Fundamentals of Textile Testing

IFAI Expo 2017
New Orleans, LA

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General Testing Information

Find 4 differences in the pictures below....
Why Test?

- Research and Development
- Selection of Raw Materials
- Process Development
- Product Testing
  - Compliance testing
  - End use performance
  - Lot to lot comparison
  - Defect detection
  - Advertising

Note: The expense of testing is not at all costly when compared to the cost of returned merchandise and dissatisfied customers!

Sources of Test Methods

- In House
- ASTM
- AATCC
- ISO
- Professional Organizations
- Federal Standards
- Others

Testing of Industrial & Technical Textiles vs. Traditional Textiles

- Performance properties such as strength, durability, and thermal resistance are more important for industrial textiles, and minimum requirements for these properties are generally higher than for apparel and household textiles.
- In general, tests for comfort and aesthetics are not as important for industrial textiles.
- Product specifications for industrial textiles may be based more on performance than on construction and appearance.
- For a given property to be measured, the same standard test procedures and equipment are used for both industrial and traditional textiles!
Examples of Standards

• Standard Test Methods
  – Specify procedure, apparatus, and conditions of tests.

• Standard Definitions or Nomenclature
  – Establish uniformly accepted meanings for terms.

• Performance Specifications
  – Means of judging product acceptability.

Typical Format of a Test Standard May Include:

• Introduction/Scope/Summary
• References and Terminology
• Apparatus and Materials
• Sampling and Preparation of Test Specimens
• Conditioning
• Procedure
• Calculations and Reporting
• Precision and Bias Statement

Sample Table from a Performance Specification:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Minimum Requirements</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking Strength (load)</td>
<td>150 lbf, min</td>
<td>ASTM D5034</td>
</tr>
<tr>
<td>Tear Strength (1/4 in.)</td>
<td>10 lbf</td>
<td>ASTM D1424</td>
</tr>
<tr>
<td>Dimensional Change</td>
<td>3% max</td>
<td>AATCC 135</td>
</tr>
<tr>
<td>Colorfastness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Burnt Gas Fumes - 2 cycles</td>
<td>Class 4 (a)</td>
<td>AATCC 23</td>
</tr>
<tr>
<td>- Laundering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shade change after 1 cycle</td>
<td>Class 4 (a)</td>
<td>AATCC 61</td>
</tr>
<tr>
<td>Crocking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>Class 4 (a)</td>
<td>AATCC 8, 116</td>
</tr>
<tr>
<td>Wet</td>
<td>Class 3</td>
<td></td>
</tr>
<tr>
<td>- Light (160 AATCC SFU)</td>
<td>Class 4 (a)</td>
<td>AATCC 16</td>
</tr>
<tr>
<td>- Ozone - 1 cycle</td>
<td>Class 4 (a)</td>
<td>AATCC 129</td>
</tr>
</tbody>
</table>

*This method has been withdrawn. Use ASTM D 900 instead.
Basic Statistical Applications to Testing

Obtaining Useful Results

- A test method is useful if it gives reproducible results which correlate with the parameter of interest to the user.
- Inter-laboratory correlation is important.
- Test results are characterized by their accuracy (mean value) and their precision (standard deviation).
Accuracy vs. Precision

Accurate, but not precise:

! Actual or Standard Value; * Observed Values

Precise, but not accurate:

! Actual or Standard Value; * Observed Values

Calculation of Variance and Standard Deviation

\[ s^2 = \frac{\sum (x - \overline{x})^2}{n - 1} \]

where

- \( x \) = individual data values
- \( \overline{x} \) = mean value
- \( n \) = number of observations

Sources of Experimental Error

- Systematic (Determinate) - Can Be Detected and Corrected
  - Improper Calibration
  - Wrong Test Method
  - Instrument Malfunction
  - Calculation Errors
  - Operator Technique

- Random (Indeterminate) - Cannot Be Eliminated
  - Judgement in Reading Scales
  - Instrumental Noise
Normal Distribution

We can use the sample mean and standard deviation (x and s) to describe the population and represent the sample data as a normal distribution curve. The shape of the curve is defined by the values of mean and standard deviation.

For a Normal Distribution:
- \( x \pm s \) includes 68.27% of the population
- \( x \pm 2s \) includes 95.45% of the population
- \( x \pm 3s \) includes 99.73% of the population

Examples of Statistical Analysis of Data Sets

These analyses are based on calculations using the mean, standard deviation, and number of observations in a data set. A distribution similar to the normal distribution, called the t-distribution, is also utilized:

- **Confidence Interval**
  An expression stating that the true mean value for a population, \( \mu \), is likely to lie within a certain range centered around the sample mean, \( \bar{x} \).

- **Comparison of Means**
  A calculation to determine if the mean values for 2 data sets are significantly different.
Fiber Properties and Test Methods

Examples of Fiber Performance Properties

- Appearance and identification (shape, birefringence)
- Color
- Crimp
- Fineness (linear density)
- Length and length distribution
- Luster
- Moisture regain
- Solubility and chemical resistance
- Specific gravity
- Tensile properties (strength, elongation, modulus)
- Thermal properties (T_g, T_m) and flammability

Can you identify the fibers below?
Identification of Fibers

- Qualitative: AATCC Test Method 20
- Quantitative: AATCC Test Method 20A
- ASTM D376

Identifying Characteristics of Fibers

- Absorbance of IR Radiation
- Appearance
  - Cross-Sectional View
  - Longitudinal View
- Reaction to Flame
- Birefringence
- Density
- Melting Point
- Solubility
- Staining

Crimp

- Crimp Frequency - ASTM D3937
- Crimp Amplitude - No Standard Method
Fineness or Linear Density

- **Cotton Fibers**
  - Micronaire - Function of both fineness and maturity - micrograms per inch
    - ASTM D5867 (HVI)
    - ASTM D1448 (Micronaire, Fibronaire)

- **Synthetic Fibers**
  - Linear Density - Denier, tex, decitex
    - ASTM D 1577 (Direct Weighing or Vibroscope)

Moisture in Fibers

- **Moisture Content**
- **Moisture Regain**

Test Methods:
- ASTM D1776 (Conditioning)
- ASTM D629 – Section 9
- ASTM D2495 (Cotton – Oven Drying Method)

Tensile Properties:
**Strength (Tenacity) and Elongation**

- **Cotton Fibers**
  - ASTM D5867 (HVI)

- **All Other Fibers**
  - ASTM D3822 (Single Fibers)
Typical Fiber Stress-Strain Curves

Thermal Properties of Fibers

- Non-thermoplastic Fibers (No Melting Point)
  - Natural Fibers
  - Synthetic Fibers Regenerated from Natural Materials, e.g., Rayon
  - Aramids
- Thermoplastic Fibers
  - Polyamides
  - Polyesters
  - Acrylates
  - Olefins
  - Acetates

Methods for Measuring Fiber Melting Point

- Fisher-Johns Melting Point Apparatus (See ASTM D276 or AATCC Test Method 20)
- Hot Stage Microscope
- Differential Scanning Calorimetry (DSC)
Yarn Properties and Test Methods

Yarn Examples

Spun Yarns
- Lower strength
- Higher stretch
- Higher bulk
- Softer hand
- Better absorbency
- Higher pilling tendency

Flat Filament Yarns
- Higher strength
- Lower stretch
- Lower bulk
- Stiffer hand
- Lower absorbency
- Lower pilling tendency

Yarn Performance Properties
- Coefficient of Friction
- Count
- Evenness
- Hairiness
- Tenacity: Strength and Elongation
- Twist
Yarn Methods

Coefficient of Friction
- ASTM D3108 (Yarn-to-Metal)
- ASTM D3412 (Yarn-to-Yarn)

Yarn Count
- Indirect – Hanks per pound:
  - Cotton System: 1 Hank = 840 yd.
  - Worsted System: 1 Hank = 560 yd.
- Direct:
  - Denier: grams per 9000 meters
  - Tex: grams per 1000 meters
  - Decitex: grams per 10,000 meters

Yarn Count Methods
- ASTM D1059 – Short Lengths
- ASTM D1907 – Skeins

Example Calculations of Yarn Count for a measured length of 1.000 m and mass of 0.0186 g:

Cotton Count:
\[
\frac{(1.000 \text{ m}) \times (453.6 \text{ g}) \times (1.0936 \text{ yd}) \times (1 \text{ hank})}{(0.0186 \text{ g})} = 31.7 \text{ (hanks/lb)}
\]

Denier:
\[
\frac{(0.0186 \text{ g})}{1.000 \text{ m}} \times 9000 = 167 \text{ (g/9000 m)}
\]

Evenness and Hairiness
- ASTM D1425 – Capacitance Testers (%CV, Mass Diagram, Spectrogram, Hairiness Index)

Uster Tester 5 (UT5)
Tensile Strength

- ASTM D2256 (Single Strand)
- ASTM D1578 (Skeins)

MTS & Tests

Specialized Instruments

Uster Tensorapid

 Twist – Measured for Ring Spun Yarns

- ASTM D1422 (Untwist-Retwist for single spun yarns)
- ASTM D1423 (Direct Counting)

Notes:
- "t" measured with tpi and (yarn number) / 2
- "t" measured in turns per cm?

Types of Spun Yarn:

- King type (1x1)
- Open end type (7x7)
- Air jet twist (1x1)

Fabric Properties and Test Methods
Important Fabric Properties

- Fabric Construction
- Fabric Appearance
  - Abrasion Resistance
  - Snagging and Pilling Resistance
  - Dimensional Stability
  - Wrinkle Recovery and Smoothness
  - Color Measurement and Evaluation
  - Colorfastness
  - Hand
- Fabric Performance
  - Comfort
  - Flammability and Thermal Resistance
  - Permeability (Air and Liquid)
  - Soil Release
  - Strength and Extensibility

Construction Test Methods

- ASTM D3776 - Fabric Weight
- ASTM D1777 – Fabric Thickness
- ASTM D3775 – Warp and Filling Count
- ASTM D1059 - Yarn Number
- ASTM D3882 – Bow and Skew

Abrasion Test Methods

For Woven Fabrics:
- ASTM D3885 (Flexing and Abrasion)
- ASTM D1515 (Oscillatory Cylinder)

For Woven or Knitted Fabrics:
- ASTM D3884 (Rotary Platform)
- ASTM D3886 (Inflated Diaphragm)
- ASTM D4158 (Uniform Abrasion)
- ASTM D4159 (Martindale)
- AATCC 93 (Accelerator)
- AATCC 119/120 (Frosting)
Possible Evaluation Criteria for Abrasion Testing

- Appearance (holes or broken yarns)
- Color Change
- Rupture of Specimen
- Strength Change
- Weight Change

Abrasion Testers for Woven Fabrics

- Wyzenbeek
- Flex and Abrasion

Abrasion Testers for All Fabrics

- Martindale
- Taber Abraser
Snag Resistance

- ASTM D3939 (Mace)
- ASTM D5362 (Bean Bag)

Pilling Resistance

- ASTM D3511 (Brush and Sponge)
- ASTM D3512 (Random Tumble)
- ASTM D3514 (Elastomeric Pad)
- ASTM D4970 (Martindale)

Pilling Testers

- Random Tumble Pilling Tester
- Martindale
Effects of Laundering and Cleaning on Fabrics

- Dimensional Stability
  - AATCC 135 (Home Laundering)
  - AATCC 96 (Commercial Laundering)
  - AATCC 136 (Drywashing)

- Wrinkle Recovery
  - AATCC 128 (Appearance Method)
  - AATCC 66 (Recovery Angle Method)

- Smoothness
  - AATCC 88B (Seams)
  - AATCC 88C (Crease Retention)
  - AATCC 124 (Fabric Smoothness)

AATCC Smoothness Appearance Replicas

Color in Textiles

- Color Matching
  - Instrumental Assessment
  - Visual Assessment

- Colorfastness Testing
  - AATCC definition of Colorfastness: "the resistance of a material to change in any of its color characteristics, or transfer of its colorants to adjacent materials, as a result of the exposure of the material to any environment that might be encountered during the processing, testing, storage, or use of the material."

Reference: Technical Manual of the American Association of Textile Chemists and Colorists
Instrumental Measurement of Color

• Standards
  – AATCC Evaluation Procedure 6 (Instrumental Color Measurement)
  – AATCC Evaluation Procedure 7 (Change in Color)
  – AATCC 110 (Whiteness)
  – ASTM E313 (Whiteness)

• General Procedure for Color Difference Measurement
  – Measure reference specimen
  – Measure test specimen
  – Calculate color difference
  – Report
    - Equipment used
    - Illuminant
    - Observer angle – 1964 10° or 1931 2°
    - Sample presentation

Standard Procedures for Visual Assessment of Colorfastness

• AATCC Evaluation Procedure 1 (Gray Scale for Color Change)
• AATCC Evaluation Procedure 2 (Gray Scale for Staining)
• AATCC Evaluation Procedure 8 (9-Step Chromatic Transference Scale)

Gray Scale for Color Change

• AATCC Evaluation Procedure 1
• Used to assess fading in original sample after exposure to test conditions of laundering, light, perspiration, heat, water, ozone, etc.
• Assign rating from 1 to 5
  - Grade 5
    - No change in original sample
    - 3 reference chips of neutral gray Y = 12 ± 1
    - Color difference of the pair 1.9 ± 0.2
  - Grade 4, 3, 2, 1
    - Paired with Grade 5 chip
    - Geometric steps of color difference
  - Half-step Grades
  - Intermediates between the whole step pairs
Gray Scale for Staining
- AATCC Evaluation Procedure 2
- Used to evaluate transfer of color from a dyed or printed fabric to a standard white fabric after test conditions of laundering, perspiration, water, crocking, etc. Can assess multifiber fabric or crock squares.
- Assign rating from 1 to 5:
  - Grade 5: No change in original sample
  - 2 reference white chips Y ≥ 85
  - Color difference of the pair = 0 ± 0.2
  - Grades 4, 3, 2, 1
  - Paired with Grade 5 chip
  - Geometric steps of color difference
  - Half-step Grades
  - Intermediates between the whole step pairs

General Use of Gray Scales
- Position original and test specimens with sharp junction (no gap). Have specimens oriented consistently.
- Back all specimens uniformly.
- Align with scale pair.
- Use a Gray Mask with Y = 53 ± 1. (For Gray Scale for Staining, select appropriate mask opening – multifiber, crock or general staining.)
- Angle of incident light is 45° ± 5°.
- Angle of viewing is 90° ± 5°.
- Assign grade from 1 to 5 (a grade of 0 is permissible).

9-Step Chromatic Transference Scale
- AATCC Evaluation Procedure 8
- Used to evaluate transfer of color from a dyed or printed fabric to a standard white fabric after test conditions of laundering, perspiration, water, crocking, etc. Can assess multifiber fabric or crock squares.
- Assign rating from 1 to 5:
  - 54 Color Chips
  - 5 hues and neutral gray
  - 9 Rows
  - Circular hole between rows
  - White mask
General Use of 9-Step Scale

- Position test specimen.
  - Back all specimens uniformly.
  - CLEAN test material.
- Mask with white cardboard mask.
- Angle of incident light is 90° ± 5°.
- Angle of viewing is 45° ± 5°.
- Assign grade from 1 to 5 (a grade of 0 is permissible).

Methods for Evaluation of Colorfastness

- AATCC 6 – Acids and Alkalis
- AATCC 23 – Burnt Gas Fumes
- AATCC 8, 116 – Crocking
- AATCC 132 - Drycleaning
- AATCC 61 – Laundering (Accelerated)
- AATCC 16 – Light
- AATCC 172 – Non-Chlorine Bleach
- AATCC 155 – Oxides of Nitrogen
- AATCC 109, 129 – Ozone
- AATCC 15 - Perspiration
- AATCC 107 – Water

Accelerated Laundering Machine

Crockmeters

Fabric Hand Test Methods

- ASTM D123, Annex A
- AATCC Evaluation Procedure 5
- ASTM D1388 (Stiffness-Cantilever)
- ASTM D4032 (Stiffness-Circular Bend)
- BS 5058 (Cusick Drape)
- Specialized test devices
  - Kawataba System
  - Fabric Touch Tester (FTT)
Flammability

- ASTM D4391 – Definitions and Terminology
- ASTM D4723 – Index of Test Methods (numerous methods)
  Examples:
  - ASTM D2863 (Limiting Oxygen Index)
  - ASTM E413 (Textile Materials-Vertical Test)
  - CPSC 16 CFR 1610 (Wearing Apparel-45° test)
  - CPSC 16 CFR 1632 (Mattresses)

Air and Liquid Permeability

Air Permeability

- ASTM D737 (Frazier Air Permeability)

Water Repellency and Resistance

- AATCC 22 (Spray Test)
- AATCC 16 (Rain Test)
- AATCC 42 (Impact Penetration)
- AATCC 70 (Dynamic Absorption)
- AATCC 127 (Hydrostatic Pressure)

Oil Repellency

- AATCC 118 (Oil Repellency)

Water Repellency Testing
Soil Release

- AATCC 130 – Soil Release: Oily Stain Release Method
- AATCC 121 – Carpet Soiling: Visual Rating Method
- ASTM D4020 – Stain Removal

Strength Testing

- Tensile (Woven Fabrics)
- Tear (Woven Fabrics)
- Burst (Knitted Fabrics)

Tensile Strength Methods

- ASTM D5034 (Grab Test)
- ASTM D5035 (Strip Test)
- ASTM D4964 (Elastic Fabrics)
Tear Strength Methods

- ASTM D2261 (Tongue Tear)
- ASTM D1424 (Elmendorf)
- ASTM D5587 (Trapezoid Tear)

Load-Elongation Curve for Fabric Tongue Tear Test:

Seam Slippage Test Method

- ASTM D1683 (Seam Slippage and Efficiency)

Burst Strength Methods

- ASTM D3786 (Hydraulic or Pneumatic)
- ASTM D3787 (Ball Burst-CRT)
- ASTM D6797 (Ball Burst-CRE)

Mullen Burst Tester

Ball Burst Tester

TruBurst Burst Tester
Questions?

Thank you for coming!

Zeus Textiles
Extension