Dyeing Man-Made Fibers
and
Properties that Can Be Achieved
OBJECTIVES IN DYEING SYNTHETIC FIBERS

(1) Dye fiber to the desired shade

(2) Maintain necessary fastness properties

(3) Obtain a level uniform dyeing

(4) Prevent destruction of the fabric or fibers

(5) Maintain cost levels
MAJOR SYNTHETIC FIBERS

POLYAMIDES - Nylon 6,
               Nylon 6, 6

POLYACRYLONITRILES - ACRYLICS
                      MODACRYLICS

POLYESTERS (Disperse Dyeable)
           (Basic Dyeable)

MODIFIED CELLULOSICS - [ACETATE]↑
                       TRIACETATE
DYES FOR ACRYLIC FIBERS

CATIONIC DYES

DISPERSE DYES

ACID DYES
FOR ACID DYEABLE TYPE
POLYACRYLONITRILE FIBERS

\[ \text{CH}_2 \rightarrow \text{CH}_1 \]

ACRYLONITRILE

100% POLYACRYLONITRILE IS DIFFICULT TO DYE

ACRYLIC FIBERS \hspace{1cm} \text{AT LEAST 85\% ACRYLONITRILE}

MODACRYLIC FIBERS \hspace{1cm} 35 - 85\% ACRYLONITRILE
SOURCES OF BARRE IN NYLON

CHEMICAL END GROUPS

ORIENTATION AND CRYSTALLINITY

X-SECTION, SURFACE ROUGHNESS

NON-UNIFORM TEXTURING

NON-UNIFORM KNITTING TENSION
FACTORS IN SELECTING DYES FOR NYLON

ECONOMY

SHADE (BRIGHTNESS OR DULLNESS)

FASTNESS REQUIREMENTS

LEVEL DYEING PROPERTIES

BARRÉ CONTROL
LEVELING ACID DYES ON NYLON

Requires Acetic or Formic Acid for Dyeing

Exhausted with Additional Formic Acid

Good Leveling Properties

Good Barre Coverage

Poor Wetfastness Properties

Lightfastness Varies
<table>
<thead>
<tr>
<th></th>
<th>ACID LEVELING</th>
<th>MILLING</th>
<th>NEUTRAL DYEING</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOLECULAR WT.</td>
<td>LOW</td>
<td>MEDIUM</td>
<td>HIGH</td>
</tr>
<tr>
<td>ANION AFFINITY</td>
<td>LOW</td>
<td>MEDIUM</td>
<td>HIGH</td>
</tr>
<tr>
<td>DYEBA T PH (APPROX.)</td>
<td>3</td>
<td>4-5</td>
<td>6-7</td>
</tr>
<tr>
<td>ACID DYEING ASS’T.</td>
<td>SULFURIC- FORMIC</td>
<td>ACETIC</td>
<td>NONE</td>
</tr>
<tr>
<td>RATE OF DYEING</td>
<td>FAST</td>
<td>MEDIUM</td>
<td>SLOW</td>
</tr>
<tr>
<td>MIGRATION</td>
<td>FAST</td>
<td>SLOW</td>
<td>VERY SLOW</td>
</tr>
<tr>
<td>LEVELING EFFECT OF NA₂ SO₄</td>
<td>HIGH</td>
<td>LOW</td>
<td>NONE</td>
</tr>
<tr>
<td>WETFASTNESS</td>
<td>LOW</td>
<td>HIGH</td>
<td>VERY HIGH</td>
</tr>
</tbody>
</table>
NEUTRAL DYEING ACID DYES

DYED FROM NEUTRAL SOLUTION

COMPLETE EXHAUSTION WITH AMMONIUM SULFATE

LEVEL WELL

GOOD BARRÉ COVERAGE

GOOD LIGHTFASTNESS

GOOD WETFASTNESS PROPERTIES
MILLING ACID DYES ON NYLON

REQUIRES ACETIC ACID FOR DYEING

EXHAUSTED WITH ADDITIONAL ACETIC OR FORMIC

DO NOT COVER BARRE

LIGHTFASTNESS VARIES

WETFASTNESS GENERALLY GOOD
NEUTRAL DYEING ACID DYES

DYED FROM NEUTRAL SOLUTION

COMPLETE EXHAUSTION WITH AMMONIUM SULFATE

LEVEL WELL

GOOD BARRE COVERAGE

GOOD LIGHTFASTNESS

LIMITED WETFASTNESS PROPERTIES
ACID METALIZED DYES ON NYLON

DULL SHADES

EXHAUSTED WITH FORMIC ACID

POOR LEVELING PROPERTIES

LIGHTFASTNESS GENERALLY GOOD

WETFASTNESS GENERALLY GOOD

$\text{O}^\text{dye} \text{Cr}$

$\text{O}^\text{dye} \text{Co}$

$\text{O}^\text{dye} \text{Cu}$

1960's pre-metalized dyes

- Still complexed with metal
- But not added in dye baths
- Was done into the past

Increases size of molecule.
Compounds which combine with either dye or fiber at low temperature -

They are released at high temp. and dyeing takes place.

Reduce the rate of dyeing below the boil -

May be critical in pastel shades to obtain level dyeings -
NEUTRAL METALIZED DYES ON NYLON

DULL SHADES

DYED NEUTRAL OR SLIGHTLY ALKALINE

FAST STRIKE

POOR LEVELING

LIGHTFASTNESS GOOD

WETFASTNESS GOOD
CHROME DYES ON NYLON

FOR EXCELLENT WETFASTNESS IN HEAVY SHADES

APPLY SAME AS ACID DYES

AFTER - CHROME

TREAT DYED GOODS WITH

FORMIC ACID
SODIUM DICHROMATE
SODIUM THIOSULFATE

CHROME COMPLEXES WITH DYE MOLECULES
RETARDING SYSTEMS FOR NYLON

ANIONIC SURFACTANT

CATIONIC/NONIONIC SURFACTANT

SALTS
DYEING NYLON AT ELEVATED TEMPERATURES

FOR SELECTED DYES DYEING AT 235 - 250 F IMPROVES

1. SHADE BUILDUP
2. PENETRATION
3. LEVELING
4. BARRE
5. FASTNESS PROPERTIES
6. FAULTY DYEINGS MADE AT THE BOIL

Dispersion in Nylon
- dye easily (in carrier)
- poor to moderate fastness
- good shade range
- not a dyestuff for all usages
DISPERSE DYES ON NYLON

APPLY SAME AS ON ACETATE

DO NOT BUILD AS GOOD AS ON ACETATE

LEVEL WELL

FASTNESS PROPERTIES ARE POOR
DYEING MECHANISM

H₂N – NYLON – COOH

+ HA (ACID)

↓

+H₃N – NYLON – COOH

+ Na⁺ DYE–

↓

DYE–H₃⁺N – NYLON – COOH + NAA
DYES FOR NYLON

ACID DYES
- water soluble
- food colorings

ACID METALIZED DYES

NEUTRAL METALIZED DYES

CHROME DYES

DISPERSE DYES
**BASIC DYE PROPERTIES**

- Ionic Dyes $D^+$ net positive charge
- Good water solubility - best below pH7
- As a class - high color value - among the brightest dyes available
- Almost unlimited shade range
- Many have fluorescence properties
- Lightfastness on acrylics varies from poor to good. On other fibers it can be very poor.
- Washfastness is generally good
- Chlorine fastness is poor
- High strike rate
- Poor leveling
BASIC DYES ON ACRYLICS

DYEING MECHANISM

\[ \text{Dye} + \text{Acrylic} \rightarrow \text{Strong Ionic Bonds} \]

\[ \text{Dye}^{+} + \text{Acrylic}^{+} \rightarrow \text{Dye}^{++} \text{Acrylic}^{+} \]

\[ \text{So}_3^{-} - \text{Acrylic} - \text{So}_3^{-} \]

Add to fabric: 15 - 20 g./l.
DYEING OF ACRYLICS WITH BASICS

Dye is mixed with:

0.25% EDTA

10.0% Sodium sulfate (glaubers salt)

0.5% Nonionic surfactant

1.5 - 3.0% Retarder

0.5 - 1.0% Acetic acid (56%)

Raise dyebath @ 3° F/min to 180° F, then slowly

1° F/min or less to 212° F. Run for 1.0 - 1.5 hr.

Make any adds after cooling to 170° F, then raise

slowly back to 212° F, run 20 min.

Note. Always cool bath slowly to avoid crack

and crease marks in the fabric.
COMBINATION SHADES

CATIONIC DYES EXHAUST AT VARIOUS RATES

IN COMBINATIONS, ONE DYE MAY EXHAUST FIRST AND BLOCK OTHER DYES.

RESULTS:

SHADE DOES NOT BUILD ON TONE
MAY NOT OBTAIN DESIRED SHADE

K - Values

1 - Fastest Exhaustion  
5 - Slowest Exhaustion

FOR COMBINATION SHADES, USE DYES WITHIN ONE UNIT OF EACH OTHER.
DISPERSE DYES ON ACRYLICS

FOR LIGHT AND MEDIUM SHADES ONLY

LEVEL WELL

DYE AT BOIL FOR 1½ - 2 HOURS

SELECTED DISPERSE DYES HAVE GOOD FASTNESS PROPERTIES
TEMPERATURE DEPENDENCE OF RATE OF DYING OF BASIC DYES ON ACRYLIC FIBERS
GENERAL PROPERTIES OF MODACRYLICS

SHRINK SEVERLY ABOVE A CRITICAL TEMPERATURE

DELUSTER IN DYEBATH

MUST COOL DYEBATH SLOWLY

SENSITIVE TO DRY HEAT

DYEABLE WITH SELECTIVE CATIONIC DYES

DYEABLE WITH SELECTIVE DISPERSE DYES
ACID DYEABLE ACRYLICS

DYEABLE WITH ACID, CATIONIC, AND DISPERSE DYES

NOT WIDELY USED

DYED AT BOIL AT VERY LOW pH

SELECTED ACID DYES HAVE GOOD FASTNESS PROPERTIES
PROPERTIES OF POLYESTER

MORE HYDROPHOBIC THAN TRIACETE

DYED WITH DISPERSE DYES

CAN BE DYED WITH AZOIC DYES

REQUIRE CARRIER OR PRESSURE TO DYE

CATIONIC DYEABLE TYPE

CAN BE HEAT SET

Heat setting decreases dye withstand
DYES FOR POLYESTER

DISPERSE

BASIC or CATIONIC
PROPERTIES OF DISPERSE DYES

INSOLUBLE IN WATER

WATER DISPERSIBLE

NONIONIC

DYES ALL SYNTHETIC FIBERS

SUBLIME WHEN HEATED

STAINS CELLULOSE FIBERS

STAINS PROTEIN FIBERS
DYEING SYSTEMS FOR POLYESTER

NORMAL AQUEOUS SYSTEM

CARRIER SYSTEM

PRESSURE SYSTEM

THERMOSOL SYSTEM

polyester fibre

bitaryl carriers swell polyester and ebonite

Fibre swells and open spaces for dyes

cold to the touch ➔ dye trapped
CLASSES OF DISPERSE DYES

LOW ENERGY (Acidic - Triacidic)

MEDIUM ENERGY

HIGH ENERGY
DYEING MECHANISM

PARTITIONING OF A SOLID BETWEEN TWO IMMISCIBLE SOLVENTS

DYE FORMS A SOLID SOLUTION IN THE FIBER
PROPERTIES OF AN IDEAL CARRIER

1. HIGH EFFICIENCY, EVEN WHEN APPLIED AT MINIMUM CONCENTRATION, AND INDEPENDENT OF THE CONSTITUTION OF THE DISPERSE DYE.

2. RAPID EMULSIFIABILITY AND GOOD STABILITY OF THE CARRIER EMULSION UNDER DYEING CONDITIONS.

3. LOW VOLATILITY IN STEAM.

4. NO OBJECTIONABLE ODOR.

5. MINIMUM SWELLING OF THE FIBER, AND MINIMUM INFLUENCE ON THE FIBER SHRINKAGE.

6. NO PROMOTION OF THE UPTAKE OF DISPERSE DYES BY OTHER FIBERS IN BLENDS.

7. READILY REMOVED FROM THE FIBROUS MATERIAL.

8. NO INFLUENCE ON THE FASTNESS TO LIGHT AND HEAT-SETTING OF THE DYED SHADES.

9. LOW TOXICITY.
FACTORS IN SELECTING DYES FOR POLYESTER

ECONOMY

FASTNESS REQUIREMENTS

LEVEL DYEING OR BARRE CONTROL

STABILITY AT HIGH TEMPERATURE

DISPERSION (ESPECIALLY PACKAGE DYEING)
TRIMERS

SMALL POLYESTER POLYMERS inherent with manufacture of fiber.

SEPARATE FROM POLYESTER ABOVE 212 F

CONGLOMERATE ON AND CLOG MACHINES

RESTRICT FLOW IN PACKAGE DYEING

GIVE DYEING DULL OR SPOTTED APPEARANCE

TO ELIMINATE TRIMER PROBLEMS

1. USE CARRIER THAT CONTROLS TRIMER RELEASE

2. DROP BATH WHILE HOT

3. AFTER SCOUR GOODS WITH CAUSTIC AND HYDRO
FACTORS IN SELECTING CARRIERS FOR POLYESTER

ECONOMY

USE IN ATMOSPHERIC OR HIGH TEMPERATURE DYEING

LEVELLING AND BARRÉ COVERAGE

EFFECT ON LIGHT FASTNESS

RESISTANCE TO SPOTTING

EASE OF REMOVAL

TOXICITY

ODOR DURING AND AFTER DYEING

CONTROL OF STAIN WHEN DYEING BLENDS

COMPATIBILITY AND FOAMING IN JET DYEING

TRIMER CONTROL
CATIONIC DYEABLE POLYESTER

POLYESTER WITH SULPHONIC ACID GROUP

DYED WITH CATIONIC OR DISPERSE DYES

REQUIRES CARRIER FOR DYEING

REQUIRES GLAUBER’S SALT IF DYED UNDER PRESSURE

LIGHTFASTNESS OF MOST CATIONIC DYES NOT GOOD

OTHER FASTNESS PROPERTIES OF CATIONIC DYES ARE GOOD

USUALLY IN BLENDS

RESERVE

CROSS - DYEING
SUBLIMATION OF DISPERSE DYES

PROCESS OF DYE GOING FROM SOLID TO VAPOR WHEN HEATED

SUBLIMATION DECREASES WITH AN INCREASE IN SIZE OF DYE MOLECULE

LEVEL DYEING PROPERTIES DECREASE WITH AN INCREASE IN SIZE OF DYE MOLECULE
DYEING ACETATE WITH DISPERSE DYES

WET OUT GOODS

ADD SURFACTANT OR DISPERSING AGENT AT 100 – 120 F

ADD DYE IN PORTIONS OVER 10 – 15 MINUTES

RAISE BATH SLOWLY TO 160 – 185 F (212° F)

DYE 30 – 60 MINUTES

RINSE AT 100 – 120 F
PROPERTIES OF ACETATE

HYDROPHOBIC

WILL NOT DYE WITH WATER SOLUBLE DYES

WILL SAPONIFY IN CAUSTIC SOLUTION

MAY DELUSTER

USUALLY DYED WITH LOW ENERGY DISPERSE DYES

CAN BE DYED WITH AZOIC DYES
PROPERTIES OF TRIACETATE

MORE HYDROPHOBIC THAN ACETATE

WILL NOT SAPONIFY EASILY

WILL NOT DELUSTER IN BOILING WATER

USUALLY DYED WITH DISPERSE DYES

LIGHT AND MEDIUM SHADES DYES
3 - 6 HOURS AT BOIL

HEAVY SHADES DYES 3 - 6 HOURS AT BOIL WITH CARRIER
(TRIPROPYLPHOSPHATE TYPE)

CAN BE DYED UNDER PRESSURE AT 265 F

CAN BE HEAT SET (10 - 15 SEC AT 425 - 450 F)

FASTNESS PROPERTIES OF DYES GENERALLY BETTER THAN ON
ACETATE
FASTNESS PROPERTIES OF DISPERSE DYES ON ACETATE
(GENERAL)

LIGHTFASTNESS - GOOD

WASHFASTNESS - FAIR

CROCKFASTNESS - GOOD

PERSPIRATION - FAIR

GAS FADING

OZONE AND OXIDES OF NITROGEN (GAS FUMES) CAUSE SOME DYES (ESPECIALLY BLUES) TO FADE. REDUCED BY TREATING WITH GAS FADE INHIBITOR BEFORE OR DURING DYEING.
# DYEStuff Properties

<table>
<thead>
<tr>
<th>Dyes</th>
<th>Cost</th>
<th>Ease of Application</th>
<th>Washfastness</th>
<th>Lightfastness</th>
<th>Crockfastness</th>
<th>Perspiration Fastness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Low</td>
<td>Average</td>
<td>Fair-Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Basic</td>
<td>Average</td>
<td>Average-Fairly Hard</td>
<td>Poor-Good</td>
<td>Poor-Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Direct</td>
<td>Cheap</td>
<td>Easy</td>
<td>Poor-Good</td>
<td>Fair-Good</td>
<td>Wet-Poor</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Disperse</td>
<td>Average</td>
<td>Fairly Hard</td>
<td>Good</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Naphthol</td>
<td>Average</td>
<td>Hard</td>
<td>Good</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Reactive</td>
<td>Expensive</td>
<td>Average-Fairly Hard</td>
<td>G-E (if soaped)</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Cheap</td>
<td>Fairly Hard</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Vat</td>
<td>Average</td>
<td>Fairly Hard</td>
<td>Good - Excellent</td>
<td>Good - Excellent</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>
## Dyes on Fibers

<table>
<thead>
<tr>
<th>Type of Fiber</th>
<th>Acid</th>
<th>Basic</th>
<th>Direct</th>
<th>Disperse</th>
<th>Naphthol</th>
<th>Reactive</th>
<th>Sulfur</th>
<th>Vat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Cotton</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Wool</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Synthetic Rayon</td>
<td>*</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Acetate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyester</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrylic</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Special Fiber Types
<table>
<thead>
<tr>
<th>Dyes</th>
<th>Cost</th>
<th>Ease of Application</th>
<th>Washfastness</th>
<th>Lightfastness</th>
<th>Crockfastness</th>
<th>Perspiration Fastness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Low Average</td>
<td>Average</td>
<td>Fair-Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Basic</td>
<td>Average</td>
<td>Average-Fairly Hard</td>
<td>Poor-Good</td>
<td>Poor-Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Direct</td>
<td>Cheap</td>
<td>Easy</td>
<td>Poor-Good</td>
<td>Fair-Good</td>
<td>Wet-Poor Dry-Good</td>
<td>Poor-Good</td>
</tr>
<tr>
<td>Disperse</td>
<td>Average</td>
<td>Fairly Hard</td>
<td>Good</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Naphthol</td>
<td>Average</td>
<td>Hard</td>
<td>Good</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Reactive</td>
<td>Expensive</td>
<td>Average-Fairly Hard</td>
<td>G-E (if soaped)</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Fair-Good</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Cheap</td>
<td>Fairly Hard</td>
<td>Good</td>
<td>Fair-Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Vat</td>
<td>Average</td>
<td>Fairly Hard</td>
<td>Good-Excellent</td>
<td>Good-Excellent</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>