

Nitrocellulose fiber comparative characterization

Dr. Lee Goetz* and Amy Morris
BAE Systems, Radford Army Ammunition Plant,
Radford, Virginia, United States
October 22, 2019



Nitrocellulose Manufacture Modernization Efforts at Radford Army Ammunition Plant

Project overview:

- Designing and building an efficient nitrocellulose (NC) facility to replace the current NC facility at the Radford Army Ammunition Plant
 - Capable of producing all NC Grades per MIL-DTL-244C using sheeted wood pulp or sheeted cotton linters
- Performing risk mitigation efforts to manufacture nitrocellulose at a similar Bowas process NC manufacturer
- Enhancing lab characterization capabilities to deepen understanding of key properties from cellulose to nitrocellulose to propellant

New Technologies:

- Cutters
- Cellulose Handling System
- Disc Refiners
- Nitration Process
- Pressure Boiling
- Dual Centrifuges
- Pack out Process System



Nitrocellulose Process Design Changes

- Sheeted cellulose sources

- Sulfite wood pulp



- Kraft wood pulp
- Cotton linters

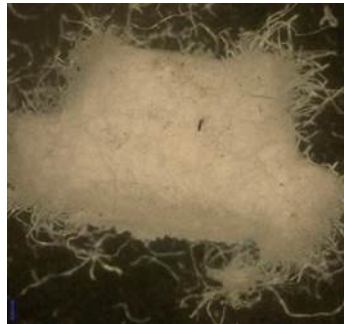


- Cellulose preparation

- Tearing



- Cutting

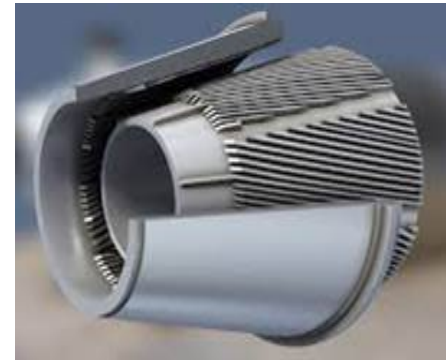


- NC refining methods

- Conical



- Disc



Nitrocellulose Characterization and Test Methods

Nitrogen content

Fineness

Viscosity

Stability

Ether alcohol solubility

Acetone insolubles

Fiberization quality
(Agglomerates/Bundles)

- Described in MIL-DTL-244C
- Established historical test methods
- Provide baseline analysis
- Will be performed during commissioning

- “Once in a lifetime” opportunity to test at the boundaries and establish baseline comparisons with the legacy process
 - What additional characterization methods are available?

Nitrocellulose Fiber Dimensional Test Methods

Indirect Methods



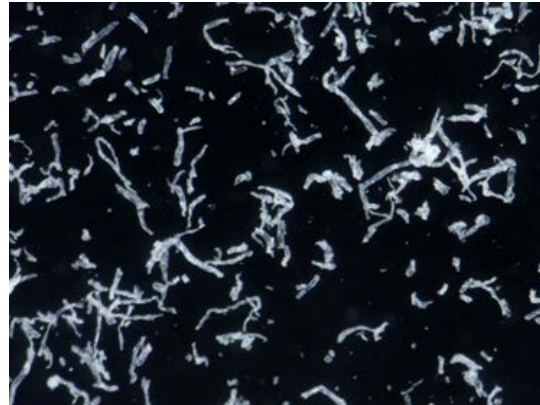
Direct Methods

- Fineness
 - May be sensitive to agglomerates content
- Fiberization quality (agglomerates)
 - Not effective for fiber length
- Microscopy

What other tests are available for fibers?

- Particle size analyzers
 - Laser diffraction/image analysis
 - Limited dimensional range
 - NC has been analyzed to varying degrees of success and implementation

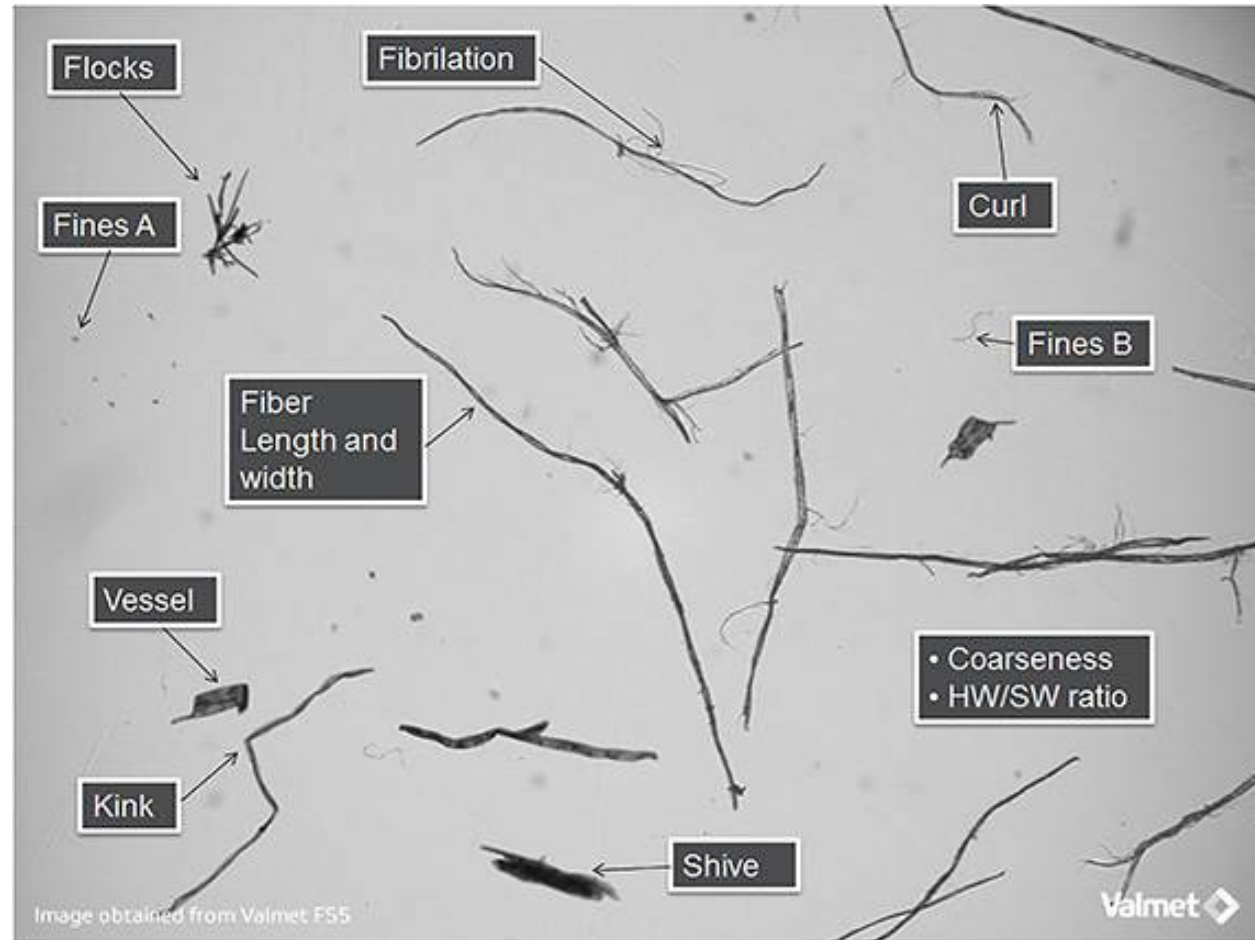
- Pulp fiber quality analyzers
 - Image analysis
 - Developed for cellulose pulp-type fibers



Cellulose Fiber Analyzers via Image Analysis

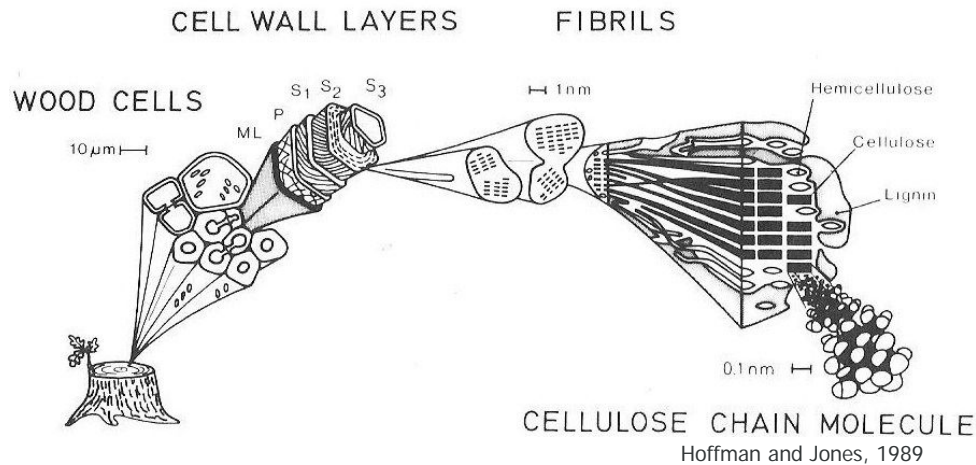


- Sheeted cellulose (cotton linters and wood pulp)
- Never dried or dried nitrocellulose
- Sampling per production sampling protocols or by experimental design

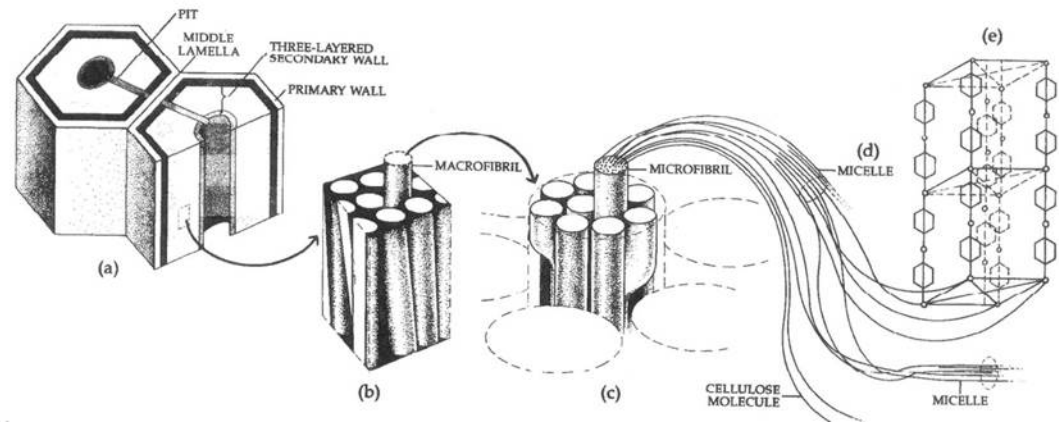
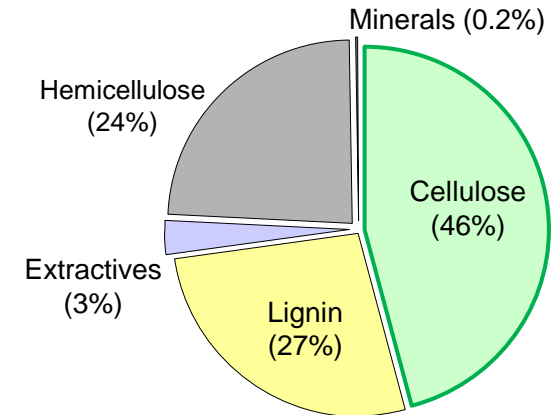


Wood Pulp Cellulose

- Source: Softwood trees (northern and southern)
- Wood: cellulose, lignin, hemicellulose



Slash Pine (*pinus elliottii*)



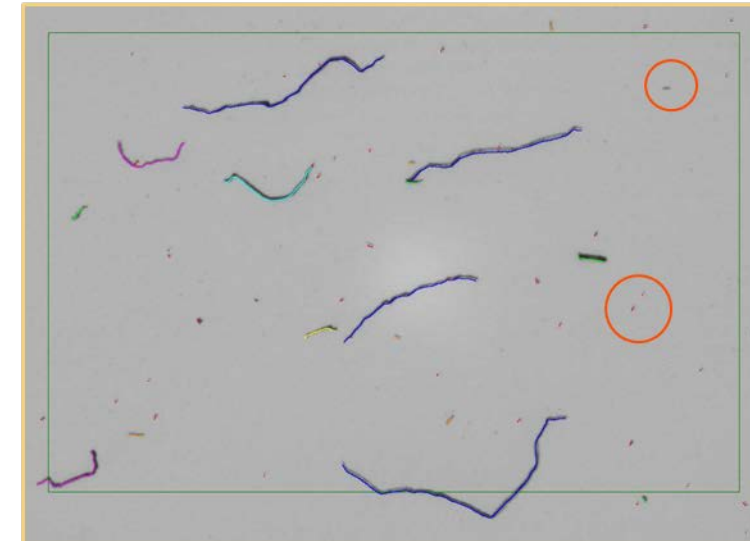
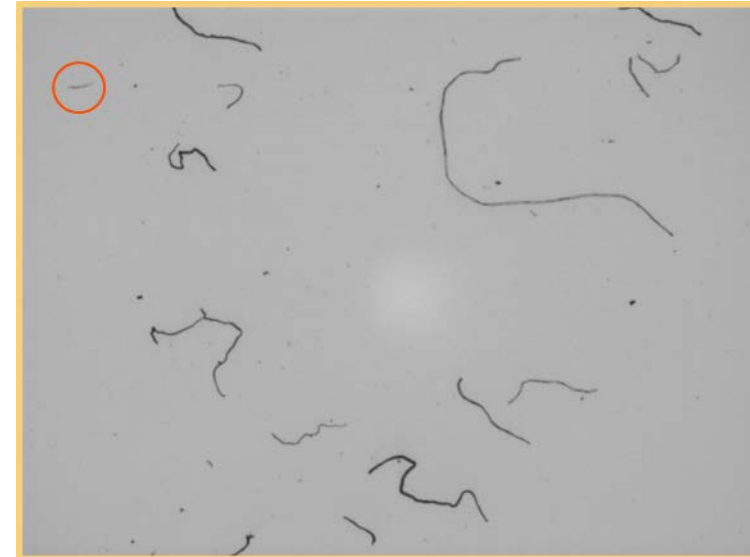
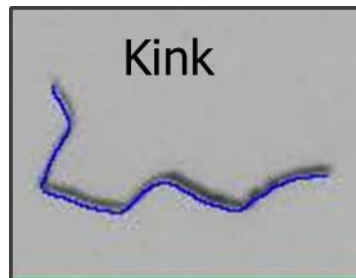
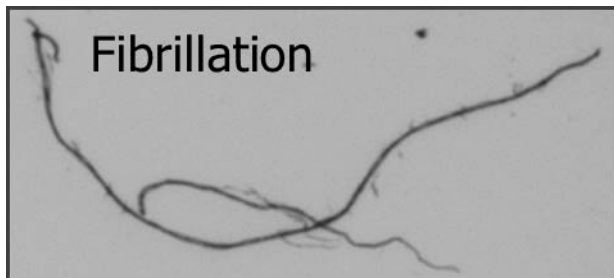
Esau, 1960

Fiber Analyzer Implementation and Evaluation

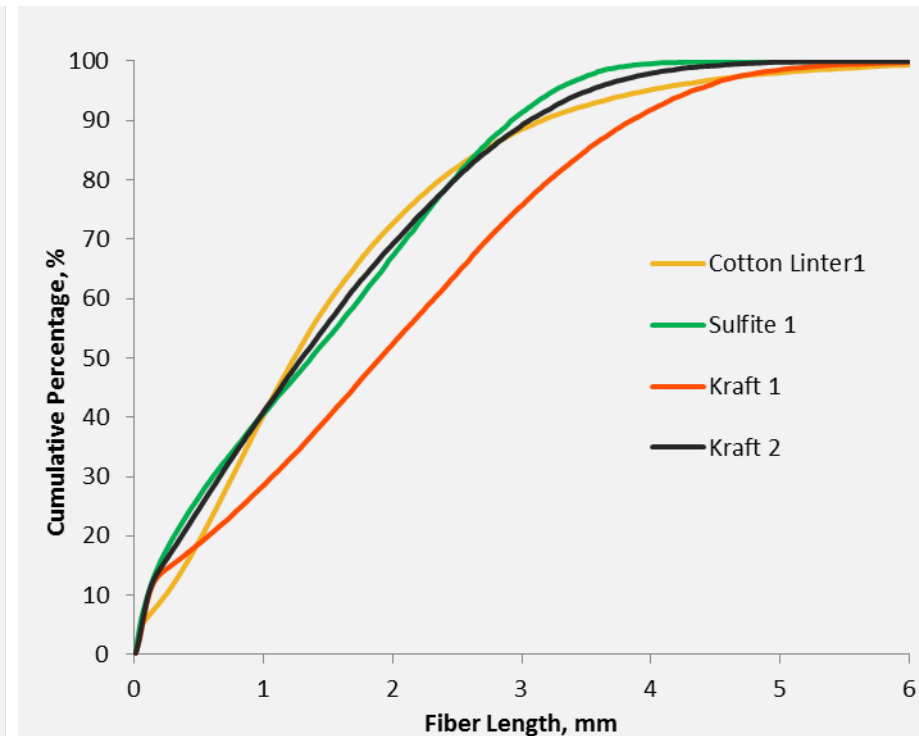
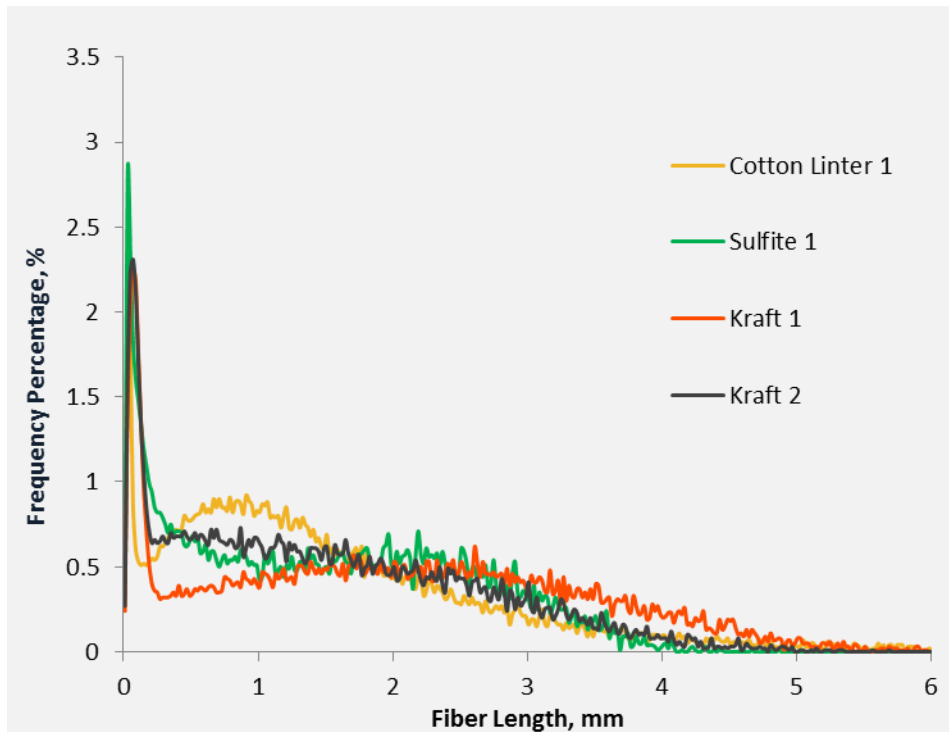
- 1: Incoming sheeted cellulose pulps – cotton linter, sulfite and kraft pulp
- 2: Kraft wood pulp Grade B nitrocellulose refining trials
- 3: Cotton linter pulp Grade B nitrocellulose
- 4: Cotton linter pulp Grade D nitrocellulose

Application 1: Incoming Cellulose Fiber Properties

- Sulfite to Kraft wood pulp transition evaluations
- Kraft wood pulps
 - Wider fibers
 - Lower fines content and lower fibrillation
 - Kraft 2 pulp has comparable average fiber length to Sulfite 1 and Cotton linter 1

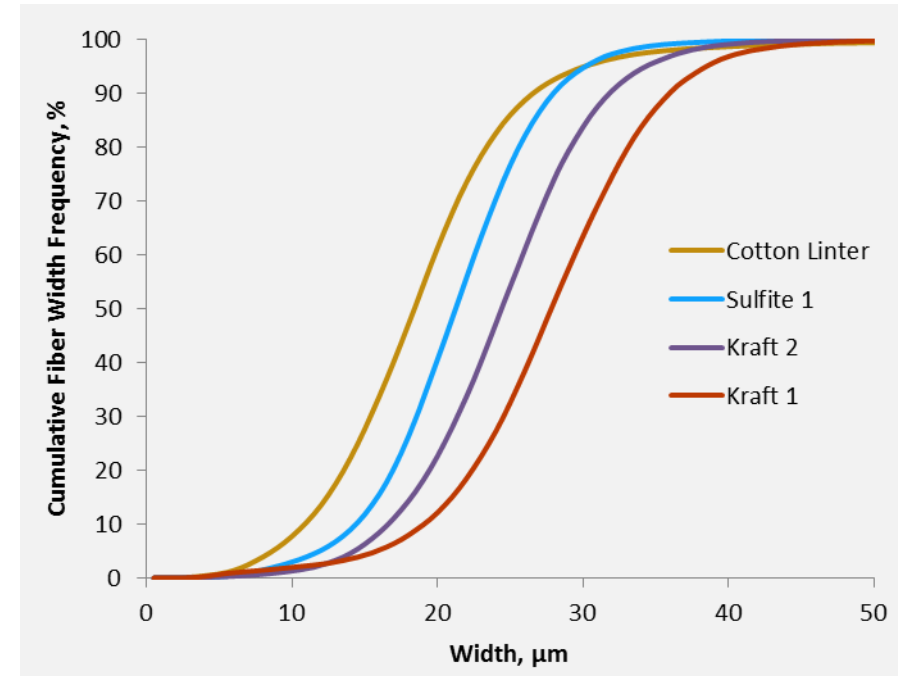
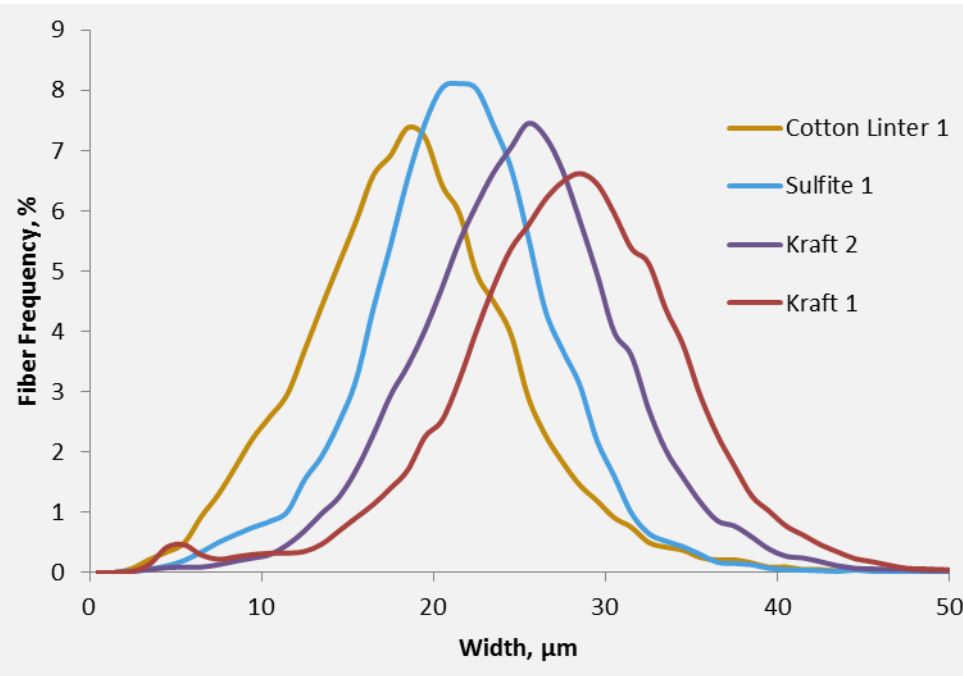


Cellulose Fiber Length Distributions



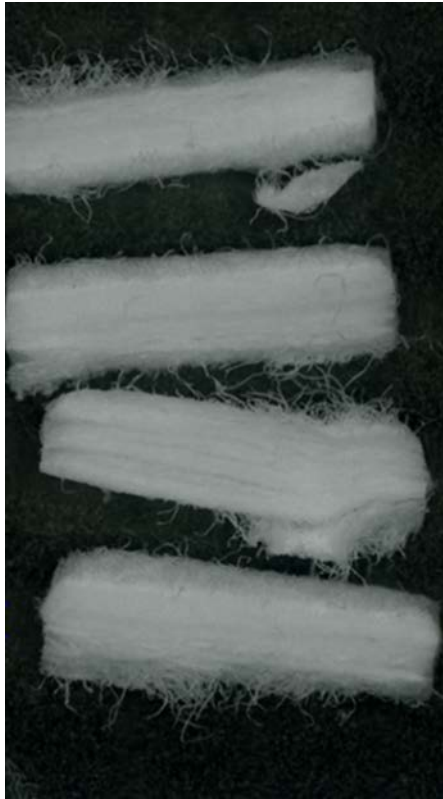
- Fiber length distributions vary by fiber source, production processes
 - Kraft 1 has broadest fiber length distribution
 - Kraft 2 similar distribution to sulfite 1
 - Cotton linter 1 differs from wood pulps

Cellulose Fiber Width Distributions

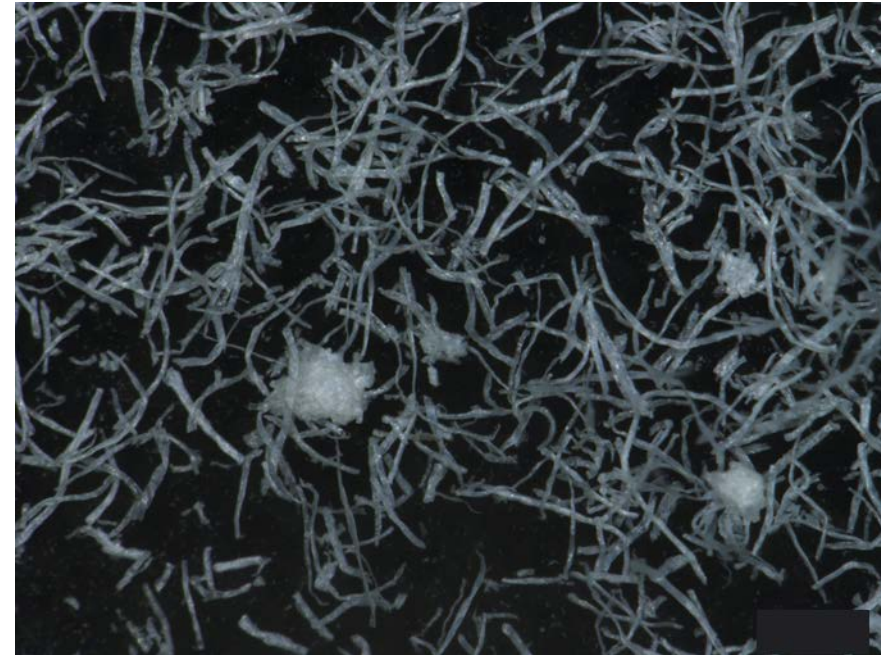


- Fiber widths vary by fiber origin
- Similar distribution spans

Application 2: Grade B Wood Pulp

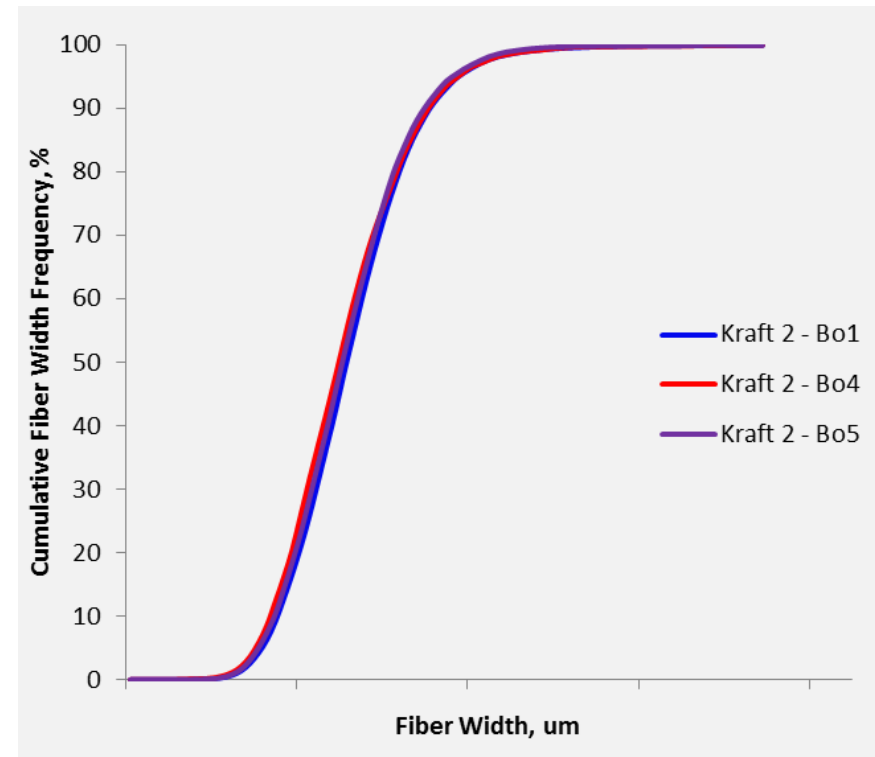
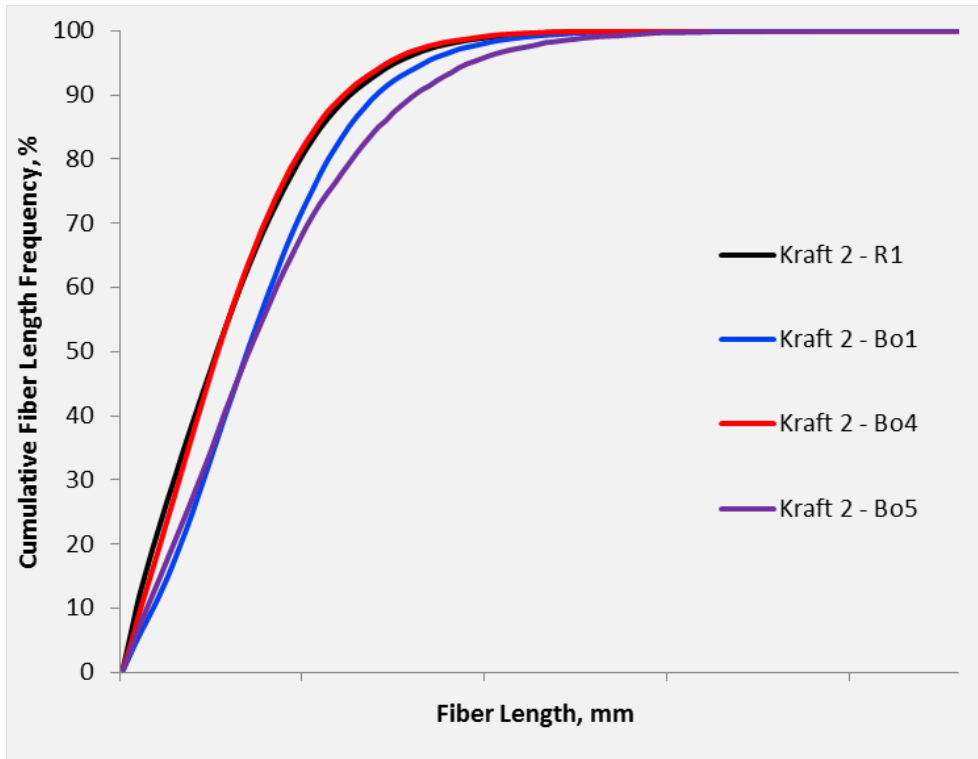


- Kraft 2 wood pulp
 - Cutting cellulose process
-
- Refining: Disc or Conical

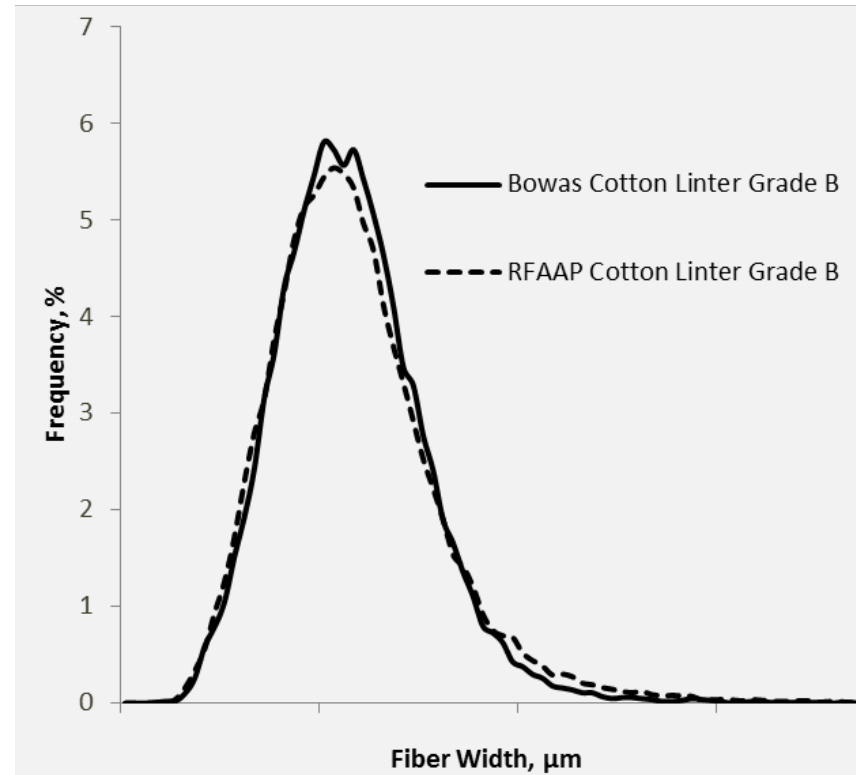
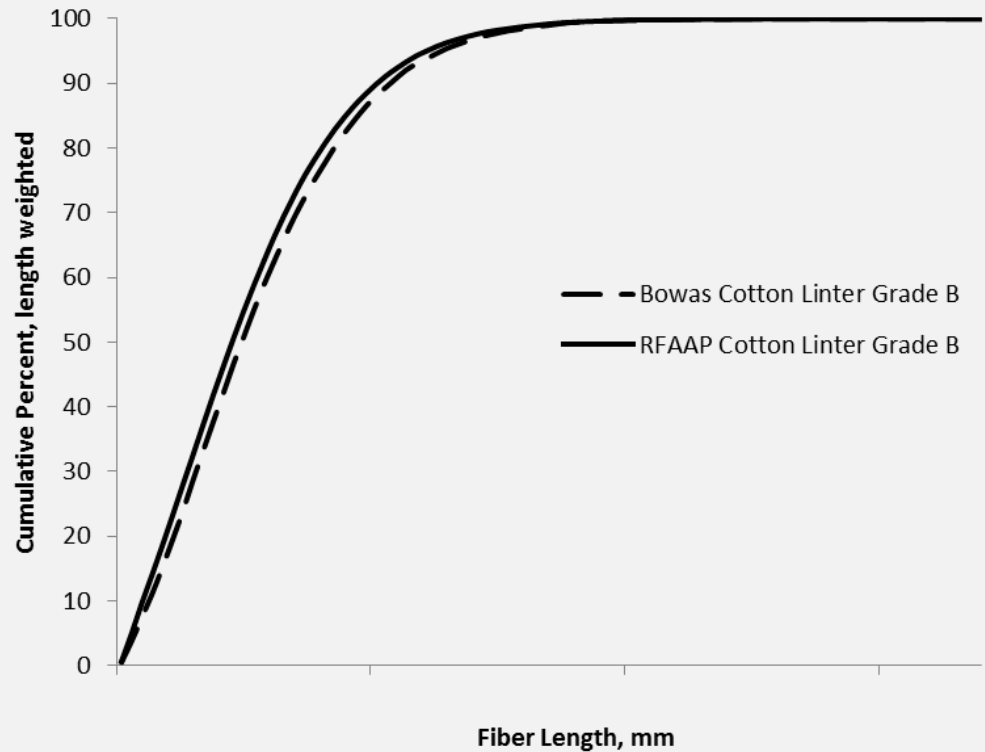


- Grade B Nitrocellulose

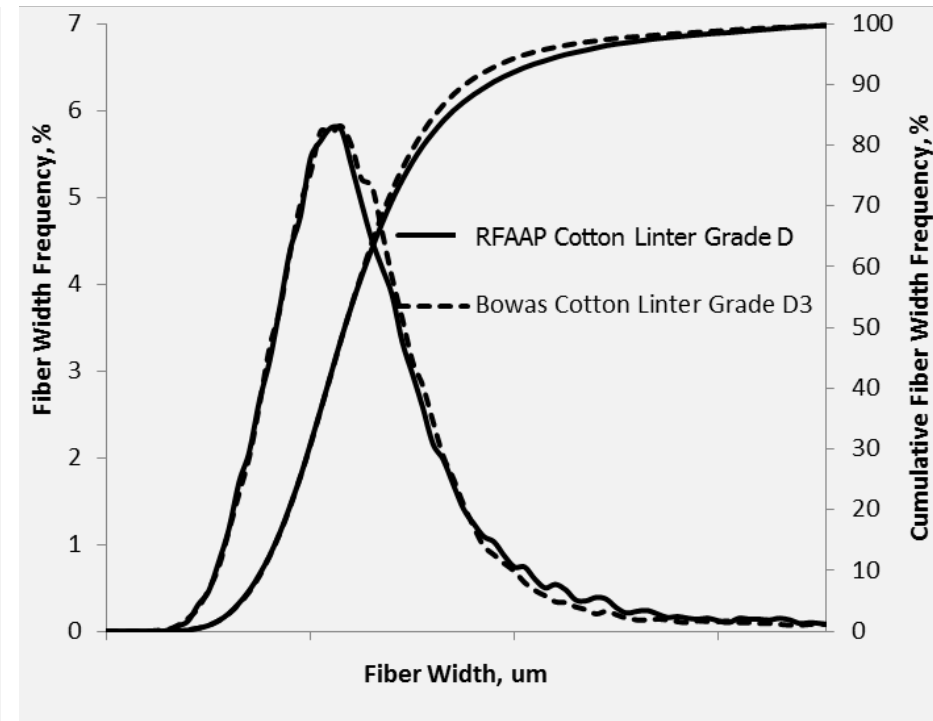
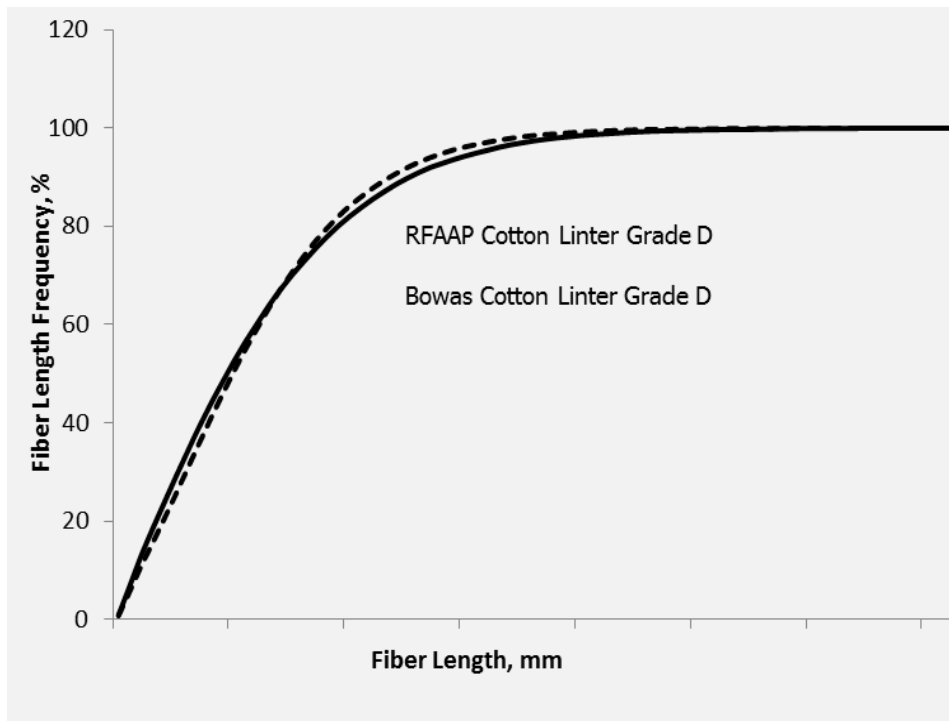
Application 2: Grade B Wood Pulp



Application 3: Grade B Cotton Linters



Application 4: Grade D Cotton Linter



Summary and Conclusions

- Modern nitrocellulose facility is under construction with several process design changes from the current RFAAP
- Opportunity to investigate and implement additional test methods to supplement data provided by current test methods (MIL-DTL 244C)
- Lab testing mission is to support NC commissioning and subsequent propellant qualification
- Fiber image analyzer has been used to evaluate incoming cellulose, in-process nitrocellulose, and nitrocellulose grades and blends
- BAE Radford has performed baseline studies with RFAAP kraft NC, RFAAP Grade D, and Bowas NC process nitrocellulose
- Continuing efforts:
 - Correlating NC properties to propellant processing and performance
 - Understanding essential cellulose and NC properties to propellant processing performance

Acknowledgements

- Mr. Phillip Abbate, TARC team
- CCDC-AC
- PM JAMS
- Lab Testing IPT members

■ Thank you