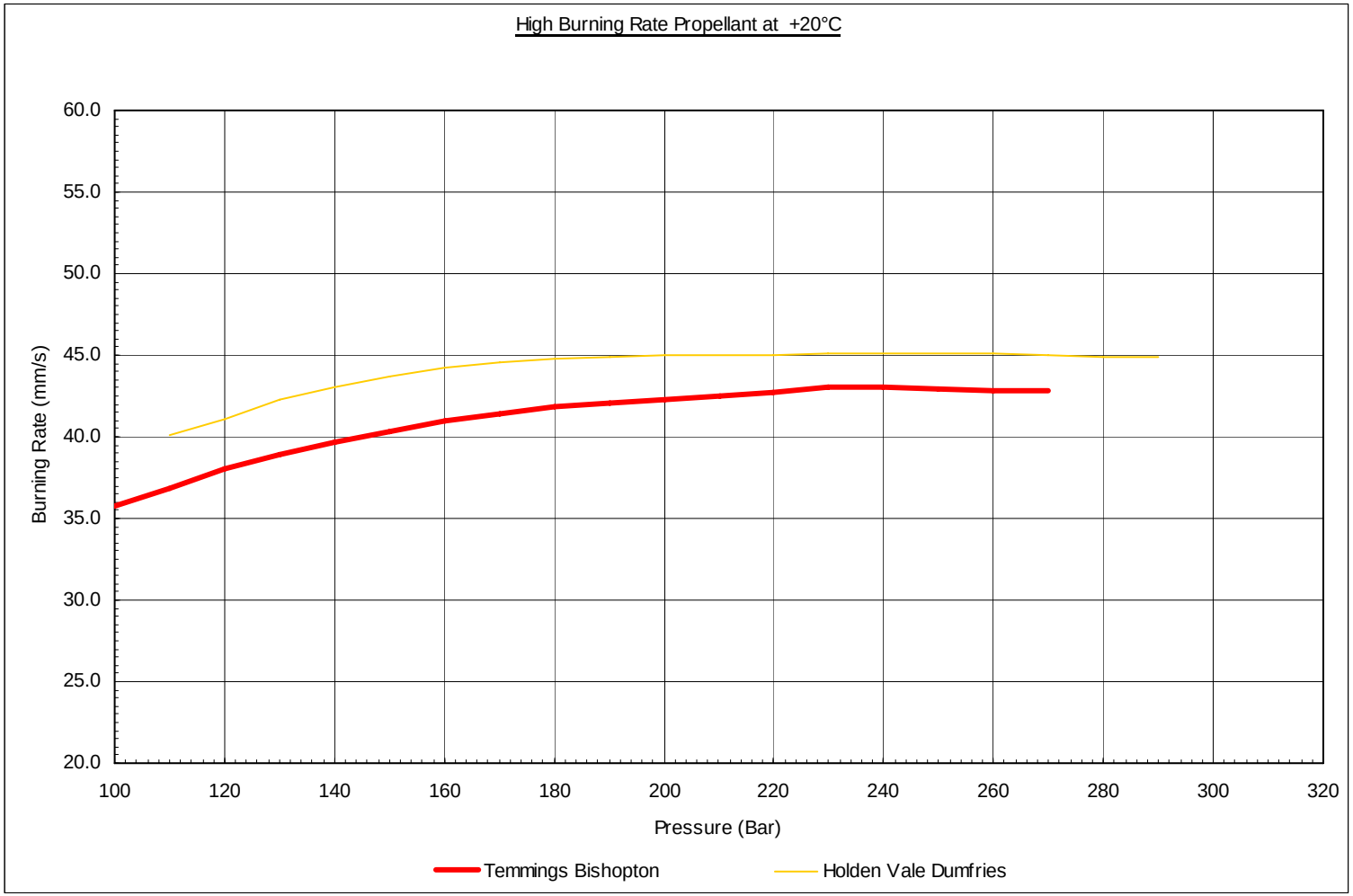

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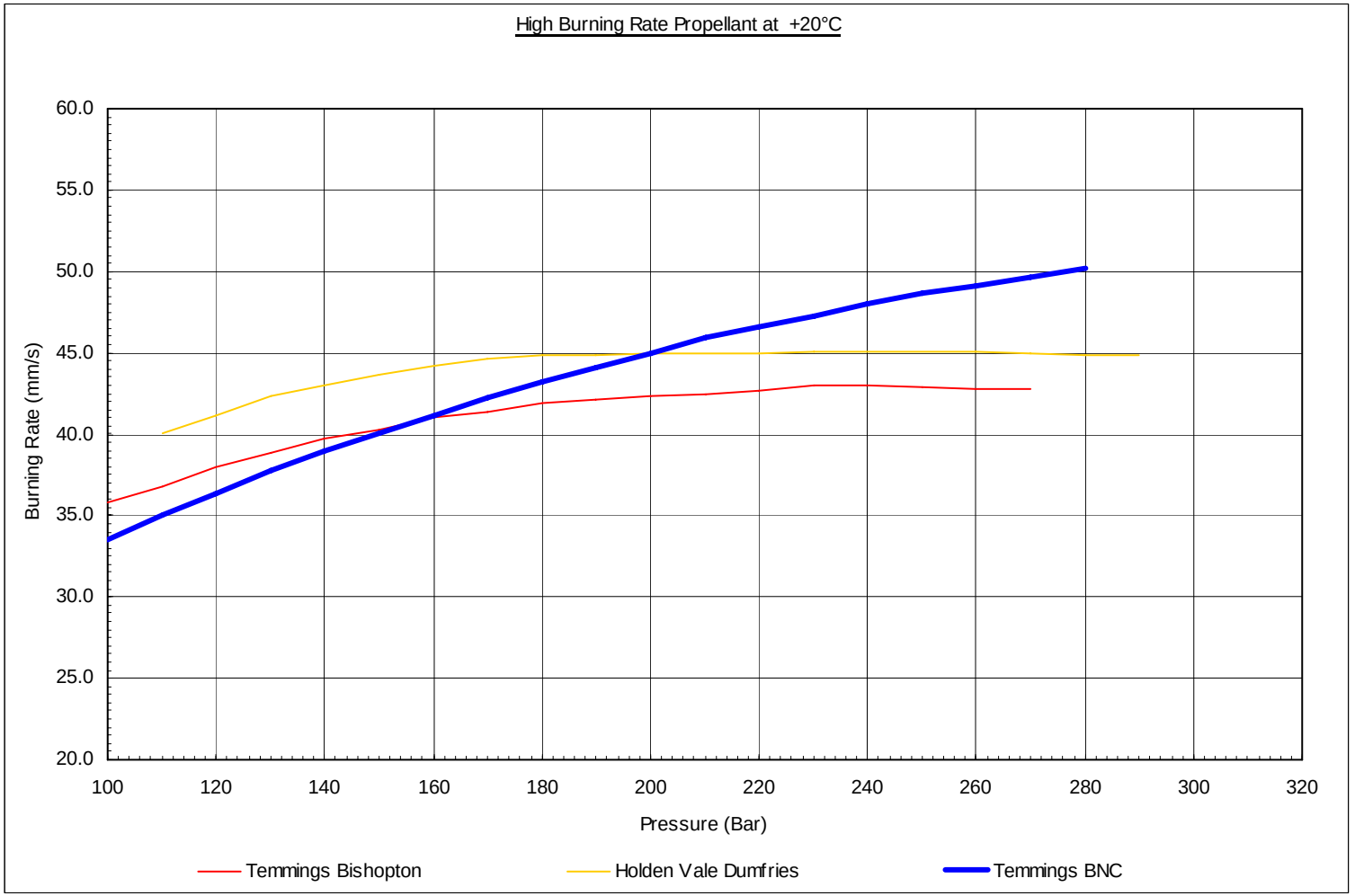

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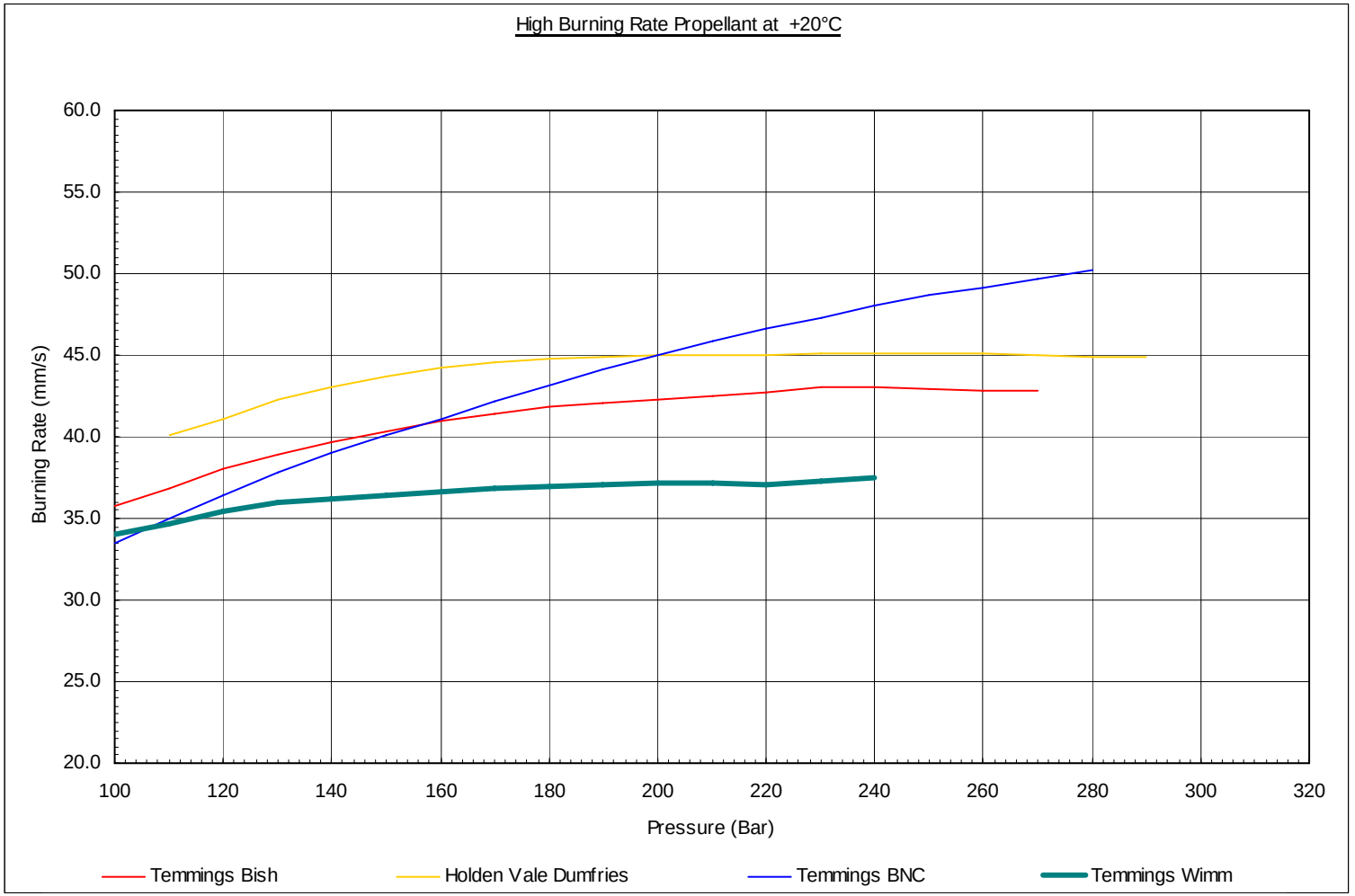
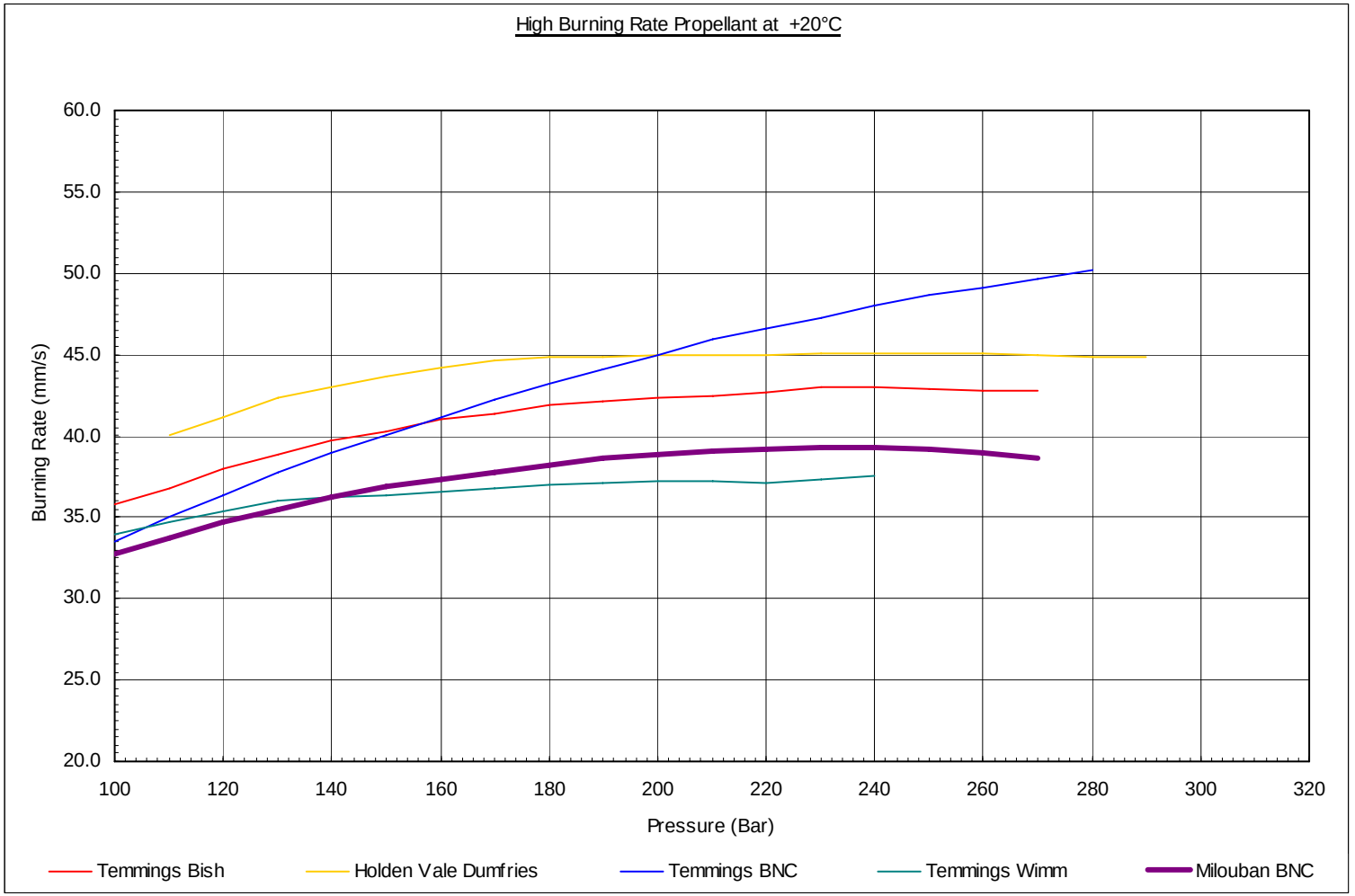


Ballistic Performance – NC/Cellulose Types



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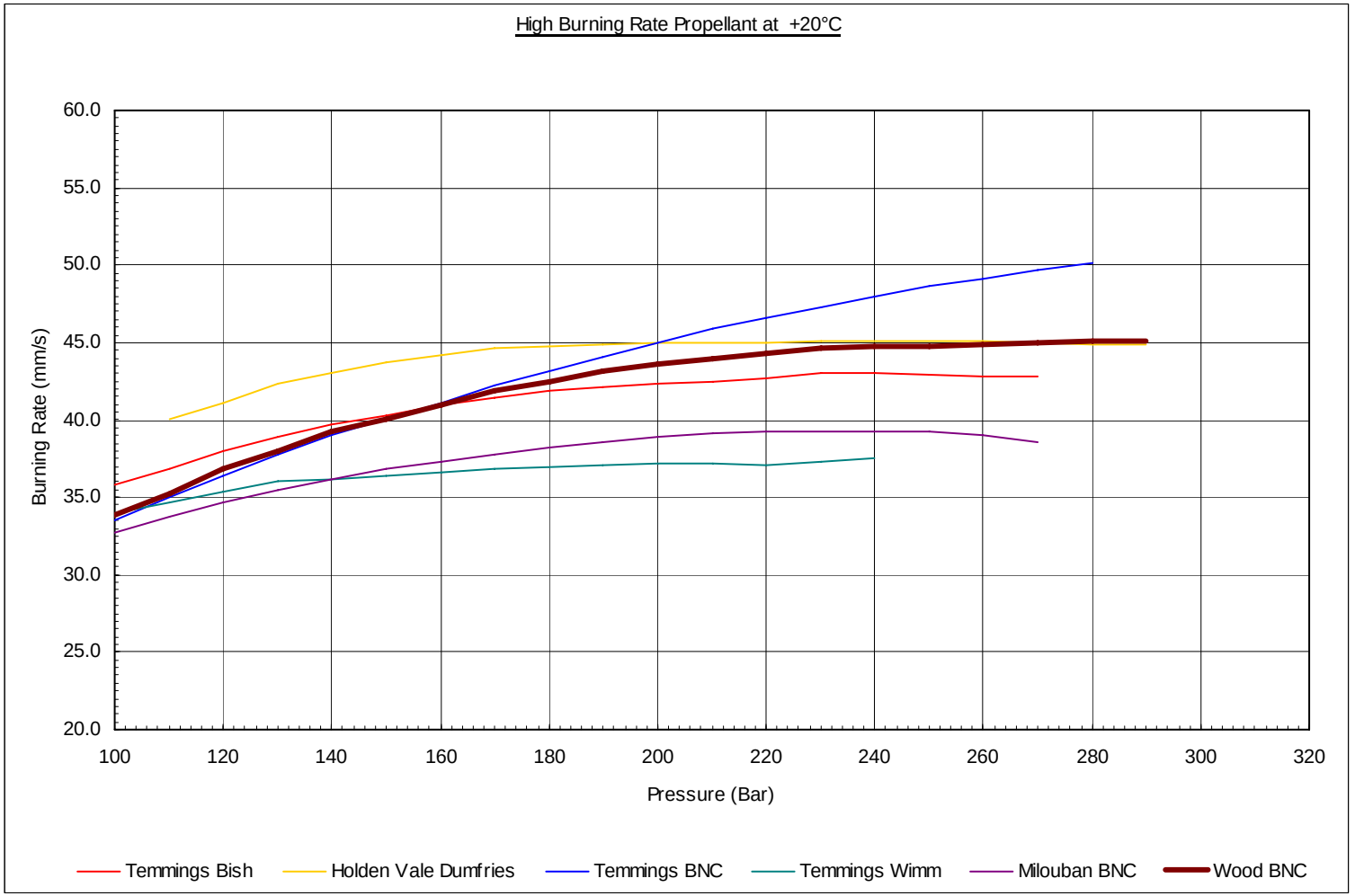

Mechanical and Chemical Properties

- Trend Data:

	Tensile		DMTA	
NC Type	Ustr +60°C (MPa)	%E -30°C	**Storage Modulus E' (MPa)**	T Peak (°C)
Cotton	0.140	10.9	10.0	-51.3
Wood	0.163	7.5	7.81	-49.9

NC Type	N	P	N-P
Cotton	0.57	0.33	0.34
Wood	0.57	0.30	0.40

Initial Conclusion: Differences in mechanical and chemical properties are real but relatively minor.

Conclusion

- Despite the very significant differences in cellular structure between cotton linter and wood-pulp – it is possible to make viable propellants without any process change.
- However batch changes of cotton linter based nitrocellulose have led to major changes in processing characteristics and performance.
- The root causes of variation in nitrocellulose performance in double base propellant are unidentified.
- Does gelatinised rheometry & solubility profiling of NC give better performance prediction?

NC Specification – Def. Stan 13-175

- Nitrogen Content
- Soluble Matter
- Mineral Matter
- Grit
- Fineness (Settling Test)
- Viscosity
- LBR Test
- Bergmann-Junk Test
- Abel Heat Test
- Acidity/Alkalinity

These tests have not proven useful predictors of performance