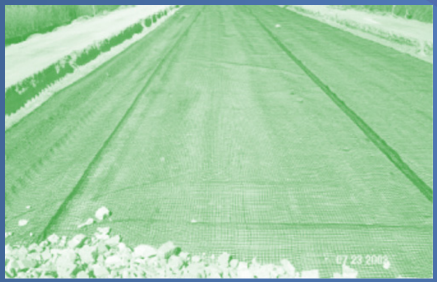
Association of the
Nonwoven Fabrics Industry

India Nonwovens & Geotextiles Course



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AGENDA

Day 1

9:00 a.m. **Registration**

9:30 a.m. **INAUGURAL**

10:00 a.m. **Program Preview**
Video overview, nonwoven products and applications, machinery and raw material information sources.

10:30 a.m. **DISCUSSION BREAK**

10:45 a.m. **Definition and Overview of Nonwovens**
Description of basic nonwoven manufacturing principles and systems used in Technical Textiles and Geotextiles – Raw Materials, Web Forming and Bonding, Composite Nonwovens Structures, Finishing.

12:00 p.m. **LUNCH**

1:00 p.m. **Nonwovens Overview** –Continued

2:15 p.m. **BREAK**

2:45 p.m. **Company Showcase Presentations**

3:45 p.m. **Standard Test Methods for the Nonwovens Industry**

4:15 p.m. **SHORT BREAK**

4:15 p.m. **Nonwovens Markets and Future Directions**
An overview of markets where nonwoven fabric materials are used, market sizes, and future growth projections.

5:30 p.m. **Reception**

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AGENDA (continued)

Day 2

9:30 a.m. **Fabric Manufacturing Basics**
A Comparative Overview of Weaving, Knitting, and Nonwoven Fabric Formation Principles, Fabric Properties and Characteristics.

10:15 a.m. **DISCUSSION BREAK**

10:30 a.m. **Geotextile Fundamentals**
Geotextile Terminology, Functions, Performance Criteria, Test Methods and Associated Applications for Wovens, Knits, Nonwovens & Geogrids.

12:00 p.m. **LUNCH**

1:00 p.m. **Choosing the Optimum Nonwoven Product and Process**
An Examination of Options Available and the Application of Gate Theory and Basic Financial Principles and Methods Involved in Establishing a Profitable Nonwovens Manufacturing and Sales Organization.

2:15 p.m. **DISCUSSION BREAK**

2:45 p.m. **Company Showcase Presentations**

3:45 p.m. **SHORT BREAK**

4:00 p.m. **International Geotextile Suppliers**
Past, Present, and Future

4:30 p.m. **Prospects for Increased Geotextile Usage in India**
Projection of future applications and developments in manufacturing, materials, processes, and products.

5:00 p.m. **Closing Remarks**

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Nonwoven Product Applications

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Product Application Categories

- Personal Care & Hygiene
- Healthcare
- Home
- Leisure & Travel
- Clothing
- Home Furnishings
- School & Office
- Automotive
- Construction
- Geotextiles
- Industrial
- Agriculture

Personal Care & Hygiene

- Baby Diapers
- Feminine Hygiene Products
- Adult Incontinence Products
- Wet Wipes
- Training Pants
- Personal Cleansing Wipes
- Cosmetic Removal Pads
- Nursing Pads
- Nasal Strips
- Adhesive for Dental Plates
- Disposable Underwear
- Medicated Pads

Healthcare

- Surgical: Caps, Gowns, Masks, Shoe Covers
- Drapes, Wraps and Packs
- Sponges, Dressings, Wipes
- Bed Linens
- Contamination Control Gowns
- Examination Gowns
- Transdermal Drug Delivery
- Shrouds
- Patient Gowns
- Wound Care
- Burn Dressings
- Laporatomy Sponges
- Underpads
- Procedure Packs
- Heat Packs
- Ostomy Bag Liners
- Fixation Tapes
- Incubator Mattress
- Alcohol Preps
- Newborn Gowns
- Receiving Blankets
- Bandages

Home

- Wipes / Mops
- Fabric Softeners
- Washcloths
- Tea and Coffee Bags
- Napkins and Tablecloths
- Dusters
- Pot Descaler Bags
- Wet and Dry Floor Cleaning
- Dusting Cloths
- HVAC Filters
- Thermal Insulation
- Washing Pouches
- Vacuum Cleaner Bags
- Kitchen and Fan Filters
- Coffee Filters
- Clothing and Shoe Bags
- Stain Removers
- Food Wrap
- Window Cleaners
- Blankets
- Polish Applicators
- Shower Curtains

Leisure & Travel

- Sleeping Bags
- Luggage, Handbags, Shopping Bags
- Airline Headrests
- Pillowcases
- Sandwich Packaging
- Tents
- Food Delivery
- CD Protection
- Surf Boards

Clothing

- Interlinings
- Clothing Insulation and Protection
- Handbag Components
- Shoe Components
- Belt Liners
- Fire Protection Suits
- High Visibility Garments
- Industrial Headwear / Footwear
- Disposable Workwear
- Clothing and Shoe Bags
- Chemical Defense Suits

Home Furnishing

- Furniture Construction
  - Insulators for Arms and Backs
  - Cushion Ticking
  - Dust Covers
  - Linings
  - Stitch Reinforcements
  - Edge Trim Materials
- Bedding Construction
  - Quilt Backings
  - Dust Covers
  - Spring Wraps
  - Mattress Pad Components
  - Mattress Covers
- Window Curtains
- Wall Coverings
- Carpet Backings

School & Office

- Book Covers
- Mailing Envelopes
- Maps, Signs and Pennants
- Towels
- Bank Notes
- Scrim Reinforced Tape
- Tags and Labels
- Synthetic Leather Accessories
- Office Equipment Cleansing
- Copying Machine Components

Automotive

- Trunk Liners
- Hood Liners
- Headliners
- Shelf Trim
- Interior Trim
- Underpaddings
- Carpet Backings
- Battery Separators
- Speaker Covers
- Car Covers
- Insulation Materials
- Floor Mats
- Heat Shields
- Airbags
- Tapes
- Door Panels
- Engine Air Filters
- Fuel Filters
- Cabin Air Filters
- Oil Filters

Construction

- Roofing and Tile Underlay
- Thermal and Acoustical Insulation
- Concrete Molding Layers
- Foundations and Ground Stabilization
- Foundation Water Proofing
- Underslating
- Drywall Facing
- House Wrap
- Pipe Wrap
- Drainage

Geotextiles

- Asphalt Overlay
- Soil Stabilization
- Drainage
- Sedimentation and Erosion Control
- Pond Liners
- Impregnation Base
- Drainage Channel Liners

Industrial

- Filters – Air, Liquid, and Gases
- Clothing
- Cable Insulation
- Abrasives
- Reinforced Plastics
- Flame Barriers
- Noise Absorbent Layers
- Battery Separators
  - Alkaline Cells
  - Acid Systems
  - Rechargeable
- Coated Fabrics
- Floppy Disc Liners
- Satellite Dishes
- Composite Material Veils
- Insulation Tapes
- Conveyor Belts
- PVC Substrates
- Artificial Leather
- HVAC Duct Wrap
- Anti-Slip Matting
- Paper Makers Felt

Agriculture

- Crop Covers
- Weed Control Fabrics
- Root Bags
- Capillary Matting
- Seed Blankets
- Greenhouse Shading
- Biodegradable Plant Pots
- Tissue Culture Media
- Hydroponic Cultivation

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Nonwoven Product Applications
Information sources

Five Web Sites to Browse for Nonwoven Basics

- www.inda.org
- www.edana.org
- www.risiinfo.com
- www.nonwovens-industry.com
- www.richernet.com

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Nonwoven Fabric Manufacturing Basics: A Technology Primer

What is a Nonwoven?

- A fabric made directly from fibers or from the chemicals from which the fibers themselves are made.
- A distinct class of fiber-based materials with fabric characteristics and useful properties.

New Nonwovens Definition

- A nonwoven is made of fibers or continuous filaments, of any nature or origin,
- that have been formed into a web by any means, provided said fibers or filaments
- have not been previously transformed into yarns, and where said fibers or filaments
- have been bonded together by any means, with the exception of weaving or knitting.

New Nonwovens Definition (cont'd)

- Composite structures are considered nonwovens provided their mass is constituted of at least 50% of nonwoven as per to the above definition, or if the nonwoven component plays a prevalent role.

New Nonwovens Definition (cont'd)

- Wetlaid webs are nonwovens provided that they contain a minimum of 50% of man-made fibers or other fibers of non vegetable origin with a length to diameter ratio equal or superior to 300, or a minimum of 30% of man-made fibers with a length to diameter ratio equal or superior to 600, and a maximum apparent density of 0.40 g/cm3.

New Nonwovens Definition (cont'd)

- Felts obtained by wet milling are not nonwovens.

Nonwoven Basics

- Nonwovens are the fabrics that you don't see,
  – but are there where you need them;
- Nonwovens are the fabrics that you don't recognize,
  – but are performing in ways that others can't

Nonwoven Fabric "Definition of the Day"

- A nonwoven fabric is a flat, flexible, porous sheet structure composed of a predetermined amount and arrangement of fiber-based material held together by friction, adhesion, or fusion.

How Are Nonwoven Fabrics Made?

- The basic concept is
  - to transform fiber-based materials into flat, flexible, porous, sheet structures with fabric characteristics

Nonwoven Basics

Nonwoven fabric manufacturing technologies;

textile (*dry laid*),

paper (*wet laid*),

extrusion (*polymer laid*), and

hybrid (*combination*);

have four common phases

Fiber selection and preparation,

Web forming,

Bonding, and

Finishing.

Which Fabric is a Nonwoven?

Nonwoven Fabrics

Fiber selection and preparation

Nonwoven Fabrics

Web forming

Nonwoven Fabrics

Bonding

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Nonwoven Fabrics

Finishing

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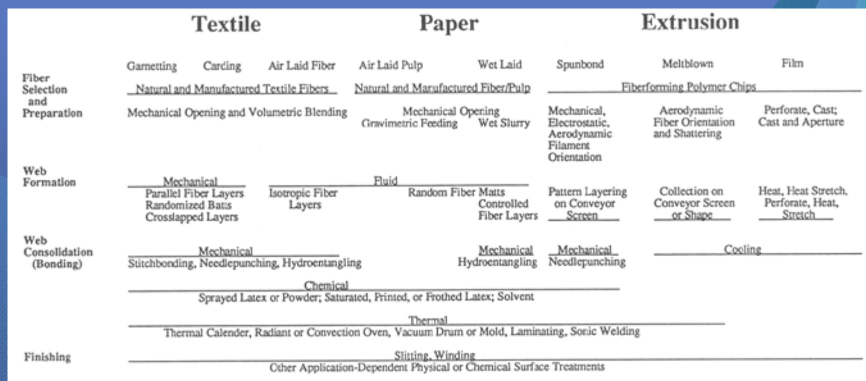
Basic Nonwoven Fabric Manufacturing Systems



Nonwoven Fabric Manufacturing Options

Fiber Selection

Abaca	Flax	Nylon	PTT
Acetate	Glass	PBI	Pulp
Acetate	Hemp	PBT	Rayon
Acrylic	Jute	PE	Sulfar
Aramid	Lyocell	PEN	Triacetate
Coir	Melamine	PET	Urethane
Cotton	Metallic	PLA	Vinyon
Elastomer	Modacrylic	PP	wool

Nonwoven Fabric Manufacturing Options

Web Formation

Carding
– Parallel
– Scrambled
– Random
Crosslap
Airlay
Wetlay

Spunbond
Meltblown
Film
Net

Bonding

Needlepunch
Hydroentangle
Stitchbond
Spray
Saturate
Print
Foam
Calender
Thruair
Ultrasonic

Nonwoven Fabric Manufacturing Options

Finishing

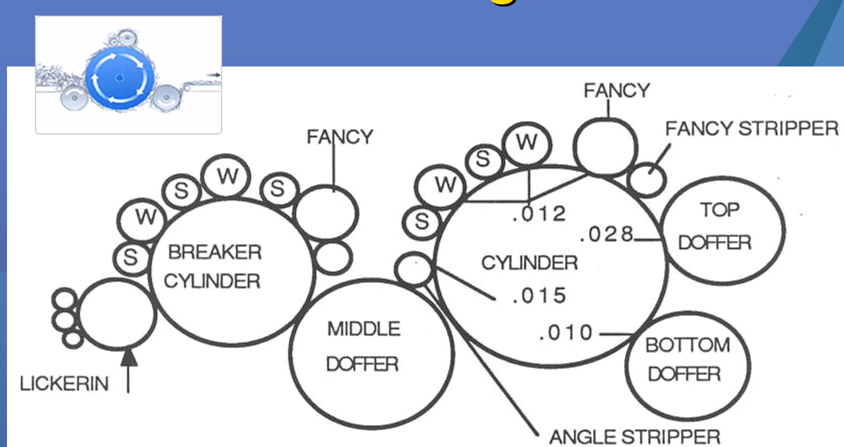
Hydrophilic
Hydrophobic
Repellent
Flame Retardant
Coating
Anitmicrobial
Dye

Print
Corrugate
Emboss
Compact
Crepe
Flock
Plasma
Encapsulate

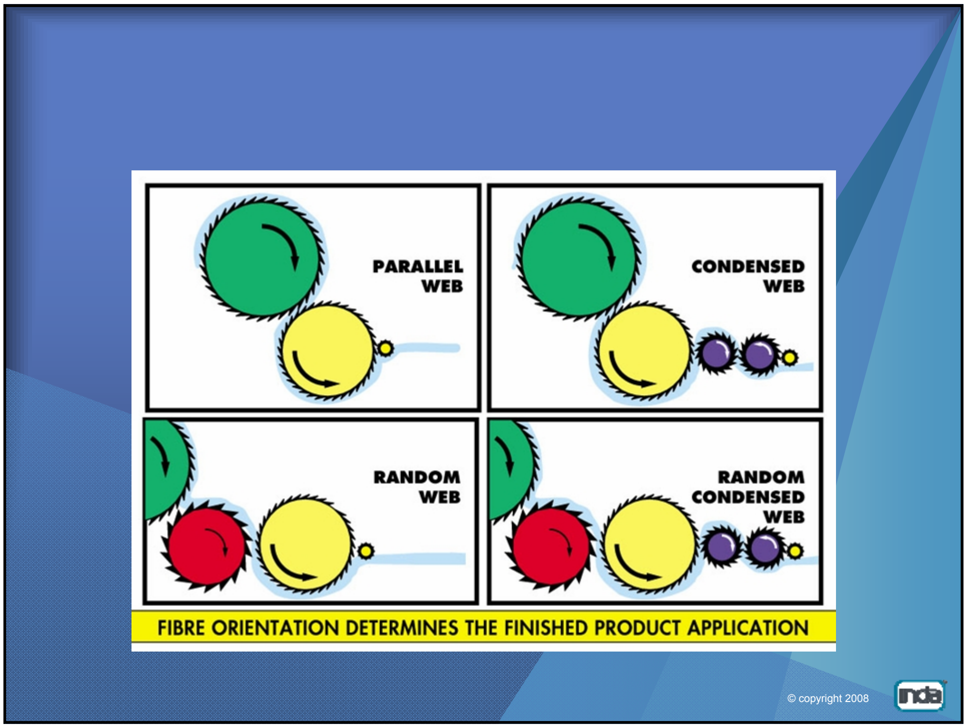
Dry Laid Nonwoven

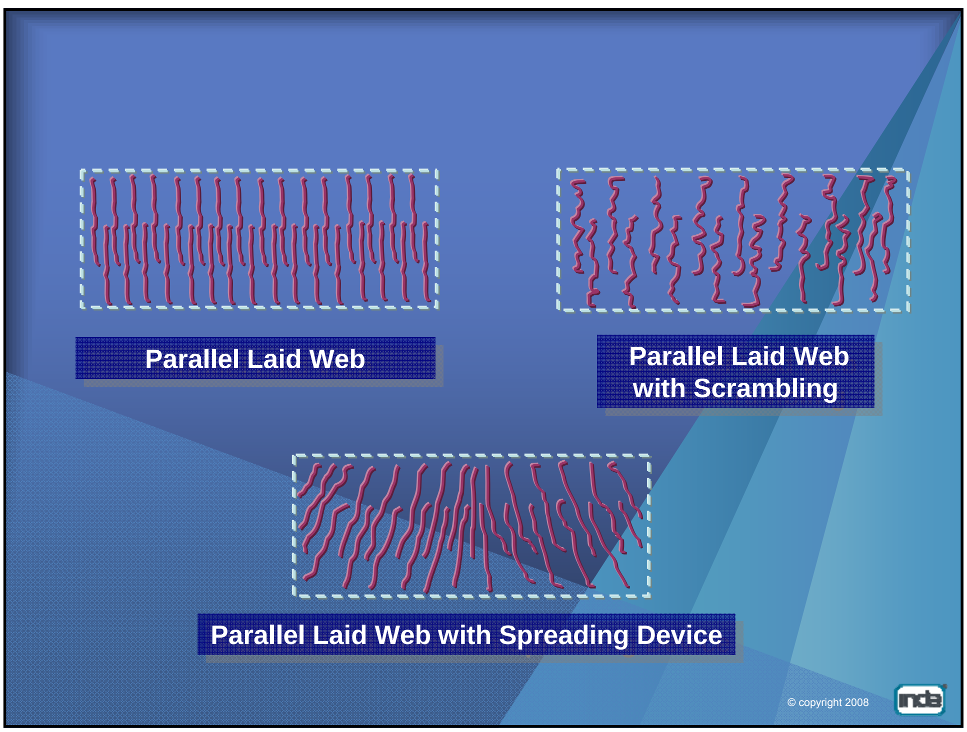
- A fabric made by placing a predetermined number of textile fibers, filaments, or yarns in a planar array through the use of textile technology and subsequently interlocking or bonding them by mechanical, chemical. or thermal means

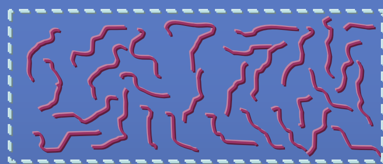
Carding



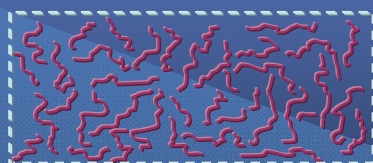
Nonwoven Card


PARALLEL WEB
CONDENSED WEB
RANDOM WEB
RANDOM CONDENSED WEB
FIBRE ORIENTATION DETERMINES THE FINISHED PRODUCT APPLICATION
© copyright 2008


Parallel Laid Web
Parallel Laid Web with Scrambling
Parallel Laid Web with Spreading Device
© copyright 2008



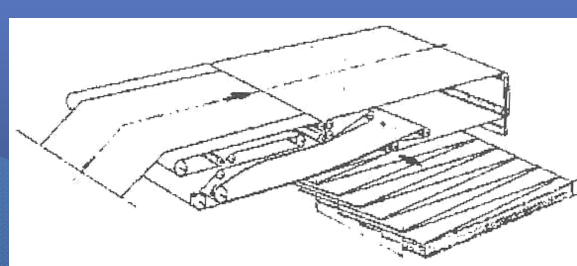
Random Laid Web



Random Laid Web with Scrambling

IDEAL Random Laid Web

Cross-Lapper



STRUTO - A Vertically Lapped Nonwoven Fabric

The diagram below – Figure 1 – shows a very simple layout of a STRUTO line and the notes describe the simple workings of the process.

A carding machine processes a properly mixed blend of basic and bonding fibers. (1). The carded web is formed into a STRUTO using a Vibration Lapper (2) to form a fiber batt on the conveyor belt of the Through-air Thermobonding Chamber (3). After passing through the chamber the STRUTO fabric is cooled and wound up (4).

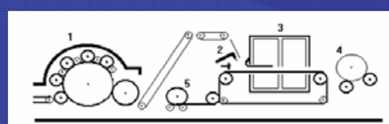


Fig.1. Scheme of the STRUTO line

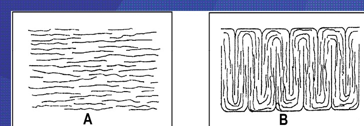
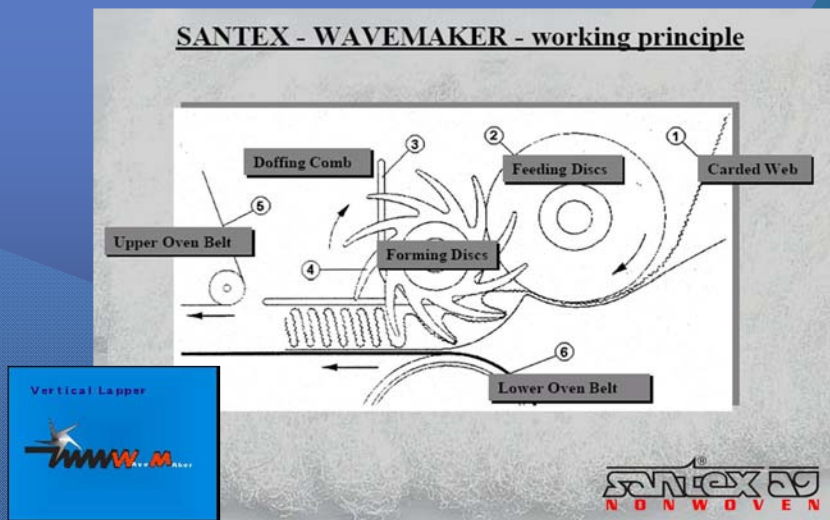


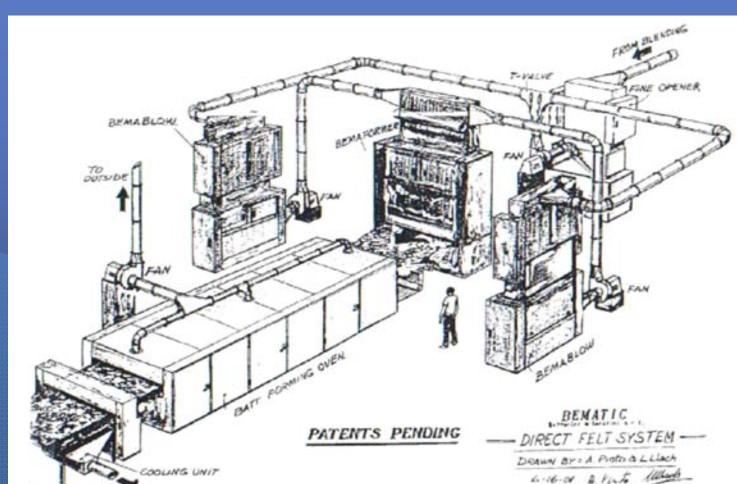
Fig.2. A) Horizontally (crosslapped) and B) Vertically Lapped Textile

STRUTO - A Vertically Lapped Nonwoven Fabric

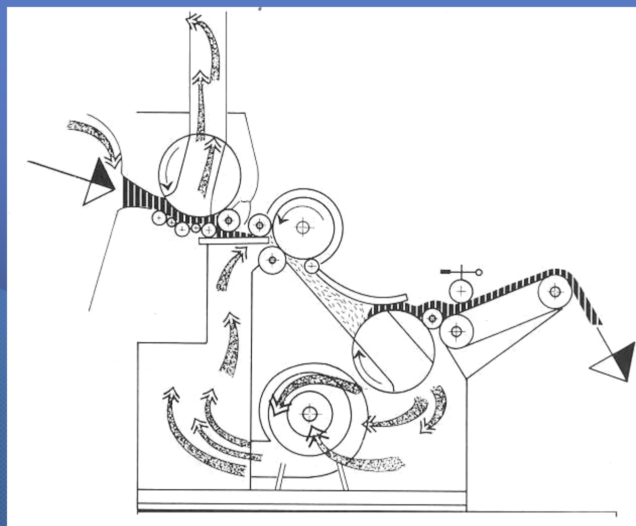
- In addition a supporting layer (5) can be brought from below onto the conveyor belt of the bonding chamber. The layer is then linked together with the STRUTO textile during the bonding process. Thus, a composite material is produced in one process.
- So a new style of bulky fabric is now formed where the vast majority of the fibers are orientated in the Vertical Plane.



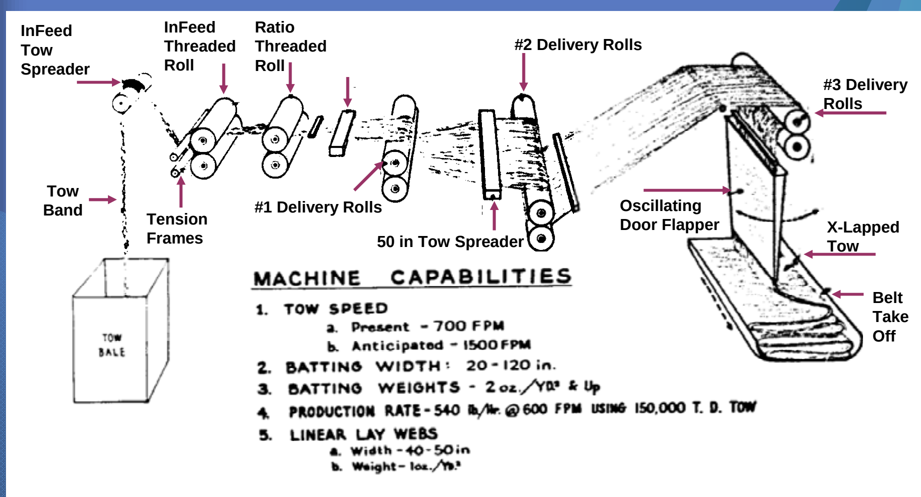
BEMATIC Direct Felt System



Air Laid Web Former



Threaded Roll Batting Producing Process



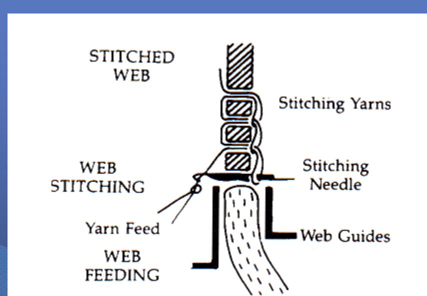
“held together by friction, adhesion, or fusion”
is achieved via various
Web Bonding Technologies,
namely:

Mechanical
Stitchbonding, Needlepunching, Hydroentangling

Chemical
Saturation, Printing, Spraying, Foaming

Thermal
Calender, Thru-Air, Ultrasonic

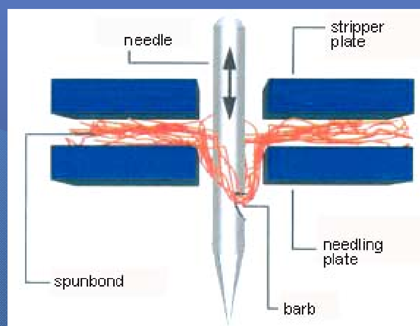
Stitchbonded

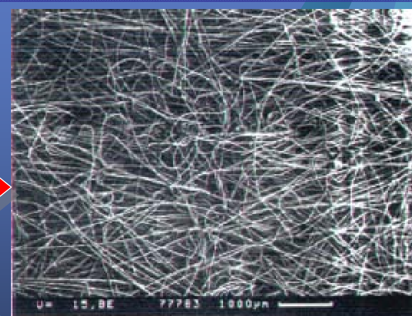


Mechanical Bonding with Yarn

Needlepunched

Consolidation by needlepunching for range of area weight 80-1000 (3000) g/m²

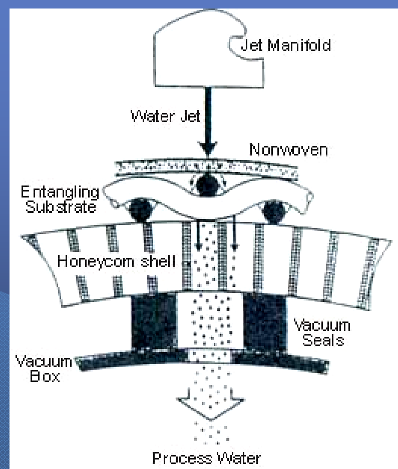




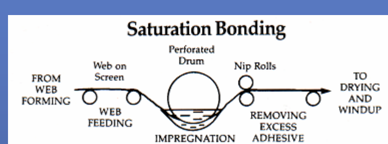
Needlepunched PET spunbond

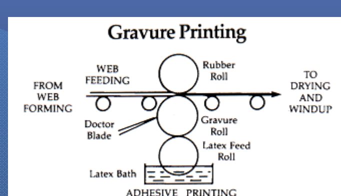
Hydro Water Column

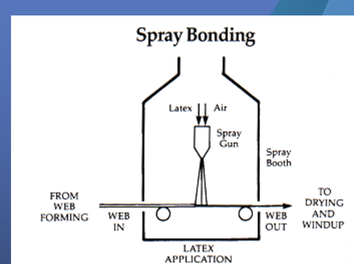
Hydroentanglement Principle



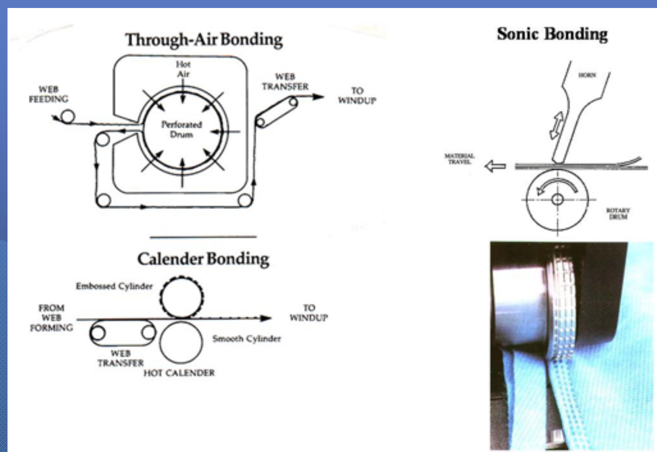
Three Methods of Chemical Bonding







Three Methods of Thermal Bonding



Textile-based Nonwovens

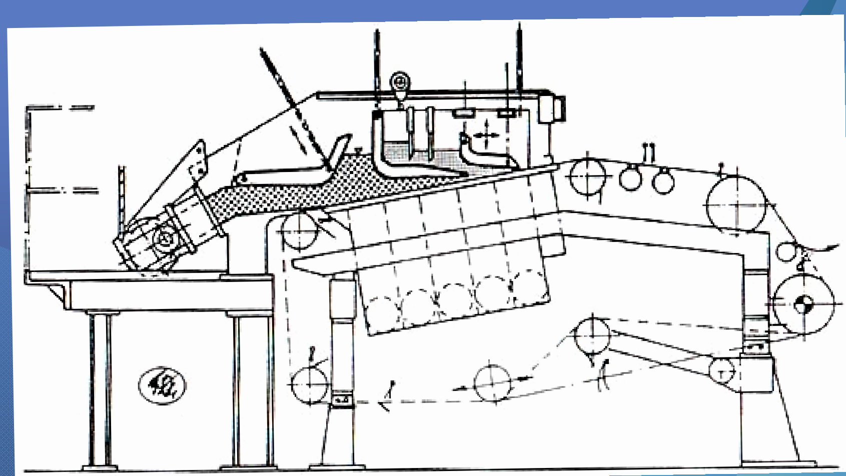
CHARACTERISTICS

- are extremely versatile
- can be used to make a wide range of fabrics
- most all textile fibers and bonding systems can be utilized
- conventional textile fiber processing equipment can be readily adapted with minimal capitalization

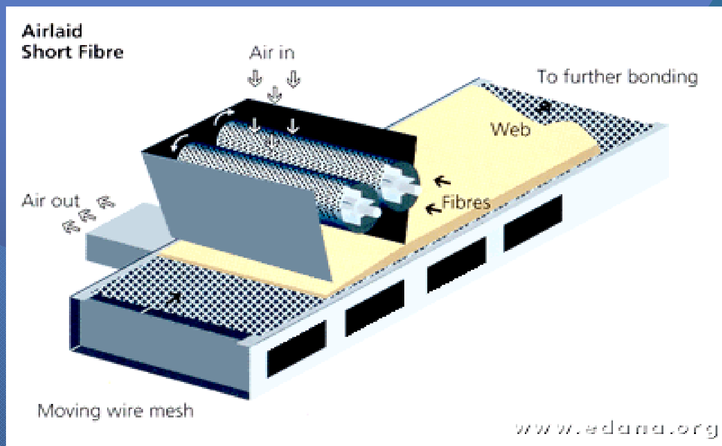
Wet Laid Nonwoven

- A fabric made by suspending short fibers in a fluid, depositing the fibers on a porous surface to separate the fibers from the fluid, and interlocking or bonding them by mechanical, chemical, or thermal means.

Inclined Wire Machine



Airlaid Pulp



Paper-based Nonwovens

CHARACTERISTICS

- operate at very high speeds
- can accommodate fibers that cannot be used in either textile or extrusion systems
- require high capitalization
- make fabrics with outstanding weight and property uniformity

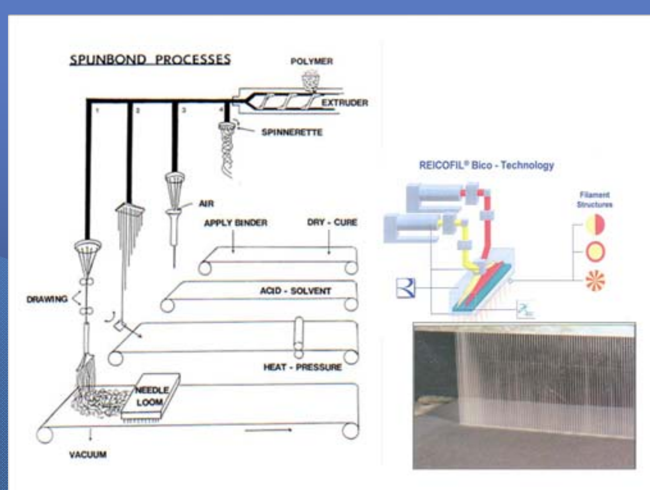
Polymer Laid Nonwovens

spunbond, meltblown, apertured film,

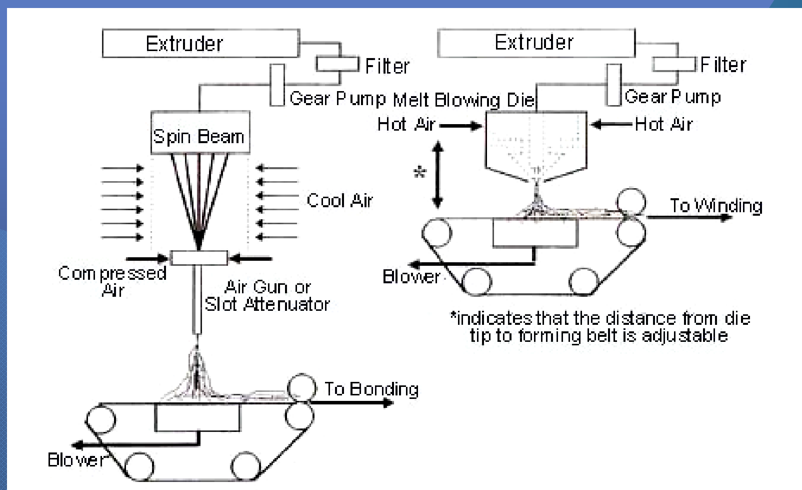
and extruded net nonwovens are "polymer laid" nonwovens.

- They are produced with machinery associated with polymer extrusion.
- In polymer laid systems fiber structures are simultaneously formed, manipulated, and bonded.

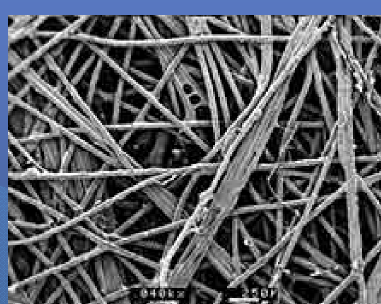
Spunlaid or Spunbond Nonwovens



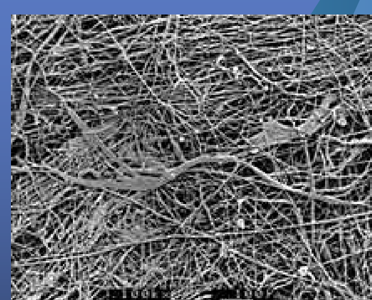
Comparison of Spunbond and Meltblown Processes



Comparison of Spunbond and Meltblown Fabrics



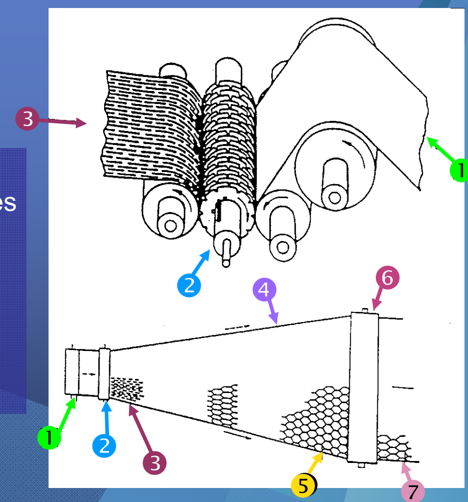
Spunbond



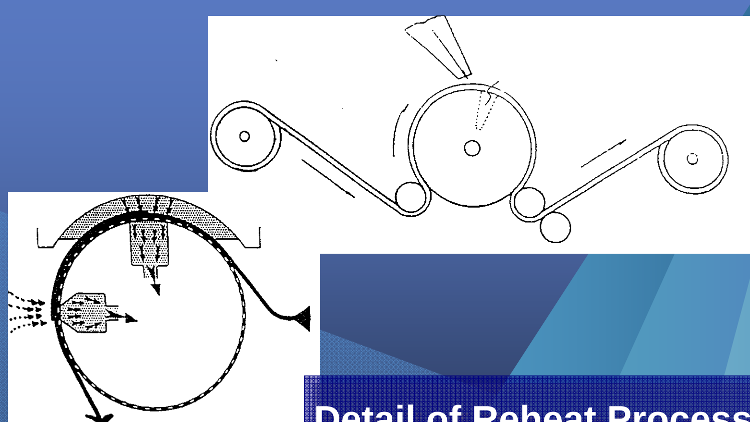
Meltblown

Production of Fibrillated Film

1. Thermoplastic film
2. Cutter disks with broken blades
3. Cut film
4. Stretching
5. Screen after stretching
6. Heated roller
7. Heat set screen
8. Take-up motion



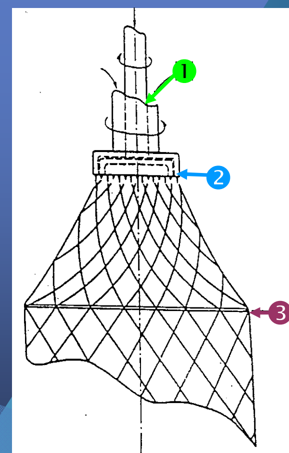
Production of Apertured Film



Detail of Reheat Process

Production of Extruded Netting

- ① Polymer melt feed
- ② Two circular systems of swing nozzles (or rotary nozzles)
- ③ Stretching ring



Extrusion-based Nonwovens

CHARACTERISTICS

– require modest capitalization

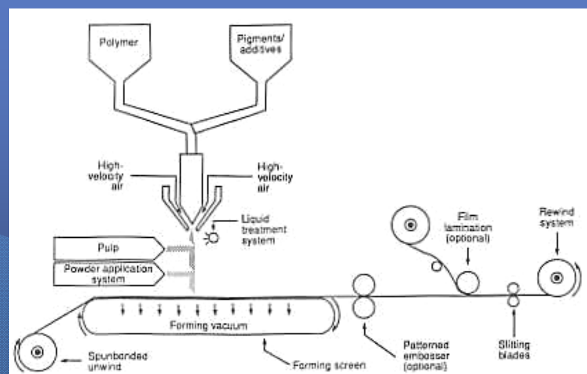
– generally use thermal-formable polymers

– make fabrics with high strength-to-weight ratios (spunbond),

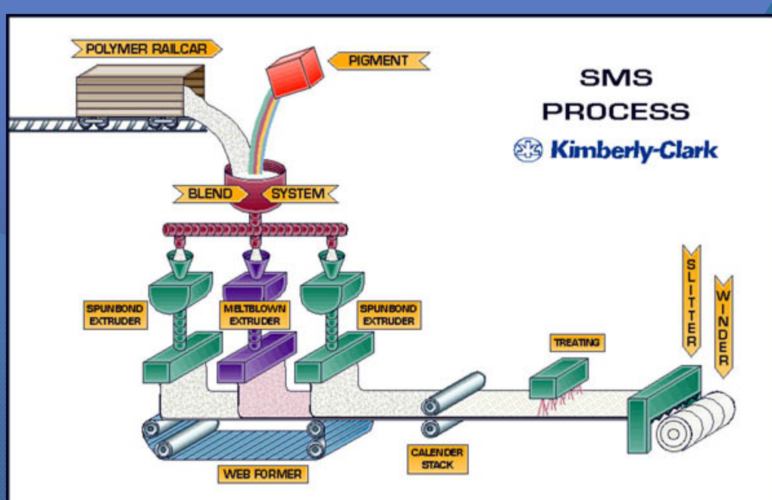
– high surface area to weight characteristics (meltblown), or

– high property uniformities per unit weight (films/nets)

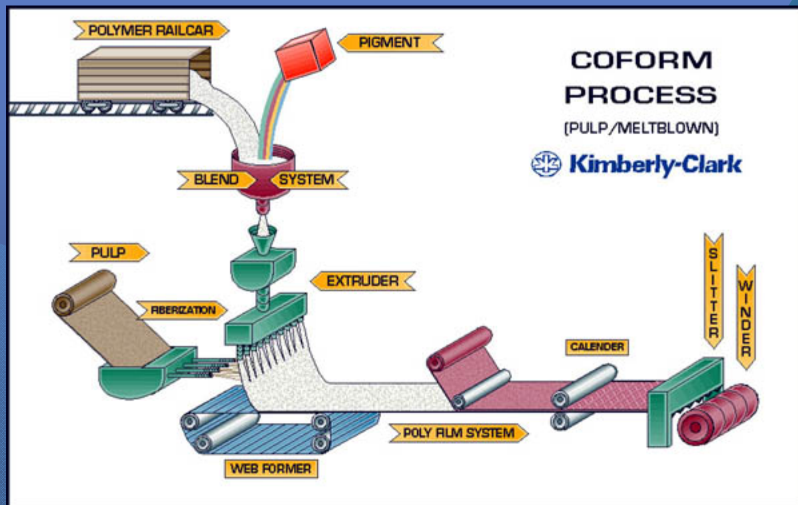
Nonwoven Hybrid Illustration



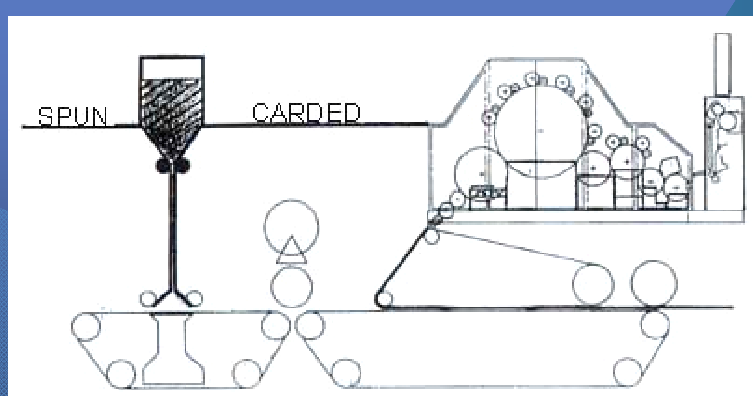
Spunbond-Meltblown-Spunbond



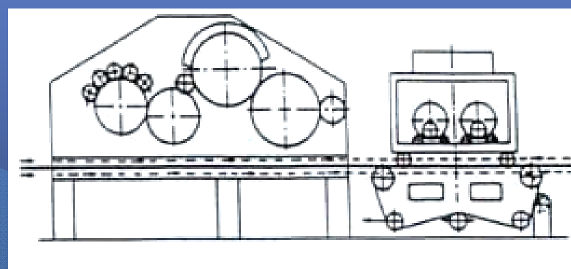
Meltblown-Pulp Coform



Spuncard Process



Short Fiber Airlaid Combined with Carding



Hybrid Nonwovens

CHARACTERISTICS

– combine the property and technology advantages of two or more individual systems and materials

– produce fabrics with synergistic properties for specific applications

Nonwoven Roll Good Technologies

Fiber-to-Fabric - wet laid processes
- dry laid processes

Polymer- to-Fabric - spunbond, meltblown, scrim/net, modified film processes

Hybridization - combining, combination, composite

thermally bonded, chemically bonded, needled, hydroentangled, stitch bonded

Nonwoven Manufacturing Technology Comparison

Technology	Investment per tonne/year US$	Throughput per meter width Kg/hour	Energy per Kg of product KWh	Web width Meters	Web weight g/m^2	Machine speed Meters/min.
Drylaid – Chemically bonded						
Minimum	800	50	2.5	1.0	13	10
Maximum	1850	270	4.5	3.5	300	150
Drylaid – Needlepunch						
Minimum	550	80	0.5	2.0	50	3
Maximum	3750	200	2.0	6.0	1000	25
Drylaid – Thermally bonded						
Minimum	960	100	0.5	2.0	10	20
Maximum	1850	270	1.5	4.0	120	300
Drylaid – Hydroentangled						
Minimum	3000	70	2.5	2.0	25	20
Maximum	8500	300	6.0	4.0	400	150
Wetlaid Minimum	1400	200	1.4	0.5	8	10
Maximum	2800	1000	6.6	4.3	300	450
Short fibre airlaid						
Minimum	1400	100	1.5	0.8	30	10
Maximum	3750	1500	4.0	3.2	500	400
Spunlaid Minimum	1350	100	1.0	1.6	10	15
Maximum	3000	350	3.5	5.3	350	400
Meltblown Minimum	2400	30	3.0	1.0	8	5
Maximum	4800	160	8.0	4.2	500	150
SMS Minimum	2150	150	1.6	2.0	15	60
Maximum	4300	300	4.0	4.2	45	350

Association of the
Nonwoven Fabrics Industry

India Nonwovens & Geotextiles Course

Standard Test Methods For the Nonwovens Industry

Test Methods

- **INDA / EDANA** - World Strategic Partners
- **ISO** – International Organization of Standardization
- **ASTM International** – D13 & F23
- **AATCC** – American Association of Textile Colorists & Chemists
- **TAPPI** – The Association of the Pulp & Paper Industry

Test Results

- Definition of the Method.
- Why is it Important?
- How is it Measured?
- Watch Outs !!!!

"The Dozen"

Weight
Thickness
Strength
Softness
Porosity
Barrier
Filtration
Contamination
Toxicity
Skin Friendliness
Fluid Management
Flushability

Weight

WSP 130.1 ISO 9073-1 ASTM D3776

Basis Weight = Weight per unit Area

Importance - Cost, Uniformity

Method

- Cut a specific size Sample
- Weigh the Sample
- Calculate weight per unit area

Watch Outs - Make sure you know the units! (GSM, GSY, OSY, GSF, GSI, Lbs/Ream)

Thickness

WSP 120.1 WSP 120.6 ISO 9073-2 ASTM D5729

Thickness - Distance between the face and back of a fabric under a specified pressure.

Importance - Controls the number of products in a package.

Watch Outs

- Many different pressures are used.
- Many different foot sizes used.
- Hundreds of different pressure gauges commercially available.

Thickness

Strength

Strength - Amount of force required to break or tear a nonwoven.

Importance - Often correlates to Fitness-for-Use in many applications.

Methods

- Strip Tensile
- Grab Tensile
- Trapezoid Tear
- Others (Tongue Tear, Burst, etc.)

Strength

Watch Outs

- Fitness-for-Use is a a combination of strength and elongation (TEA).
- Higher tensile does not necessarily yield higher tear or burst strength.

Strip Tensile

WSP 110.4 ISO 9073-3 ASTM D-5035

Method - Option A

- Cut 25 mm x 150 mm strips in MD or CD direction.
- Set gauge length to 75 mm.
- Clamp samples in grip jaws.
- Set Cross-head speed to 300 mm/min.
- Run test and record data (strength & elongation).

Strip Tensile

WSP 110.4 ISO 9073-3 ASTM D-5035

Method - Option B

- Cut 50 mm x 200 mm strips in MD or CD direction.
- Set gauge length to 200 mm.
- Clamp samples in grip jaws.
- Set Cross-head speed to 100 mm/min.
- Run test and record data (strength & elongation).

Strip Tensile

Strip Tensile

Watch Outs

- Results reported in many different units! (N/cm, N/mm, g/in, g/cm)
- Tensile results from different brands of tensile testers will be different.
- Results from different load cells can be different.

Grab Tensile

WSP 110.1 ISO 9073-18 ASTM D-5034

Method

- Cut 100 mm x 150 mm samples in MD or CD.
- Set gauge length to 75 mm.
- Clamp samples in grip jaws.
  - jaw face 1 is 25 mm x 25 mm
  - jaw face 2 is should be larger than face 1.
- Set cross-head speed to 300 mm/min.
- Run test and record data.

Grab Tensile

Grab Tensile

Watch Outs

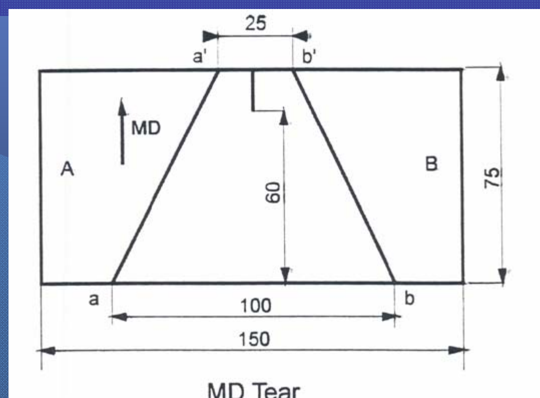
– Results generally reported in Pounds (lbs.) of tensile.
– Tensile results from different brands of tensile testers will be different.
– Results from different load cells can be different.

Trapezoid Tear

WSP 100.2 ISO 9074-4 ASTM D-5733

Method

– Cut and prepare sample as shown.



Trapezoid Tear

WSP 100.2 ISO 9074-4 ASTM D-5733

Method

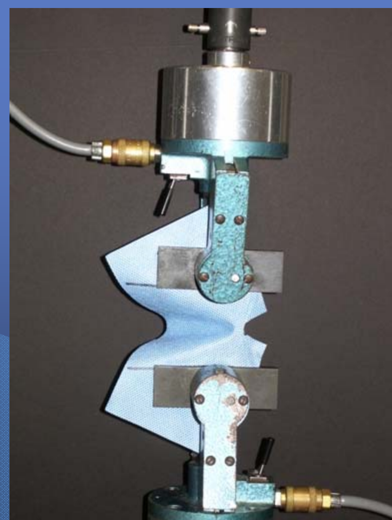
– Set gauge length to 25 mm.

– Mount samples in jaw clamps using the marked isosceles sides.

– Set cross-head speed to 100 or 300 mm/min.

– Run test and record results

Trapezoid Tear



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Trapezoid Tear

Watch Outs

- Results reported in Pounds (lbs.) or grams (g) of maximum tear force.
- Tear results from different brands of tensile testers will be different.
- Results from different load cells can be different.

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Other Strength Methods

Elmendorf Tear	WSP 100.1 ISO 3937-1 ASTM D-5734
Tongue Tear	WSP 100.3 ASTM D-5735
Ball Burst	WSP 100.5
Diaphragm Burst	WSP 30.1 ISO 13938-1 WSP 30.2 ISO 13938-2 TAPPI T403 OM-97

Softness

Softness
- Subjective quality of a fabric perceived by touch.
- Different cultures perceive softness differently.

Importance
- Skin Friendliness
- A component of "hand"

Softness

Methods

- In-house Softness Panels
- Cantilever Stiffness
- Gurley Stiffness
- Handle-o-Meter
- Cusick Drape
- Modified Cusick Drape
- Kawabata

Watch Outs

- Softness is defined differently around the world.

Softness

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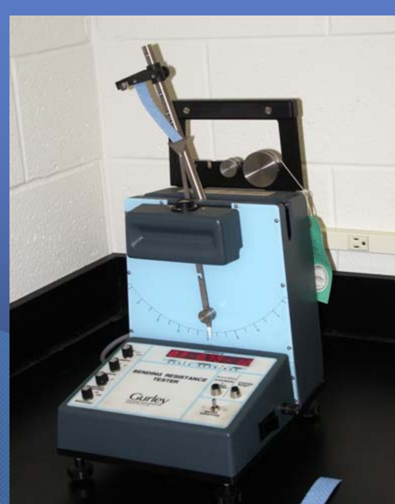
Cantilever Stiffness

Gurley Stiffness



Handle-o-meter

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Porosity

Porosity – the ratio of the volume of air or void area contained within the boundaries of a material to the total volume (solid, air, & void) expressed as a percentage.

Permeability – the ratio of flow of a fluid under a differential pressure through a material.

Importance

- A component of Fitness-for-Use in filtration & garments.
- Important for designing converting equipment.

Methods

- Air Permeability
- Capillary Flow Poremetry (Bubble Point, Mean Flow Pore size, Pore Size Distribution)
- Moisture Vapor Transmission Rate

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Air Permeability

WSP 70.1 ISO 9073-15 ASTM D737

Air Permeability – Velocity of an air flow passing perpendicularly through a test specimen under specified conditions of test area, pressure drop (ΔP) and time.

Watch Outs

- Procedures for different machines vary greatly.
- Altitude can change results!
- Different methods use different pressure drops. 100-200 PA (0.4 to 0.8 inches of water)
- Units vary (cfm, $cm^3/s/cm^2$, $l/s/cm^2$, mm/s, m/s, l/dm^2.min, dm^3, $m^3/h/m^2$, $ft^3/min/ft^2$).

Capillary Flow Porometry

ASTM F-316 ASTM F-778

Bubble Point – Test to determine the maximum pore size of a fabric in microns.

Method

- Air pressure is increased across a sample saturated with a specified liquid until the first air bubbles appear.
- Measure the differential pressures.

Capillary Flow Porometry

ASTM F-316 ASTM F-778

Method

– Calculate the maximum pore size using:

$$d = C\ t/p$$

where: d = maximum pore size

t = surface tension of liquid (dynes/cm or mN/m)

p = differential pressure

C = Constant: 2860 when p is in Pa.
2.15 when p is in cm Hg.
0.415 when p is in PSI.

Capillary Flow Porometry

Mean Flow Pore Size

– Determined by comparing the air flow through a dry sample to air flow through the same sample saturated with a liquid.

– When the pressure of wet flow equals one half that of the dry flow, the mean flow pore size can be determine.

Pore Size Distribution

– Based on wet and dry flow rates at discrete pressure intervals.

Moisture Vapor Transmission Rate

MVTR – Measures the rate of water vapor passage through a nonwoven fabric in g/hr m^2 or g/day m^2.

Classical Cup Method

ASTM E-96 INDA IST 70.2

Samples are sealed on the top of cups containing desiccant or water. The rate of moisture gain or loss is determined by measuring weight change versus time.

Advantage – Equipment is cheap.

Disadvantage – Very time consuming.

Moisture Vapor Transmission Rate

Automated Methods

WSP 70.4 WSP 70.5 WSP 70.6

ASTM D-6701

Advantage – Sample analysis time is short (1-2 hrs.)

Disadvantage – Equipment is expensive.

Barrier

Barrier – Resistance of a material to penetration by a liquid or solution.

Importance

- AAMI PB 70
- ASTM F2407-06
- Leg cuffs on diapers
- Outdoor wear
- House wraps

Barrier

Methods

- Hydrostatic Head
- Spray Impact Penetration
- ASTM F-1670-03
- ASTM F-1671-03

Hydrostatic Head

WSP 80.6 ISO 9073-16 AATCC 127-1998

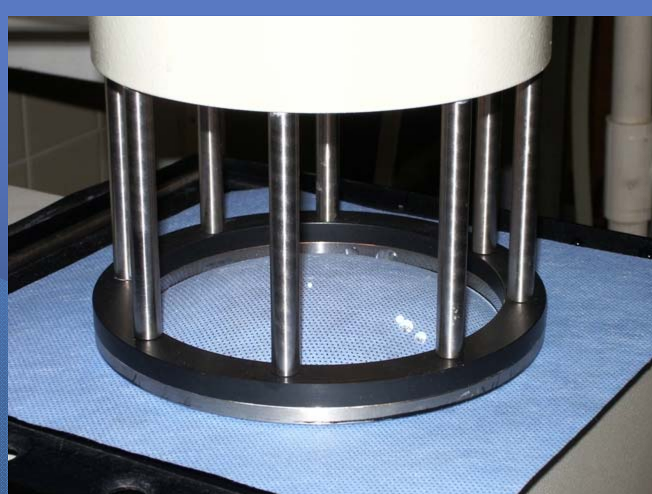
Hydrostatic head

- Measures the resistance of nonwoven fabrics to the penetration of water under varying hydrostatic head pressures.
- Test is complete when 3 drops of water penetrate through the fabric.

Watch Outs

- Results are reported in various units (millibars, centimeters, milliliters, inches).
- Ignore drops within ~6 mm of the clamping unit.

Hydrostatic Head



Spray Impact Penetration

WSP 80.3   AATCC 42-1004

Spray Impact - Measures the resistance of a fabric to the penetration of water by impact.

Importance
- Used to predict rain penetration.
- The lower the value the better the barrier.

Watch Outs
- Quality of the blotter paper is critical.
- Must use a “catch” device at the end of the spray time.
- Spray head flow rate is critical (22+/-2 seconds)

Spray Impact Penetration

Resistance to Penetration by Synthetic Blood
ASTM F-1670-03

Method
- Evaluates the resistance of materials to penetration by synthetic blood under conditions of continuous contact.
- Exposure conditions are:
  - 0 kPa (0 psig) for 5 min.,
  - followed by 13.8 kPa (2 psig) for 1 min.,
  - followed by 0 kPa (0 psig) for 54 min.

Results – Reported as pass/fail.

Watch Outs
- Test does not guarantee complete barrier.
- Cannot do relative rankings

ASTM F-1670

Resistance to Penetration by Blood-Borne Pathogens Using Phi-X-174
ASTM F-1671-03

Method

- Evaluates the resistance of materials to penetration by Phi=X-174 under conditions of continuous contact.
- Exposure conditions are:
  - 0 kPa (0 psig) for 5 min.,
  - followed by 13.8 kPa (2 psig) for 1 min.,
  - followed by 0 kPa (0 psig) for 54 min.

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Resistance to Penetration by Blood-Borne Pathogens Using Phi-X-174
ASTM F-1671-03

Results - Any penetration reported as a failure.

Watch Outs

- Not recommended as a QC test.
- $150-$250 per specimen.

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ASTM F-1671

Filtration

Filtration Efficiency- A quantitative measurement of a materials ability to filter out particles of a specific size.

Importance

- Medical (Facemasks, Blood Filters, CSR Wrap)
- Air (House & Commercial)
- Liquids (Drugs, Metals, Water, etc.)

Filtration

Methods- In-Vitro BFE, Dry Spore, Greene & Vesley

- Viral Filtration Efficiency
- Latex Sphere
- NaCl and DOP Penetration
- ASHRAE Tests
- Liquid Particle Filtration

Watch Outs

- Controlled conditions a must.
- Efficiency versus particle size is non-linear

Bacterial Filtration Efficiency

In-Vitro BFE ASTM F-2101 Military Spec-M-36954C

BFE - Measures the filtration efficiency of materials by employing a ratio of the upstream bacterial challenge to the downstream residual concentration of an aerosol of staphylococcus aureus.

Particle size - Aerosol is ~3 microns.

Watch Outs

- Maximum measurable efficiency is 99.9%
- Must balance BFE & Breathability.

BFE Apparatus

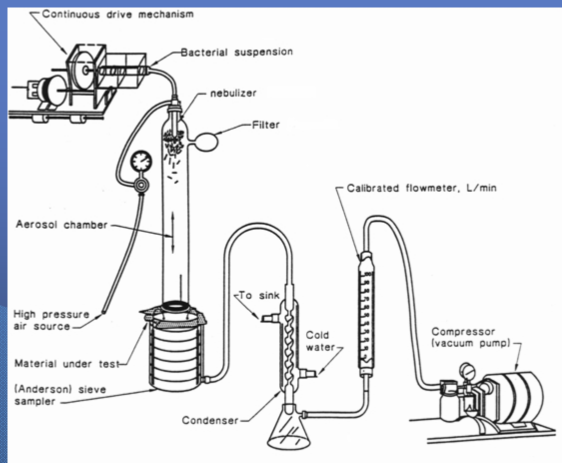

FIGURE B2 TEST APPARATUS FOR DETERMINING BACTERIAL FILTRATION EFFICIENCY

Anderson Sampler

Other Bacterial Filtration Efficiency Methods

Dry Spore

– Test is similar to In-Vitro BFE except that the aerosol particle size is ~ 5 microns.

Greene & Vesley

– Aerosol is generated by humans speaking the word "chew".

– Particle sizes are variable and larger than 5 microns.

Watch Outs

– Above methods are sometimes used in place of In-Vitro BFE when particle size is not specified in a specification.

Viral Filtration Efficiency

- VFE is similar to F-2101 except that the challenge aerosol contains Phi-X-174 Bacteriophage.

Sodium Chloride (NaCl) Aerosol Challenge

– Materials are challenged with ~0.3 micron particles.

– Efficiencies up to 99.999%.

– Flow rate up to 90 liters/minute.

Di-Octyl Phthalate (DOP) Aerosol Challenge

– Materials are challenged with ~0.3 micron particles.

– Efficiencies up to 99.999%.

– Flow rate up to 90 liters/minute.

Latex Sphere Filtration Efficiency
ASTM F2299-03

Latex Sphere

- Measures the initial filtration efficiency of materials by sampling representative volumes of upstream and downstream latex aerosol concentrations in a controlled environment.
- Latex particles range from 0.1 to 5.0 microns.
- Laser detector used to detect number & size of particles.

Watch Outs – Face velocity, particle size range, particle structure, and particle charge can impact results.

ASHRAE Standard 52.2

- Method of Testing General Ventilation Air Cleaning Devices for Removal by Particle Size

Method

- 24” x 24” sample is placed in the test duct.
- Airflow is set to the desired level (500-3,000 cfm).
- Test aerosol is injected upstream of the filter.
- Particle counter with 12 size ranges from 0.3-10 microns is used to measure particle counts upstream & downstream of the sample.
- Efficiencies from the 12 ranges are used to develop a MERV rating.

Minimum Efficiency Reporting Value

MERV Rating	Average Particle Size	Efficiency
1- 4	3.0 - 10.0	less than 20%
6	3.0 - 10.0	49.9%
8	3.0 - 10.0	84.9%
10	1.0 - 3.0	50% - 64.9%
	3.0 - 10.0	85% or greater
12	1.0 - 3.0	80% - 89.9%
	3.0 - 10.0	90% or greater
14	0.3 - 1.0	75% - 84.9%
	1.0 - 3.0	90% or greater
16	0.3 - 1.0	75% or greater

ASHRAE 52.1
Dust Holding Capacity

Definition

– The total weight in grams of ASHRAE dust caught by a filter before reaching a pre-determined pressure drop at a given rate of flow.

Components of ASHRAE Dust

72%	Standardized Air Cleaner Dust, Fine (Mean particle size – 7.7 microns)
23%	Powdered Carbon
5%	#7 Cotton Linters

Microbiological Contamination

Bioburden

– Total number of viable microorganisms in or on a material.

Importance

– High bioburden causes sterilization issues.
– High bioburden can consume biocides in wipes containing liquids.
– Early warning system for possible production problems.

Bioburden

Method

– Nonwoven is sampled aseptically.
– 10 gram sample is extracted in PEPB.
– Aliquot of the extract is filtered onto a 0.45 micron filter.
– Aseptically plate the membrane onto growth media.
– Incubate for specified time.
– Count number of Bacteria and Fungi.
– Target is 100 cfu/ml maximum.

Watch Outs

– Water purity is critical !!!!
– Human Contact is a large source of Bioburden.

Bioburden

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Bioburden

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Classical Pyrogen Test

Pyrogen - Group of chemical compounds derived from bacteria, viruses, and fungi that are fever inducing.

Endotoxin – A toxin produced by certain bacteria and released upon destruction of the bacterial wall especially in Gram Negative Bacteria.

Method

- Sample is extracted with pure water.
- Extract is then sterilized.
- Extract is injected into rabbits.
- Rabbits are monitored for temperature rise.

Watch Outs – Largest source of endotoxins is from contaminated water.

LAL

LAL - Limulus amebocyte lysate (LAL) test is an in-vitro assay for detection and quantization of bacterial endotoxins.

Method

- Sample is extracted with pure water.
- Extract is combined with LAL.
- A gel clot or color change will occur if toxins are present.
- Level of endotoxins is determined versus standards.
- Report EU/sample.

LAL

Watch Outs

- Acceptable EU levels are application specific.
- Largest source of endotoxins is from contaminated water.

Cytotoxicity

Cytotoxicity

- Rapid standardized test to determine if a material contains quantities of harmful extractables and their effect on cellular components.

AGAR Overlay

- Designed to evaluate the cytotoxicity of diffusible components from a material.

MEM Elution

- Designed to evaluate the cytotoxicity of extractables from a material.

Scoring System

0=None 1=Slight 2=Mild 3=Moderate 4=Severe

Hemolysis

Hemolysis

- Breaking open of red blood cells and the release of hemoglobin into the surrounding fluid.
- Test is designed to measure the amount of blood cell lysis caused by a material.

Method

- Material is extracted with sterile saline.
- Combine extract with citrated or heparinzed blood and incubated at 37°C for 1 hour.
- Sample is centrifuged to remove blood cells.
- Optical density is measured and % lysis determined.

Results – 5% or less generally considered safe.

Hemolysis

Other Toxicity Tests

Acute Systemic Toxicity

- Material is extracted with 2 polar and 2 non-polar solvents.
- Extracts are injected into Albino mice.
- Reactions are measured at 0, 4, 24, 48, & 72 hours.
- Animals observed for signs of toxicity, weight loss, or mortality.

Other Toxicity Tests

Intracutaneous Toxicity

- Material is extracted with 2 polar and 2 non-polar solvents.
- Backs of white New Zealand rabbits shaved.
- Small aliquots of extracts injected into the skin in 5 places.
- Reactions are measured at 0, 4, 24, 48, & 72 hours.
- Measure degree of ERYTHEMA & EDEMA.
- Score of 0-1 acceptable for most materials.

USP Class VI Plastics

- Acute Systemic Toxicity
- Intracutaneous Toxicity
- USP Muscle Implantation Study

Skin Friendliness

Primary Skin Irritation Test

- A 1”x1” sample is topically applied to intact and abraded skin of 6 rabbits and left in place for 24 hours.
- Test sites are graded at 24 & 72 hours for irritation after a single challenge.

Skin Friendliness

Delayed Contact Sensitization

- Material is extracted in 0.9 % saline solution.
- Guinea Pigs are exposed to extracts and materials multiple times over a 14 day period.
- Signs of sensitization scored.

Scoring Scale

0=None 1=Mild 2=Moderate 3=Severe

Human Repeat Insult Patch Test

RIPT – Evaluates the potential of a test material, via repeated application, to induce contact dermalsensitization in humans.

Method

- 1 cm2 piece of fabric is patched onto the back left shoulder area for 24 hours.
- Patch is removed and left uncovered for 24 or 48 hours.
- Process is repeated 9 times.
- After 13 day "rest period", the right shoulder is patched for 24 hours.
- Observations made at 24, 48, 72, & 96 hours.

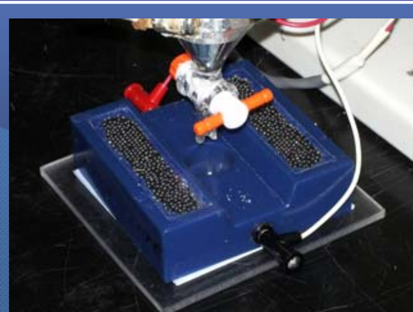
Human Repeat Insult Patch Test

Watch Outs

- FDA recommends 200 person minimum.
- Test period is 28 days.
- Expensive test.

Fluid Management

Strike-Thru	WSP 70.3	ISO 9073-8
Wet Back	WSP 80.1	
Repeated Strike-Thru	WSP 70.7	ISO 9073-13
Wet Back after Repeated Strike-Thru	WSP 70.8	ISO 9073-14



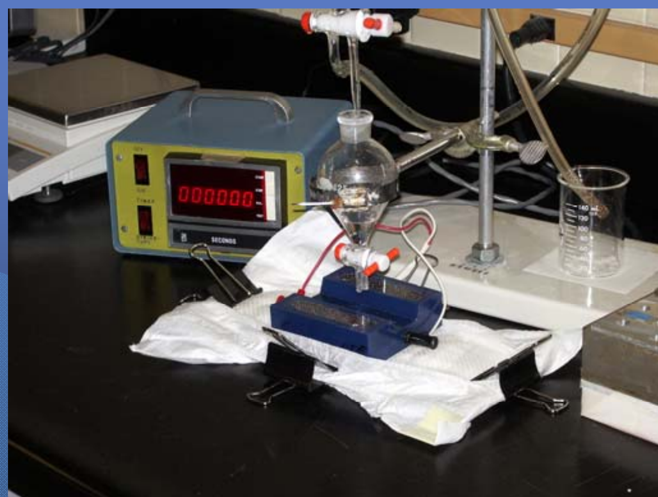
Fluid Management

Watch Outs

- Type of blotter paper can impact results.
- Results do not always correlate to diaper performance.
- More in-diaper testing today

Strike Through & Rewet

Diaper Strike Through



Nonwoven Absorption Test

WSP 10.1 ISO 9073-6

Liquid Absorbency Time

- Measures the time required for the complete wetting of a specimen strip loosely rolled into a wire basket and dropped on to the surface of the liquid from a height of 25 mm.

Liquid Absorptive Capacity

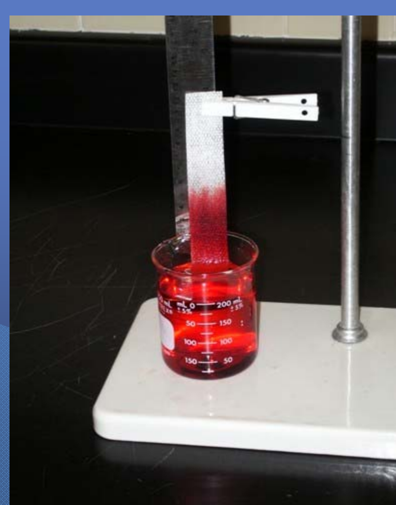
- Method provides the measure of the amount of liquid held within a test specimen after specified times of immersion and drainage. Measures the liquid stored within the test specimen.

Liquid Wicking Rate

- Method measures the rate of vertical capillary rise in a specimen strip suspended in the test liquid.

Absorptive Capacity

Vertical Wicking Rate



Flushability

- INDA & EDANA are Developing a Voluntary Guidance Document to Evaluate the Flushability of Nonwoven Consumer Products
- Current State
  - Draft guidance document developed.
  - Pilot program beginning.
  - Peer review starting with outside organizations.
- Contact INDA or EDANA with questions!!!!

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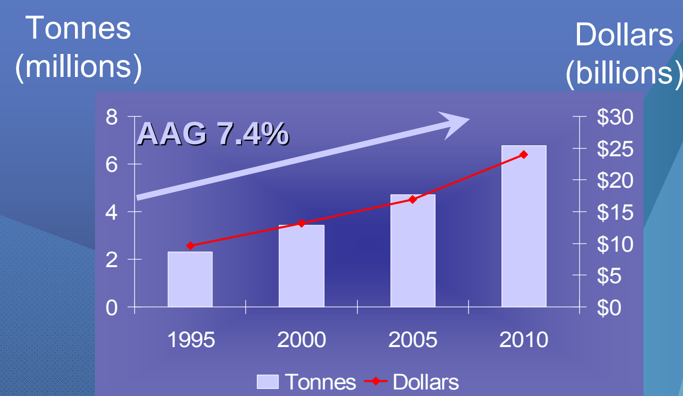
Nonwoven Markets and Future Directions: Production Growth Technology and Product Trends

Worldwide Nonwovens Production Growth



Source: INDA Estimates

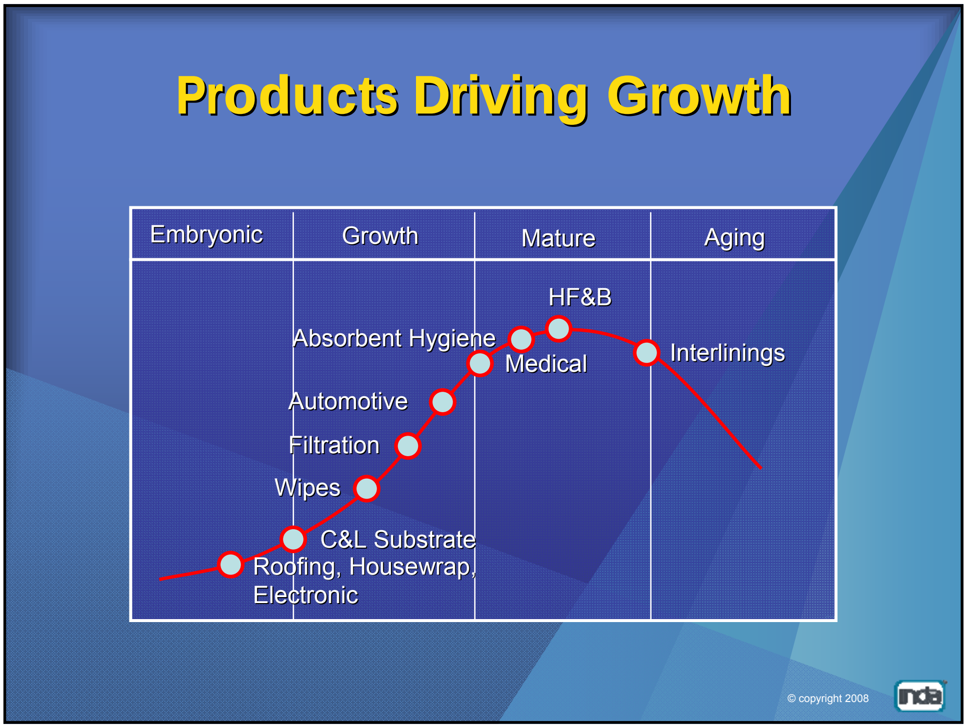
Products Driving Growth

Spunlaced	Wipes, medical apparel, surgical sponges, C&L sub'
Airlaid Pulp	Wipes, absorbent cores, medical, soaker pads
Spunbonded PP	Absorbent hygiene, HF&B, wipes, geotextiles
Melt Blown	Filtration, vacuum bags, sorbents, electrical, wipes
Needlepunch	Many markets: automotive, filtration, wipes, HF&B, coating substrate, geotextiles, C&L substrate
Spunbond PET	Automotive, fabric softener, HF&B, geotextiles, C&L
Wetlaid	Filtration, wipes, gaskets, tea bags
(Resin/TBond)	Absorbent hygiene, wipes, interlining

Forecast Worldwide Growth per Year to 2010

Red = 11-13%, Orange = 8-10%, Green = 5-7%, Blue = <5%, Lt. Blue = neg.

Source: INDA Estimates


Products Driving Growth
Embryonic
Growth
Mature
Aging
HF&B
Absorbent Hygiene
Medical
Interlinings
Automotive
Filtration
Wipes
C&L Substrate
Roofing, Housewrap, Electronic
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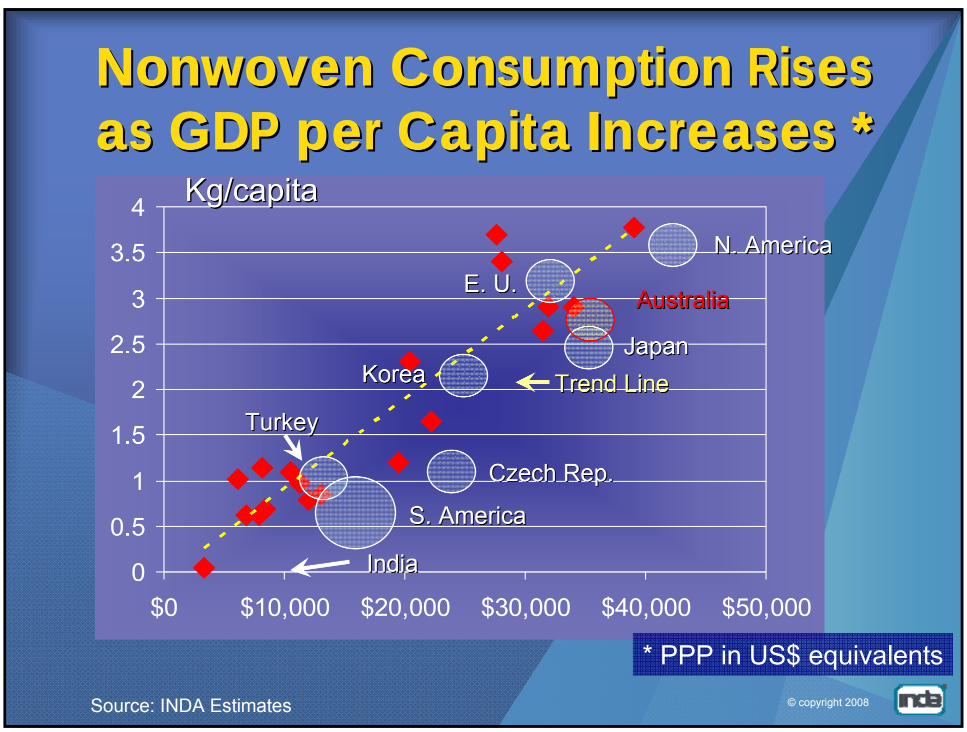
Nonwoven Consumption Rises as GDP per Capita Increases *
Kg/capita
4
3.5
3
2.5
2
1.5
1
0.5
0
$0
$10,000
$20,000
$30,000
$40,000
$50,000
N. America
E. U.
Australia
Japan
Korea
Trend Line
Turkey
Czech Rep.
S. America
India
* PPP in US$ equivalents
Source: INDA Estimates
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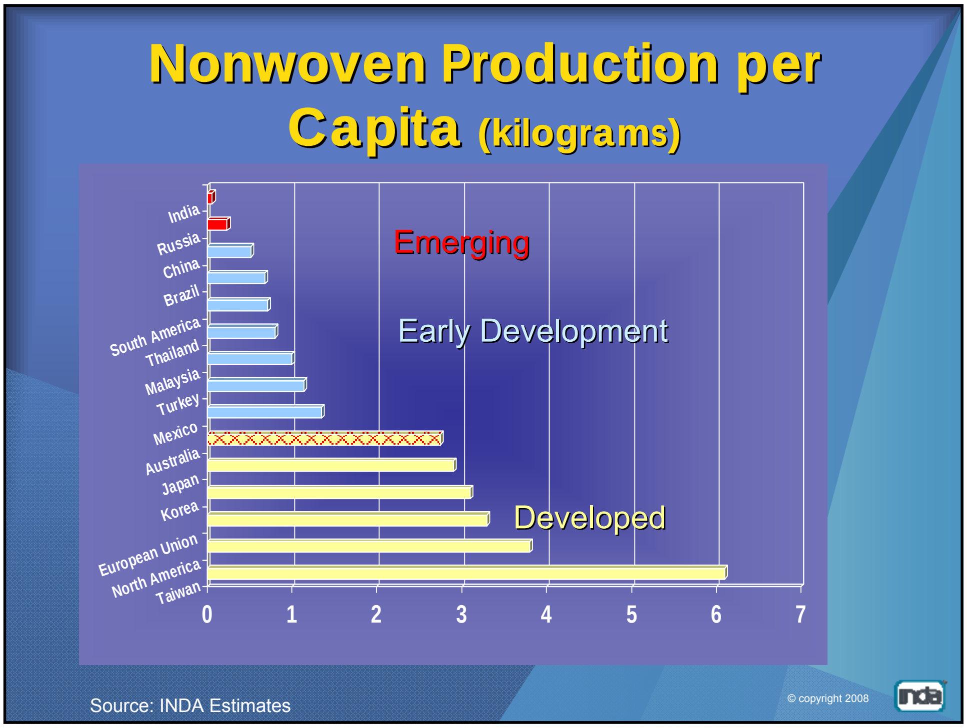
Nonwoven Production per Capita (kilograms)
India
Russia
China
Brazil
South America
Thailand
Malaysia
Turkey
Mexico
Australia
Japan
Korea
European Union
North America
Taiwan
Emerging
Early Development
Developed
0
1
2
3
4
5
6
7
Source: INDA Estimates
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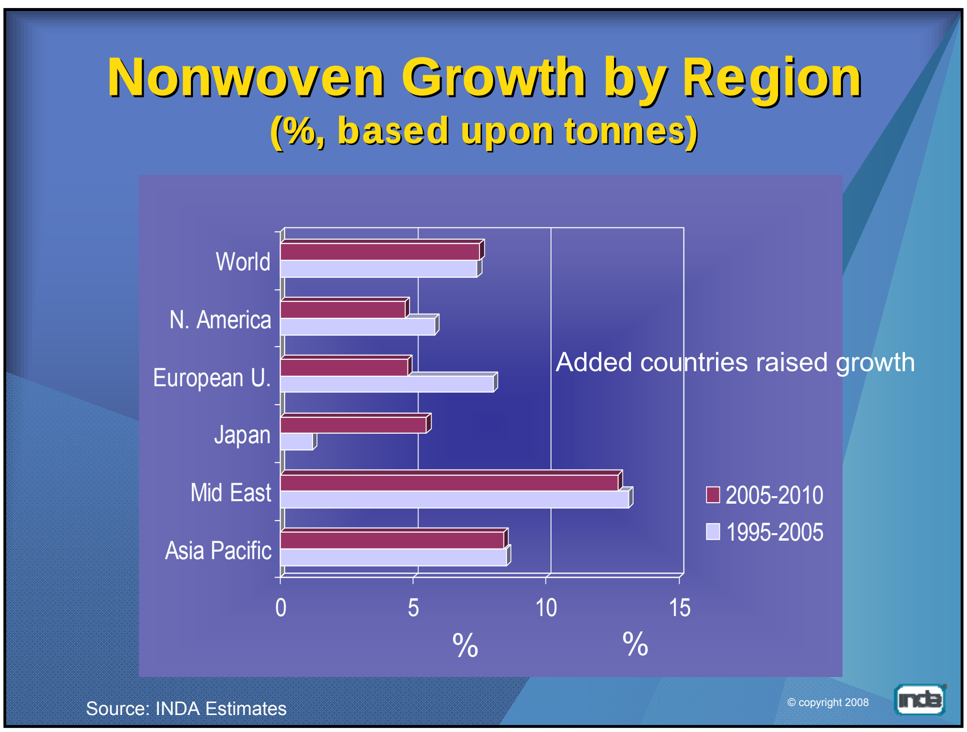
Nonwoven Growth by Region
(%, based upon tonnes)
World
N. America
European U.
Japan
Mid East
Asia Pacific
Added countries raised growth
2005-2010
1995-2005
0
5
10
15
%
%
Source: INDA Estimates
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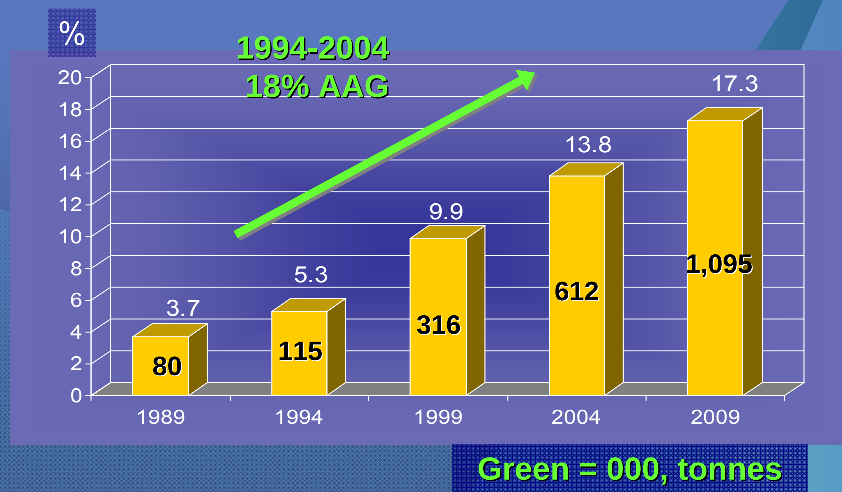
China's Rapid Growth

(percent of world total nonwoven production)



Source: INDA Estimates

2005 Nonwoven Production

(000, tonnes)

Regions	
Euro' Union	1,410
Asia-Pacific*	1,390
N. America	1,250
L. America**	340
Mid. East	205
R. of World	125

* Australia included here

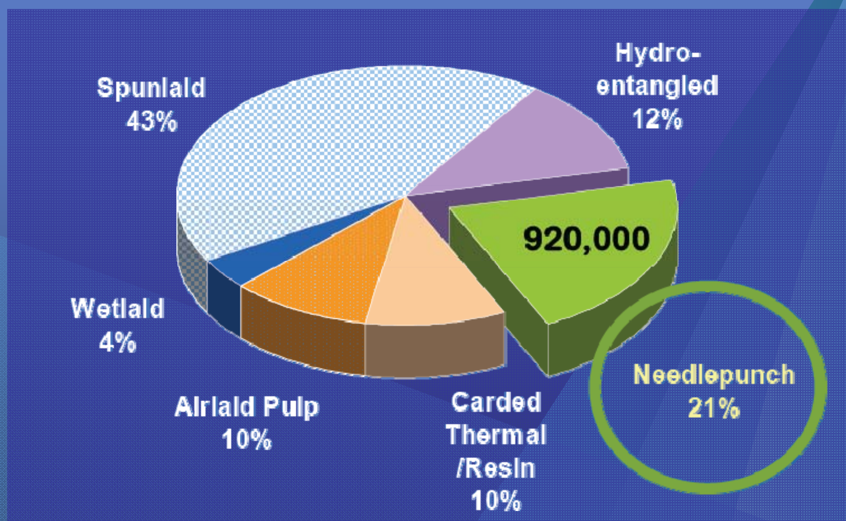
** Top 6: Argentina, Brazil, Chile, Colombia, Mexico, Venezuela

Selected Countries	
Australia	55
Brazil	130
Mexico	130
Taiwan	140
Korea	206
Turkey	80
Japan	305
S. Africa	25
Saudi Arabia	<25
India	50

Source: INDA Estimates

2004 Nonwoven Production

(% by weight – 4.4 million tonnes- synthetic fiber)



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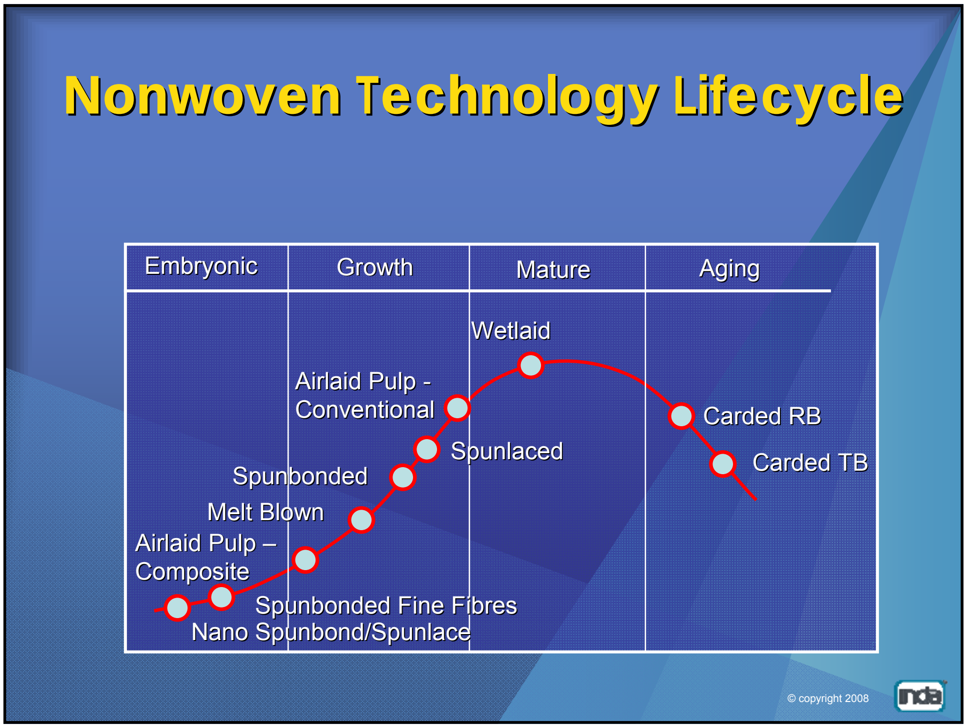
Nonwoven Markets and Future Directions: Manufacturing Technologies and Trends


Nonwoven Technology Lifecycle
Embryonic
Growth
Mature
Aging
Wetlaid
Airlaid Pulp - Conventional
Carded RB
Spunlaced
Carded TB
Spunbonded
Melt Blown
Airlaid Pulp – Composite
Spunbonded Fine Fibres
Nano Spunbond/Spunlace
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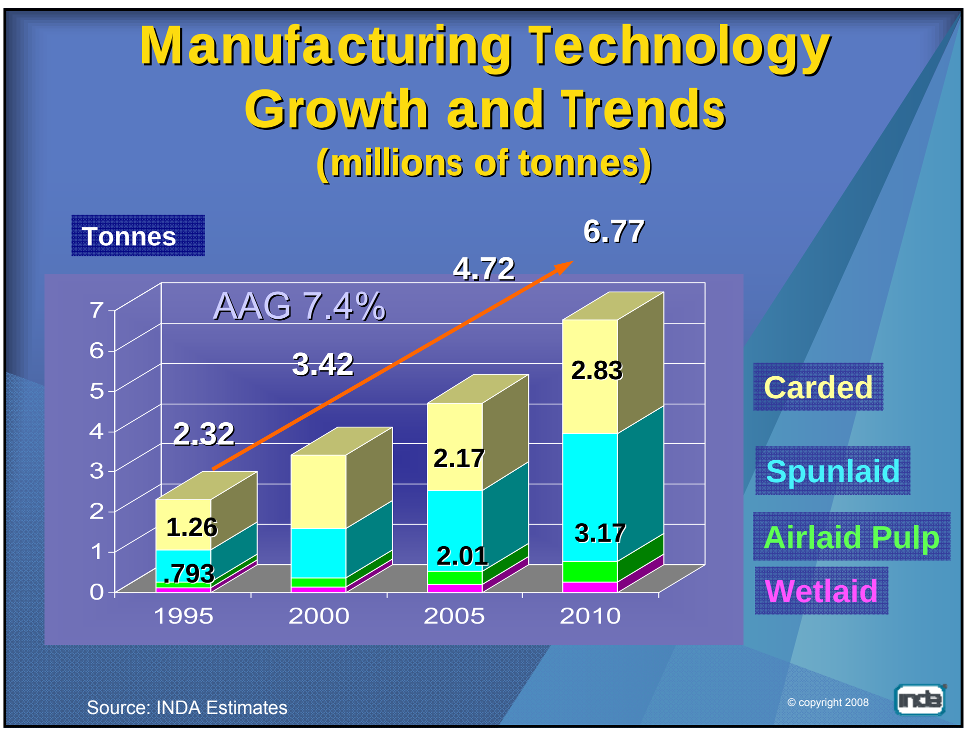
Manufacturing Technology Growth and Trends
(millions of tonnes)
Tonnes
6.77
4.72
AAG 7.4%
3.42
2.32
2.83
2.17
1.26
.793
2.01
3.17
7
6
5
4
3
2
1
0
1995
2000
2005
2010
Carded
Spunlaid
Airlaid Pulp
Wetlaid
Source: INDA Estimates
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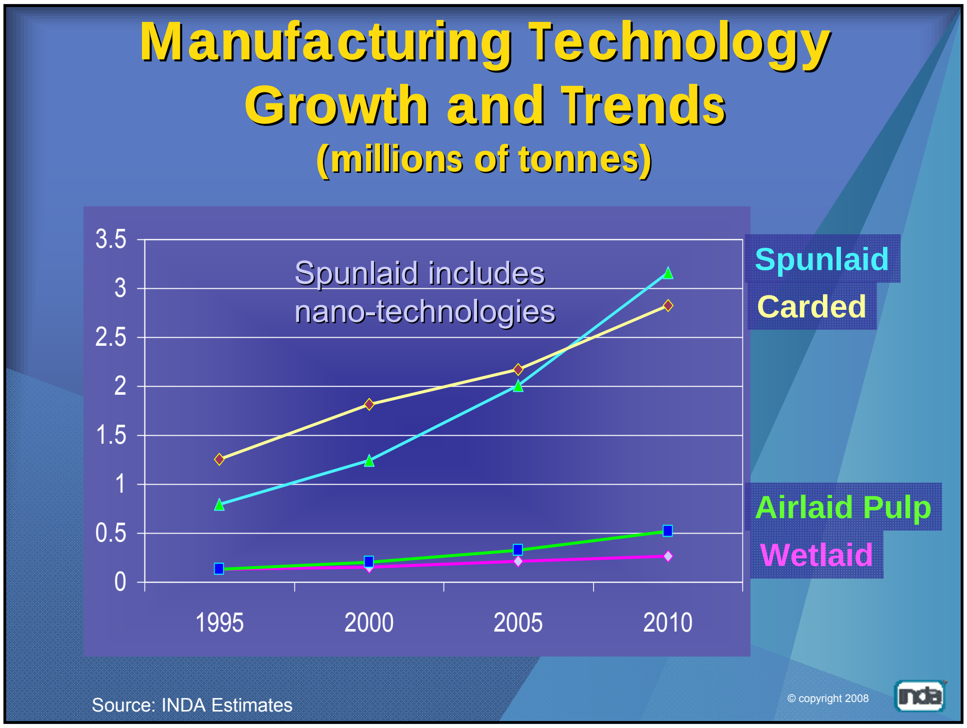
Manufacturing Technology
Growth and Trends
(millions of tonnes)
Spunlaid includes
nano-technologies
3.5
3
2.5
2
1.5
1
0.5
0
1995
2000
2005
2010
Spunlaid
Carded
Airlaid Pulp
Wetlaid
Source: INDA Estimates
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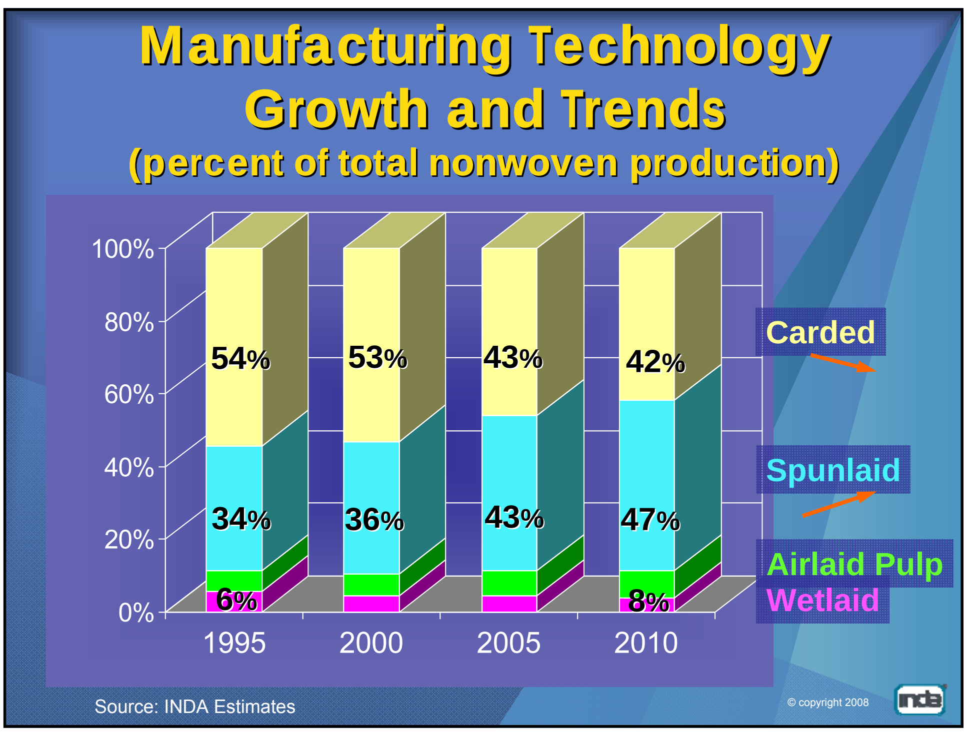
Manufacturing Technology
Growth and Trends
(percent of total nonwoven production)
100%
80%
60%
40%
20%
0%
54%
53%
43%
42%
34%
36%
43%
47%
6%
8%
1995
2000
2005
2010
Carded
Spunlaid
Airlaid Pulp
Wetlaid
Source: INDA Estimates
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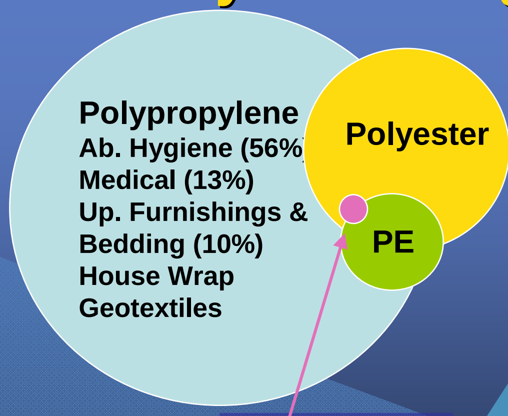
Key Spunlaid Markets by Technology



Polyester
Filtration
Furnishing & Bedding (14%)
Roofing (15%)
Geotextiles
Carpeting (14%)

Polyethylene
House Wrap
Ind'l Disp. Apparel
Courier Envelopes
Medical Packaging

Nylon
Niche Markets
Filtration
C&L Substrate

Source: INDA Estimates

Spunlaid Formation Trends

- Spunlaid will continue to increase share of total nonwovens and pass Carded volume before 2010.
- Driving Spunlaid Growth:
  - Expansion of world markets (absorbent hygiene, furniture and bedding, medical, geotextiles)
  - Efficient production and low cost per kilogram versus competition

Spunlaid Formation Trends

- Driving Spunlaid Polypropylene Growth:
  - Inherent fabric strength with softness versus competitive nonwovens
  - Market's move toward lighter weights of PP cover stock and finer denier fibers
  - Cover stock switching from Carded Thermal Bonded to Spunbonded PP
  - Technically easier to process
  - Competent turn-key technologies: Reiter; Reifenhauser; Saurer

Spunlaid Formation Trends

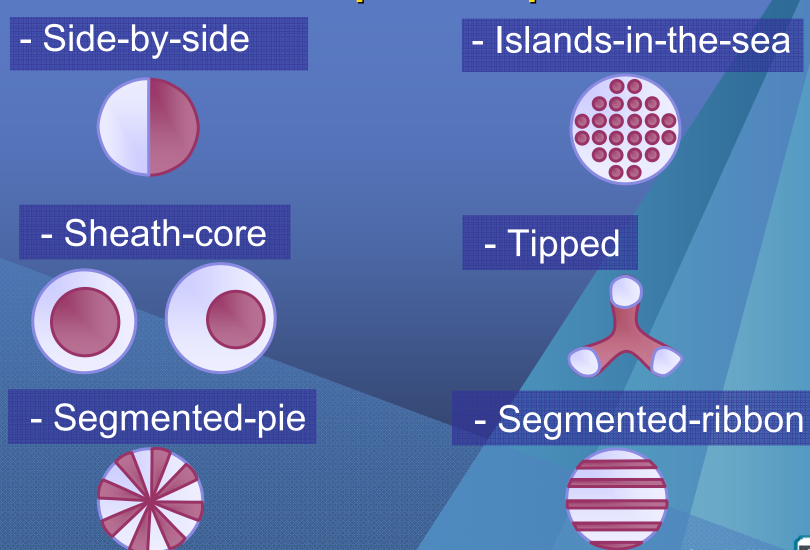
- Driving Spunlaid Polyester Growth:
  - Inherent fabric strength higher than PP
  - Polyester is used where heat is involved in post treatments: i.e. moulded auto carpeting, mod. bitumen roofing, fabric softener substrate
  - Growth markets: upholstered furnishings & bedding, filtration, landscape

Bi component, Fine Denier and Nano Spunlaid Technologies

- Bi component fiber spunlaid/spunlaced
  - Leading to new composites
- Spunbonded fine denier:
  - Lighter weights (8-10 gsm)
  - Improved web uniformity
  - Lower costs
  - Target market: absorbent hygiene, filtration

Fiber Elements:

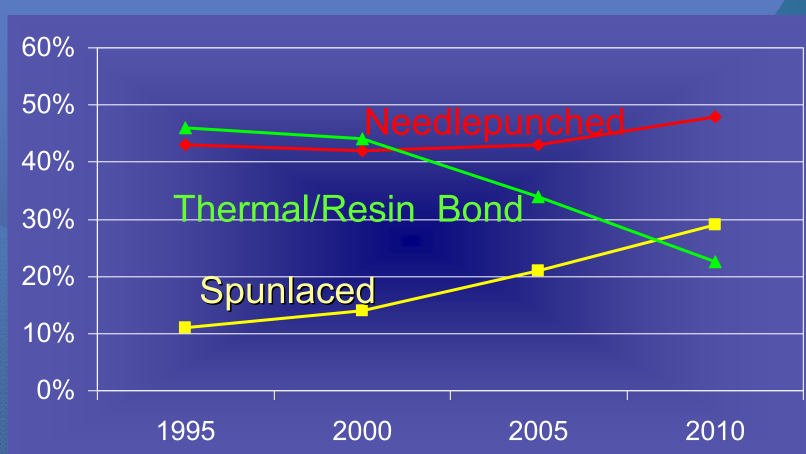
Cross-sectional Shape Bicomponent Fibers



Bicomponent, Fine Denier and Nano Spunlaid Technologies

- Bicomponent spunlaid/spunlaced
  - – Nano fibre technology
  - – Leading to new fabrics (Evolon)
  - – Could lead to further penetration of Durable markets, i.e. apparel, HF&B

Outlook for Carded Technologies
(% Share of Total Carded Nonwovens)



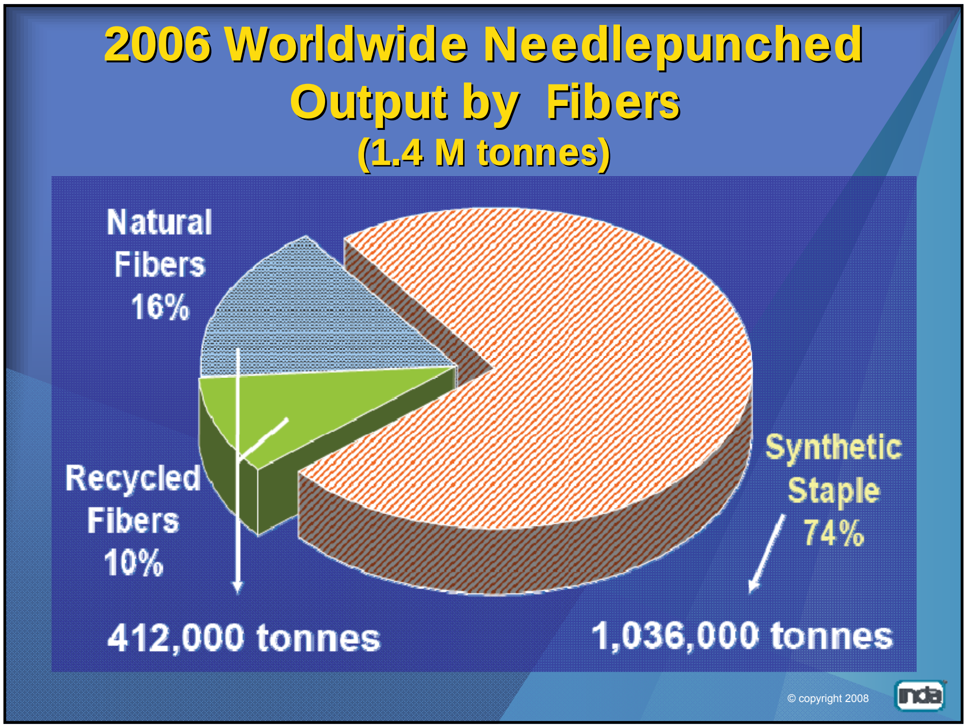
Source: INDA Estimates

Carded Formation Trends

- Carded Nonwovens are losing share but buoyed by rapid growth of Spunlaced materials and continuing growth of Needlepunched materials
- Driving Spunlaced:
  – Expanding wipes markets (softness, textile feel, strong …great aesthetics)
  – Medical apparel, surgical dressings' growth
  – Coating and laminating substrate

Carded Formation Trends

- Needlepunched nonwoven supplies numerous, mostly industrial markets: Carpeting, automotive, filtration, shoe construction, coating/laminating substrates, geotextiles. Growth driven as economies' industrialize.
- Needlepunched is often the first nonwoven technology in a embryonic market. Can process many raw materials.
- Resin and Thermal Bonded declining as replaced by other nonwoven technologies
  – Thermal bonded cover stock still important


2006 Worldwide Needlepunched Output by Fibers
(1.4 M tonnes)
Natural Fibers 16%
Recycled Fibers 10%
Synthetic Staple 74%
412,000 tonnes
1,036,000 tonnes
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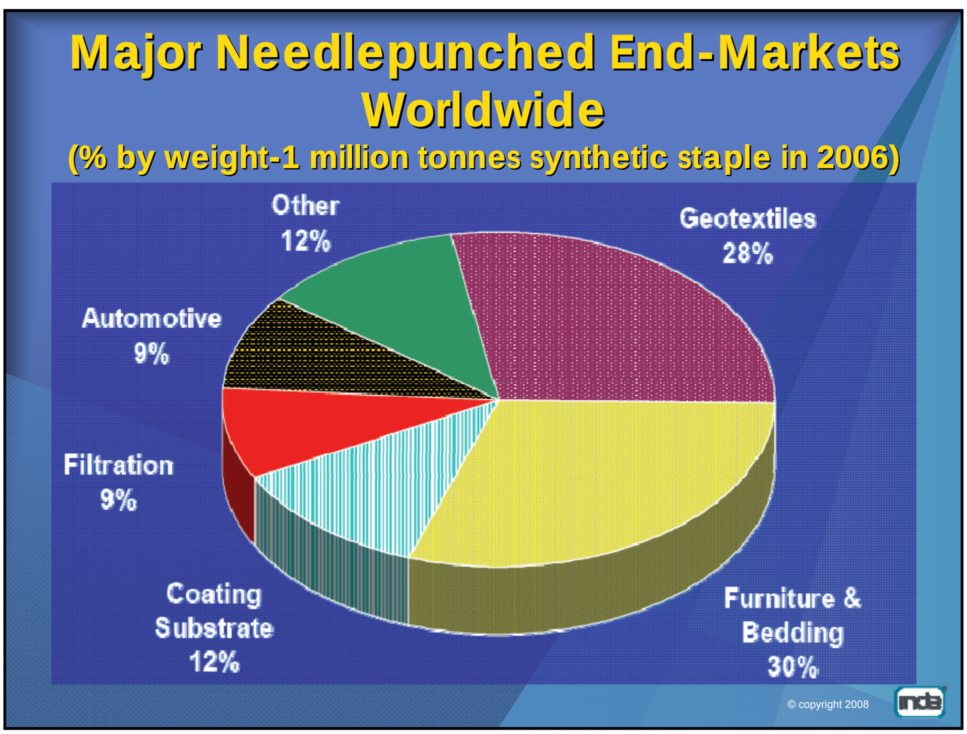
Major Needlepunched End-Markets Worldwide
(% by weight-1 million tonnes synthetic staple in 2006)
Other 12%
Geotextiles 28%
Automotive 9%
Filtration 9%
Coating Substrate 12%
Furniture & Bedding 30%
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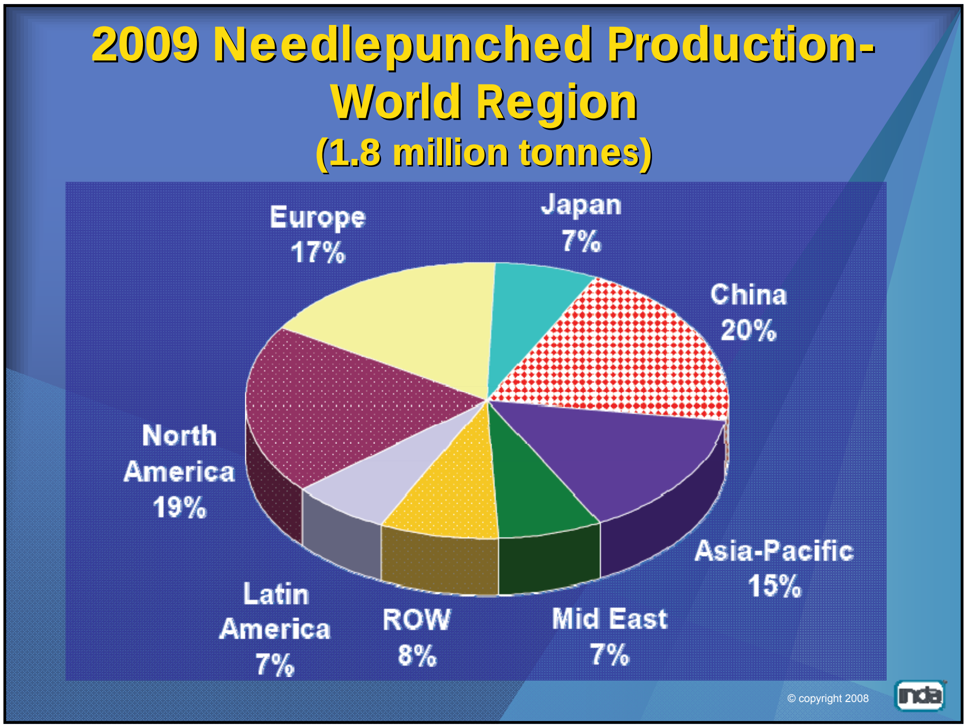
2009 Needlepunched Production-
World Region
(1.8 million tonnes)
Europe
17%
Japan
7%
China
20%
North
America
19%
Asia-Pacific
15%
Latin
America
7%
ROW
8%
Mid East
7%
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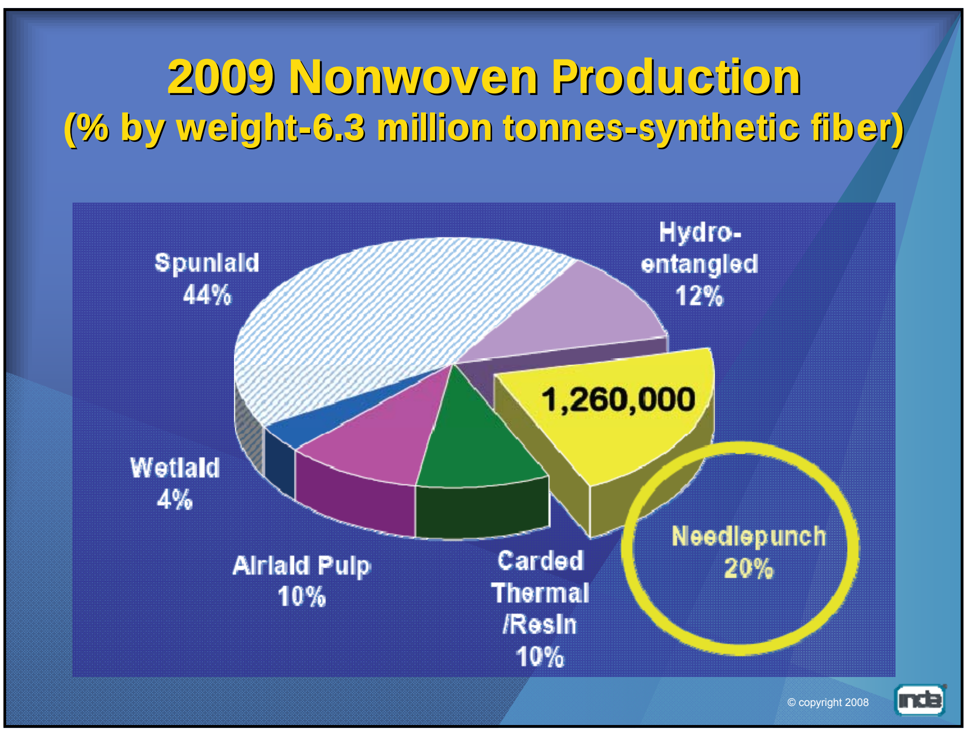
2009 Nonwoven Production
(% by weight-6.3 million tonnes-synthetic fiber)
Spunlaid
44%
Hydro-
entangled
12%
1,260,000
Wetlaid
4%
Needlepunch
20%
Airlaid Pulp
10%
Carded
Thermal
/Resin
10%
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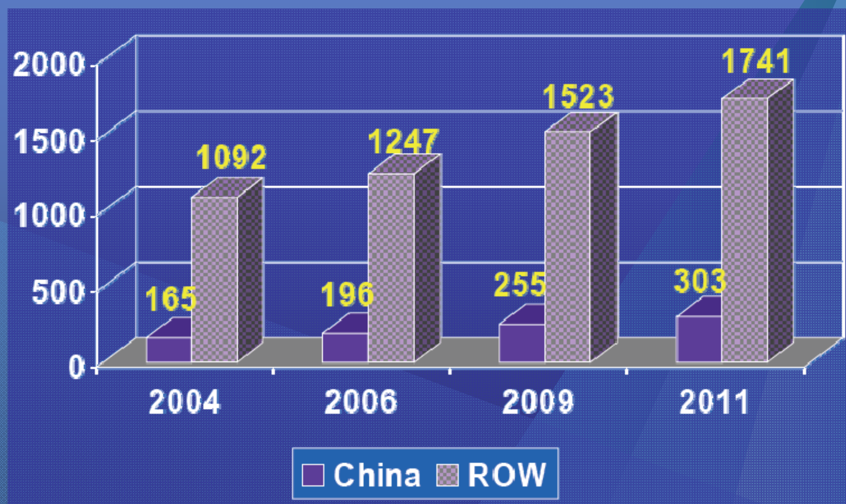
What's Driving Worldwide Growth? China Needlepunch Production



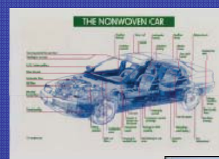
Other Growth Regions

- Brazil, leader in South America
- Turkey, largest in Middle East
- India, 60% of nonwoven output is Needlepunched

What's Driving Worldwide Growth?

- Expanding use in existing products:

Automotive



Geotextiles

Photo courtesy of Propex

Filtration

What's Driving Worldwide Growth?

- Efficient means to bond a heavy fabric
- Technical versatility and good aesthetics and physical characteristics
- Comparatively low capital cost/production unit

Outlook

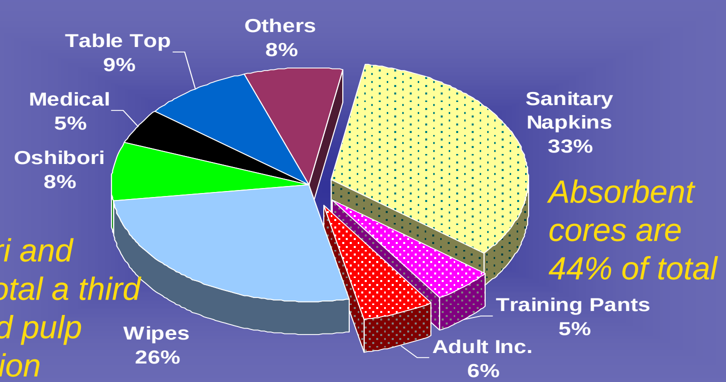
Worldwide

- Continued strong tonnage growth:40% increase in 5 years, worldwide
- Industry consolidation within mature markets
- Target developing and niche markets
- Regional growth potential: India, South America, Middle East

Airlaid Pulp Forming Trends

- Airlaid Pulp growth in 10% per year range
- Driving Growth:
  – Lowest cost nonwoven technology as using pulp
  – Wipes industry growth
  – Absorbent Hygiene Cores - feminine light day pads, adult incontinence products

Major World Airlaid Pulp Applications
(based upon 2003 tonnage)



Absorbent cores are 44% of total

Oshibori and wipes total a third of airlaid pulp production

Source: INDA Estimates

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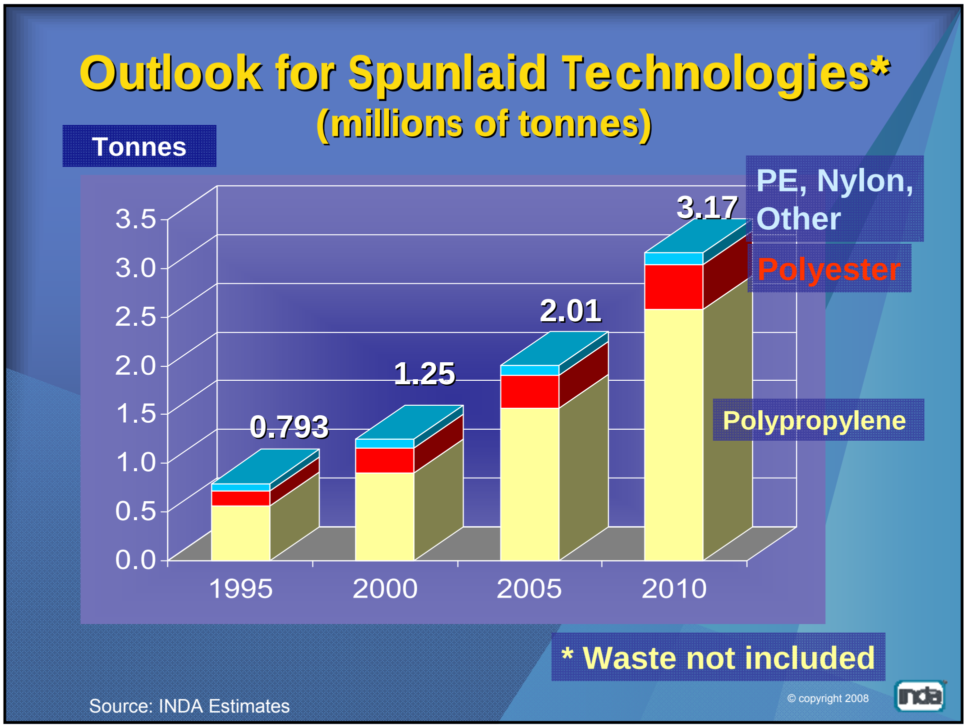
Nonwoven Markets and Future Directions: World Spunlaid Resin and Staple Fiber Trends


Outlook for Spunlaid Technologies*
(millions of tonnes)
Tonnes
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.793
1.25
2.01
3.17
1995
2000
2005
2010
PE, Nylon, Other
Polyester
Polypropylene
* Waste not included
Source: INDA Estimates
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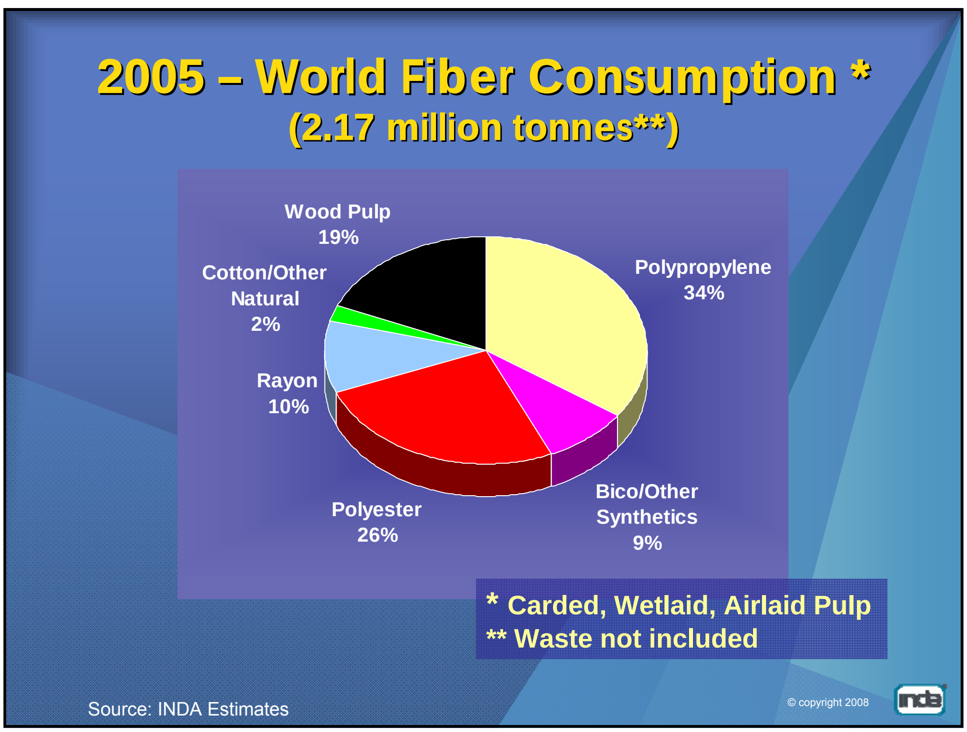
2005 – World Fiber Consumption *
(2.17 million tonnes**)
Wood Pulp
19%
Cotton/Other
Natural
2%
Rayon
10%
Polyester
26%
Polypropylene
34%
Bico/Other
Synthetics
9%
* Carded, Wetlaid, Airlaid Pulp
** Waste not included
Source: INDA Estimates
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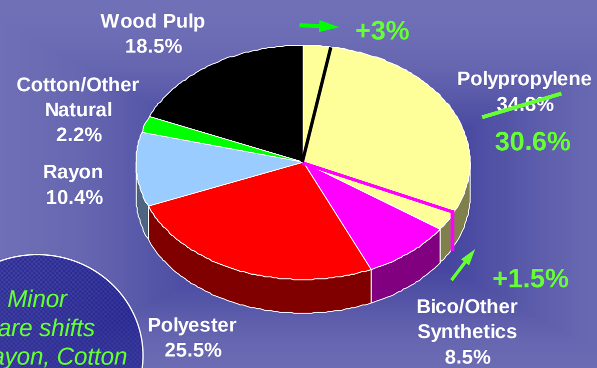
2010 – World Fiber Consumption *
(2.83 million tonnes**)



Minor share shifts In Rayon, Cotton and Polyester for 2010

* Carded, Wetlaid, Airlaid Pulp
** Waste not included

Source: INDA Estimates

Bottom Line

- Nonwovens are an important industry supplying materials for a wide variety of disposable and durable markets
- Nonwoven growth worldwide is 7-8%
- Carded spunlaced - high growth
- Airlaid pulp – high growth, but slowing
- Thermal/resin bond in sunset years
- Spunlaid will pass combined carded technologies and polypropylene is the highest growth resin

Bottom Line

- Durable markets generally grow first: the first disposable markets are feminine hygiene and baby diapers
- India is in the emerging phase of nonwoven development: rapid growth in durable markets expected
- India's textile background is an excellent resource for skilled persons
- Many parts of infrastructure are in place

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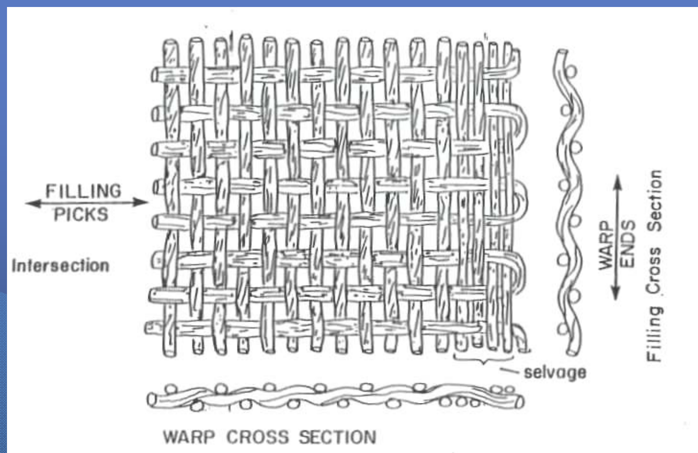
Fabric Manufacturing Basics

- A fabric is a planar structure made by
- interlooping one or more yarns,
- interlacing two or more yarn sets , or
- interlocking networks of fibers or filaments or yarns.

- ***Weaving*** is the process of interlacing two or more yarn sets at right angles to each other in a designated order.
- In woven fabric formation processes, one end of one of the yarn sets is free to be interlaced with one or more yarns in the other yarn set(s).
- In a woven fabric, longitudinal or warp yarns are called ends and transverse yarns are called picks or shots.
- The order or pattern of interlacement of ends and picks is called the weave or fabric design.

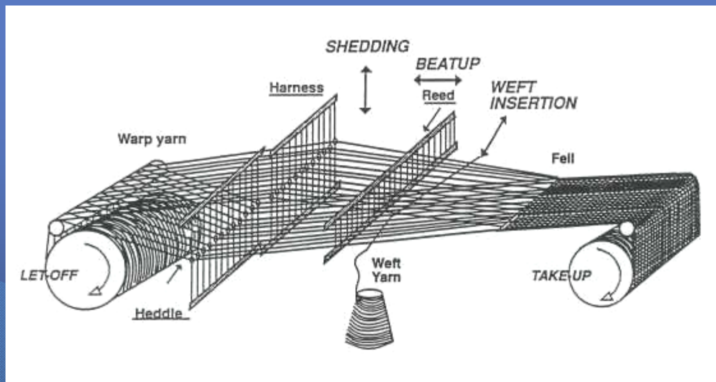
Woven Fabric



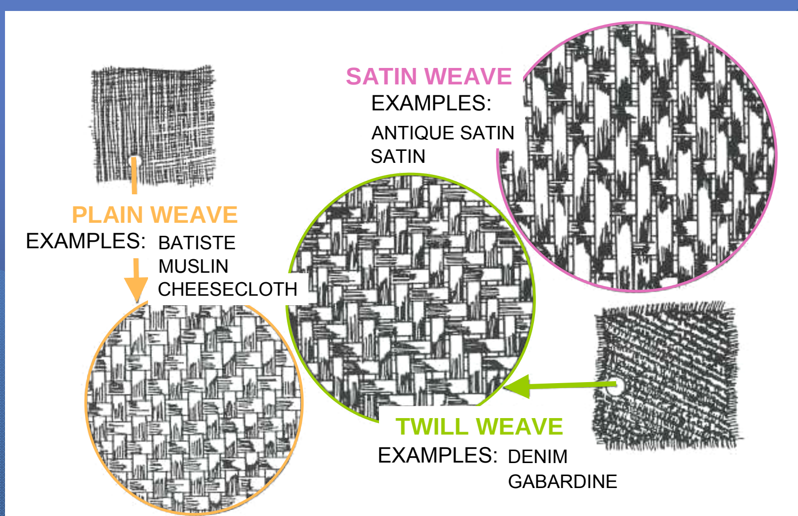
In the plain weave, warp and filling yarns are interlaced in alternate order.

The Weaving Process

- Consists of three basic operations carried out sequentially:
  - *Shedding* or separating the warp yarns to form a place (called the shed) for a filling yarn,
  - *Picking* or inserting the filling yarn across the shed, and
  - *Beating-up* or packing the filling yarn next to the previously inserted filling yarn to form the interlaced fabric.
- Interlacing results from alternating harness positions; the alternating order determines fabric design.



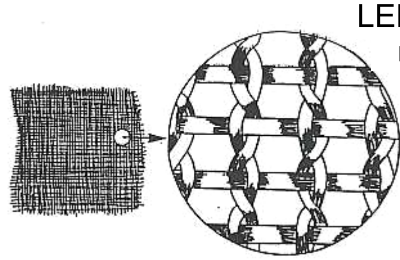
In weaving fabric is formed on a loom by interlacing two yarn sets at right angles.



LENO WEAVE

EXAMPLE:

MARQUISETTE



- Weaving is the most extensively used fabric formation technology.
- Weaving is extremely versatile.
- Woven fabrics are dimensionally stable.
- Woven fabric weight is changed by changing yarn weight, yarn spacing, and yarn placement.
- Woven fabrics fray when they are cut

- ***Knitting*** is the most direct method of converting yarn to fabric.
- Knitted fabrics are made by *interlooping* one or more yarns upon itself or themselves.
- In knitted fabric formation processes, both yarn ends are fixed, and the loops are formed by manipulating the yarn center.
- In knitted fabric, the longitudinal loops are called wales and the horizontal loops are called courses.
- The loop configuration or interlooping pattern is called the stitch.
- Each loop is formed on a needle; loops become stitches when cast from the needle and pulled through previous loops.

Knitting Technologies

Weft (Filling) Knitting – yarns from one or more individual packages are carried to needles placed across or around a machine and interlooped horizontally to form a fabric.

Warp Knitting – yarns from a beam are individually guided to needles placed on bars and interlooped adjacently and vertically to form a fabric.

Weft Knitting Machine

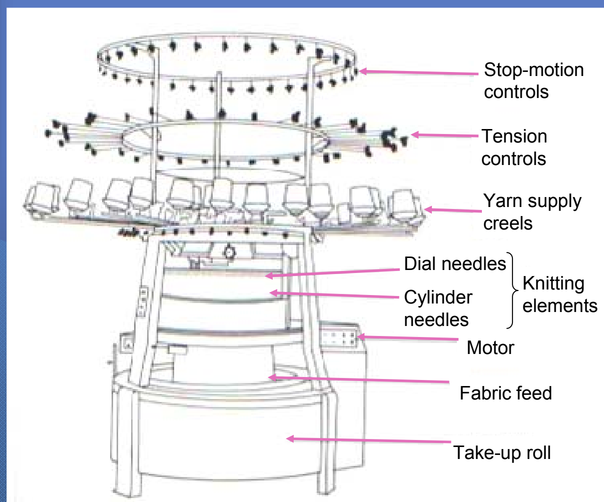
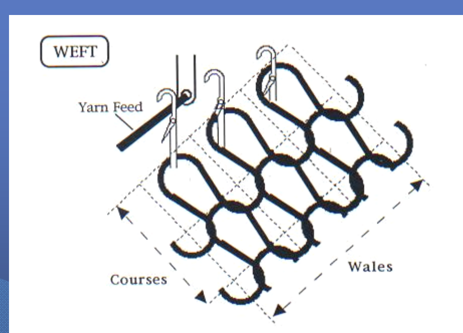
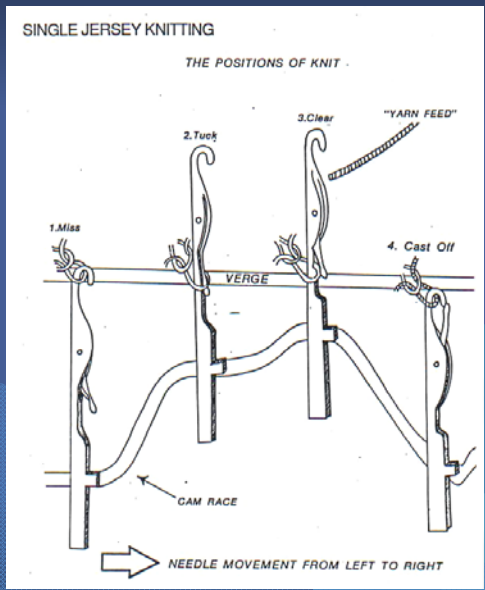


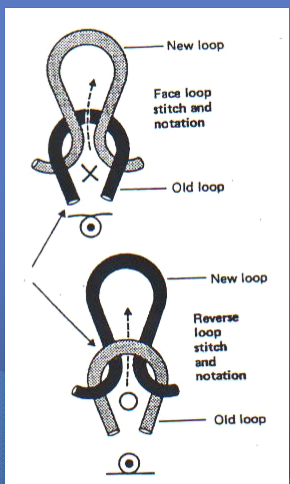
Diagram of a circular knitting machine. This is a double-knit unit. Yarns feed from the supply packages to the top and then down through various controls to the knitting area.

Weft

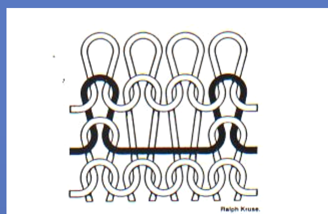


Stitch is Formed Along the Courses



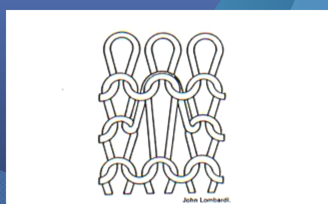


Knit



Miss-stitch. Note the floating unknit yarn in this diagram of the fabric back.

Miss/Float

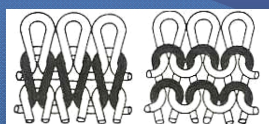


Tuck stitch. Note the elongated wale appearance in this diagram of a fabric back. The tuck stitch appears in a fabric as an inverted "V."

Tuck

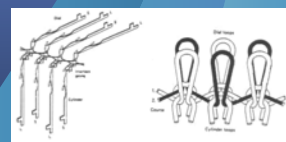
Weft Knitted Fabrics

- Are produced on both circular & flat and machines
- Are formed with latch needles
- Stitches are formed across the Wales



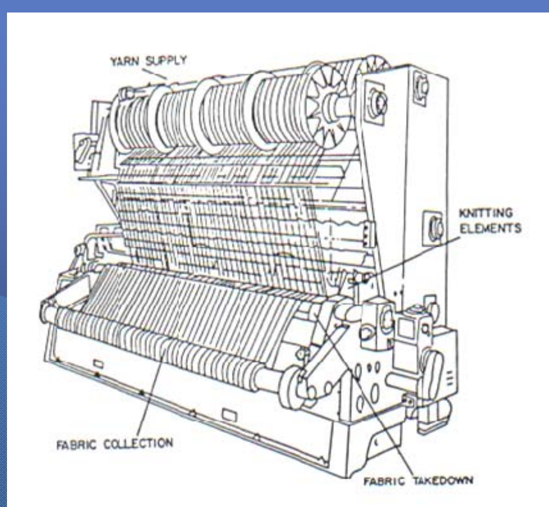
Jersey

Rib

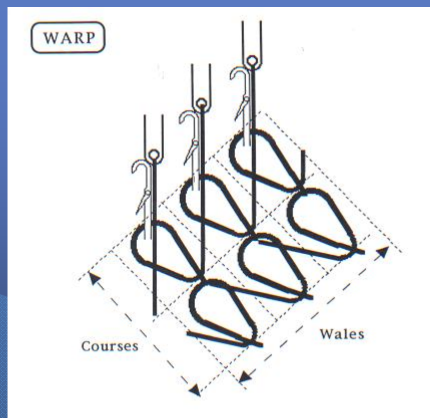


Double Knit

Warp Knitting Machine



Warp



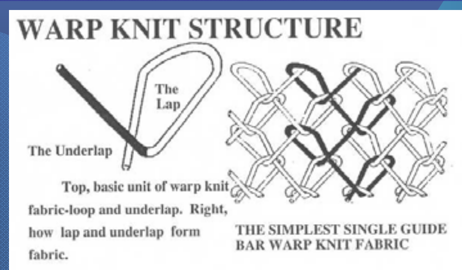
Stitch Formed Along the Wales

Warp Knitted Fabrics

- Are produced flat from beams of yarn.
- Needles are mounted on bars.
- Each needle has one or more individual yarns.
- Loops are joined diagonally in adjacent courses.
- Basic types are Tricot and Raschel.
- Fabrics stretch more crosswise than lengthwise.

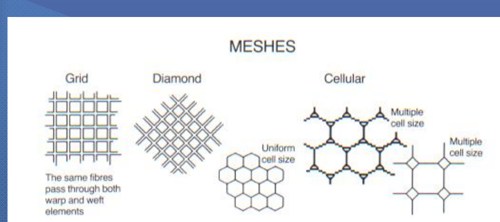
Tricot Fabrics

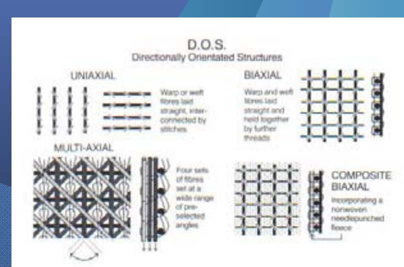
- Use Spring Beard needles & Filament yarns
- Are made at high speed (at 2000rpm and 40 cpi, production would be 50 in/min)
- Typical fabric width is 168 inches
- May have 1,2,3 or more guide bars – each fed from separate beams (most are 2 bar)



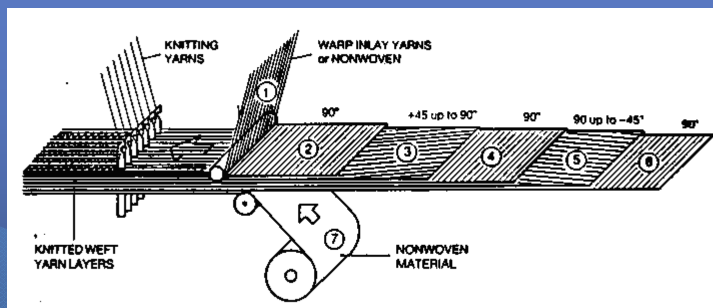
Raschel Fabrics

- Use latch or compound needles and all yarn types.
- Are made faster than weft knits, slower than tricot.
- Fabric width is typically 100 to 200 inches.
- Have more than two bars, as many as thirty.
- Fabric uses include nets, meshes and geotextiles.



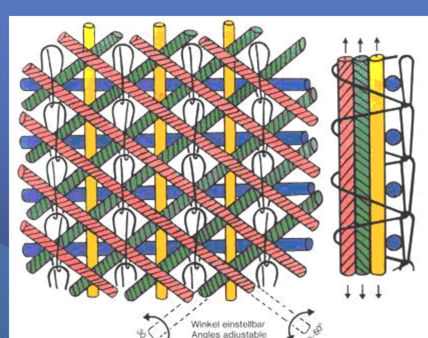


Multi-Axial Warp Knitting



Multi -Axial Weft Insertion Warp Knitting Machine Nonwoven plus 6 Yarn Layers

Multi-Axial Warp Knit Fabric Structure



- ***Knitting*** is the second most extensively used fabric formation technology.
  - Knitting is not as versatile as weaving.
  - Knitted fabrics are extensible and form fitting.
  - Knitted fabric weight is determined by yarn size and the distance between needles (machine gauge).
  - Some knitted fabrics curl when cut.

- A ***Nonwoven*** is a fabric made by
  - mechanically, chemically, or thermally interlocking layers or networks of fibers or filaments or yarns,
  - interlocking fibers or filament concurrent with their extrusion
  - perforating films, or
  - forming porous films concurrent with their extrusion
- A basic nonwoven manufacturing concept is to transform fiber-based materials into flat, flexible, porous, sheet structures with fabric characteristics.

Nonwoven fabric manufacturing technologies:

textile (*dry laid*),

paper (*wet laid*),

extrusion (*polymer laid*), and

hybrid (*combination*),

Have four common phases:

Fiber selection and preparation,

Web forming,

Bonding, and

Finishing

Nonwoven Fabric Manufacturing

Options

Fiber Selection

Abaca	PBI
Acetate	PBT
Acrylic	PE
Aramid	PEN
Coir	PET
Elastomer	PLA
Flax	PP
Glass	PTT
Hemp	pulp
Jute	rayon
Lyocell	sulfar
Melamine	triacetate
Metallic	urethane
Modacrylic	vinyon
Nylon	Wool
Cotton	

Web Formation

- Carding: parallel, scrambled, random
- Crosslap
- Airlay
- Wetlay
- Spunbond
- Meltblown
- Film
- Net

Bonding

- Needlepunch
- Hydroentangle
- Stitchbond
- Spray
- Saturate
- Print
- Foam
- Calender
- Thruair
- Ultrasonic

Finishing

- Hydrophilic
- Hydrophobic
- Repellent
- Flame
- Retard
- Coating
- Antimicrobial
- Dye
- Print
- Corrugate
- Emboss
- Compact
- Crepe
- Flock
- Plasma
- Encapsulate

Woven, Knitted & Nonwoven Fabric
Production Rate Comparison

Method	System	Square Meters/Hour
Weaving	Shuttle	15
	Rapier	30
	Water Jet	35
	Projectile	40
	Air Jet	55
Knitting	Double Knit	125
	Rib	175
	Single Jersey	250
	Raschel	800
	Tricot	1200
Nonwoven	Stitchbond	450
	Needlepunch	7200
	Card-Bond	15000
	Wetlay	30000
	Spunbond	48000

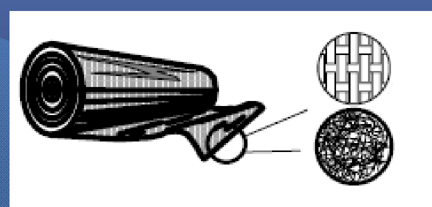
Association of the
Nonwoven Fabrics Industry

India Nonwovens & Geotextiles Course

Geotextile Fundamentals: Terminology, Functions, Performance Criteria, Test Methods & Associated Applications for Wovens, Knits, Nonwovens and Geogrids

Geotextile Terminology

- Geotextiles are continuous sheets of woven, nonwoven, knitted or stitch-bonded fibers or yarns. The sheets are flexible and permeable and generally have the appearance of a fabric. Geotextiles are used for separation, filtration, drainage, reinforcement and erosion control applications.

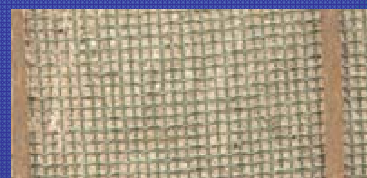


Geotextile

- any permeable textile used in any
- geotechnical engineered system, a.k.a.
- Filter Fabric, Filter Cloth, Filter Paper,
- Construction Paper.

Woven Polypropylene Geotextiles

- Woven polypropylene geotextiles function well in applications such as:
  - Separation
  - Filtration
  - Soil Reinforcement
  - Confinement



- Because,
  - The weave geometry provides excellent particle separation that controls filtration and drainage
  - Resulting high soil confinement provides greater load distribution.
  - Polypropylene is durable and chemical damage resistant.
  - Cross-roll direction strength is maintained when panels are sewn together.

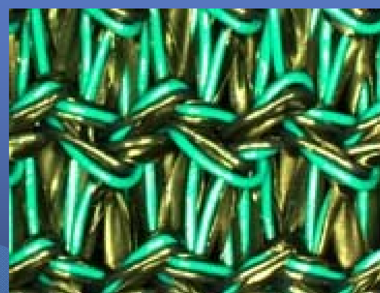
Geotextile Terminology

- A Geotextile is a planar polymeric (synthetic or natural) permeable textile material, manufactured in the form of sheet which may be woven, nonwoven or knitted used as an integral part of geo-environmental and civil engineering projects, structures or systems.

- Geosynthetic fabrics are made from polyester (PET), polyvinylalcohol (PVA), polypropylene (PP).

  PET has low elongation and high strength; PVA high strength, extremely low elongation and high chemical resistance; PP high chemically resistance and acceptable elongation.

Knitted Geotextile



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- Woven and knitted geotextiles are used in a wide range of both cohesive and non-cohesive soils to provide quick formation of a natural soil filter. They facilitate dissipation of pore pressures due to their high strength and low elongation thus improving mechanical properties of soil and enabling the construction of reinforcing ground structure.

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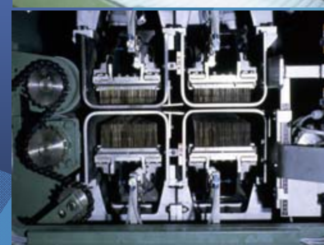
- Nonwoven geotextile fabrics are produced from 100% virgin polymers in weights ranging from 3.5 to 30 osy, needle-punched or spun-bonded, to provide maximum permeability and optimum strength. Permeability, drainage capacity, and controlled filtration properties are basic drainage and soil filtration application requirements.

Needlepunched geotextiles

Needlepunched Polypropylene Geotextile Producers

- SI Corporation
- TC Mirafi
- LINQ
- Skaps
- Western Nonwovens
- Owens Corning
- Others

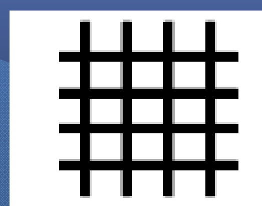


Geotextile Terminology

- Geosynthetic is a generic term for all synthetic materials used in geotechnical engineering applications, including textiles, grids, nets, membranes and composites
- Nonwoven - textile structure produced by mechanical, chemical, thermal, or solvent bonding and/or interlocking of fibers
- Woven - textile structure produced by interlacing two or more yarns, fibers, or filaments
- Knit - textile structure produced by interlooping ends of yarn

Geotextile Terminology

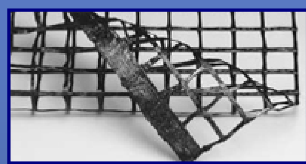
- Geogrids are geosynthetic materials that have an open grid-like appearance. The principal application for geogrids is the reinforcement of soil.



Geogrid

- A gridlike polymeric material formed by intersecting ribs joined at the junctions used for reinforcement with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project structure or system.

Geogrids



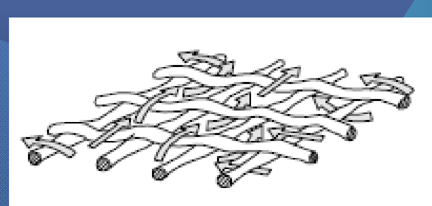
uniaxial

biaxial

- Uniaxial and Biaxial Geogrids, used for reinforcement, are constructed of high tenacity, high molecular weight woven polyester and are encapsulated with a polymer coating.

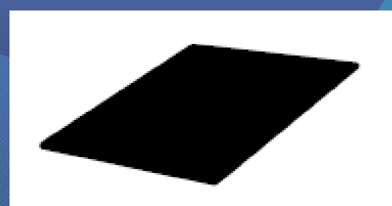
Geotextile Terminology

- Geonets are open grid-like materials formed by two sets of coarse, parallel, extruded polymeric strands intersecting at a constant acute angle. The network forms a sheet with in-plane porosity that is used to carry relatively large fluid or gas flows.



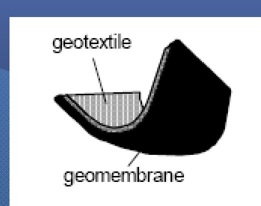
Geotextile Terminology

- Geomembranes are continuous flexible sheets manufactured from one or more synthetic materials. They are relatively impermeable and are used as liners for fluid or gas containment and as vapor barriers.



Geotextile Terminology

- Geocomposites are geosynthetics made from a combination of two or more geosynthetic types. Examples include: geotextile-geonet; geotextile-geogrid; geonet-geomembrane; or a geosynthetic clay liner (GCL). Prefabricated geocomposite drains or prefabricated vertical drains (PVDs) are formed by a plastic drainage core surrounded by a geotextile filter.

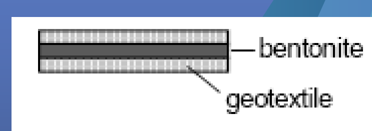


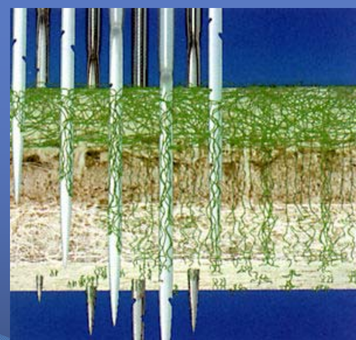
Geotextile Terminology

- Geocomposites are made by combining two or more types of geosynthetics (for example a geogrid and a nonwoven) via stitching or thermal bonding. Geocomposites display the beneficial properties of both the nonwoven and the combined structure and are used in separation and reinforcing applications .

Geotextile Terminology

- Geosynthetic clay liners (GCLs) are geocomposites that are prefabricated with a bentonite clay layer typically incorporated between a top and bottom geotextile layer or geotextilebentonite bonded to a geomembrane or single layer of geotextile. Geotextile-encased GCLs are often stitched or needle-punched through the bentonite core to increase internal shear resistance. When hydrated they are effective as a barrier for liquid or gas and are commonly used in landfill liner applications often in conjunction with a geomembrane.

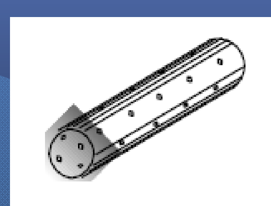




- In Geosynthetic Clay Liners (GCLs), fibers reinforce a bentonite clay layer as they are needle-punched from a cover geotextile to a carrier geotextile.

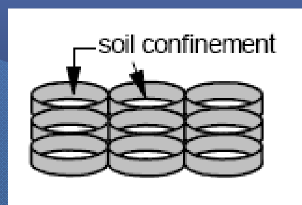
Geotextile Terminology

- Geopipes are perforated or solid-wall polymeric pipes used for drainage of liquids or gas (including leachate or gas collection in landfill applications). In some cases the perforated pipe is wrapped with a geotextile filter.



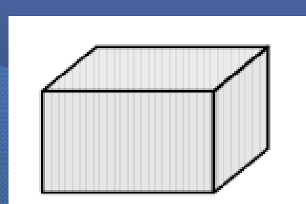
Geotextile Terminology

- Geocells are relatively thick, three-dimensional networks constructed from strips of polymeric sheet. The strips are joined together to form interconnected cells that are infilled with soil and sometimes concrete. In some cases 0.5 m to 1 m wide strips of polyolefin geogrids have been linked together with vertical polymeric rods used to form deep geocell layers called geomattresses.



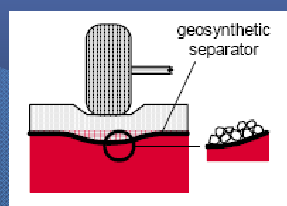
Geotextile Terminology

- Geofoam blocks or slabs are created by expansion of polystyrene foam to form a low-density network of closed, gas-filled cells. Geofoam is used for thermal insulation, as a lightweight fill or as a compressible vertical layer to reduce earth pressures against rigid walls.



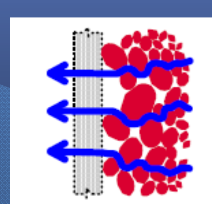
Geosynthetics Functions

- Separation: The geosynthetic acts to separate two layers of soil that have different particle size distributions. For example, geotextiles are used to prevent road base materials from penetrating into soft underlying soft subgrade soils, thus maintaining design thickness and roadway integrity. Separators also help to prevent fine-grained subgrade soils from being pumped into permeable granular road bases.



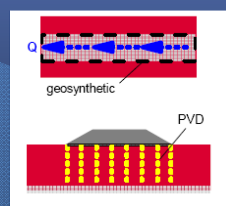
Geosynthetics Functions

- Filtration: The geosynthetic acts similar to a sand filter by allowing water to move through the soil while retaining all upstream soil particles. For example, geotextiles are used to prevent soils from migrating into drainage aggregate or pipes while maintaining flow through the system. Geotextiles are also used below rip rap and other armour materials in coastal and river bank protection systems to prevent soil erosion.



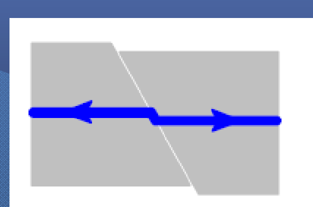
Geosynthetics Functions

- Drainage: The geosynthetic acts as a drain to carry fluid flows through less permeable soils. For example, geotextiles are used to dissipate pore water pressures at the base of roadway embankments. For higher flows, geocomposite drains have been developed. These materials have been used as pavement edge drains, slope interceptor drains, and abutment and retaining wall drains. Prefabricated vertical drains (PVDs) have been used to accelerate consolidation of soft cohesive foundation soils below embankments and preload fills.



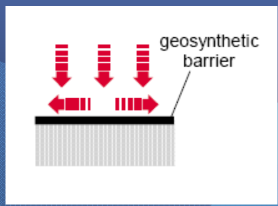
Geosynthetics Functions

- Reinforcement: The geosynthetic acts as a reinforcement element within a soil mass or in combination with the soil to produce a composite that has improved strength and deformation properties over the unreinforced soil. For example, geotextiles and geogrids are used to add tensile strength to a soil mass in order to create vertical or near-vertical changes in grade (reinforced soil walls).



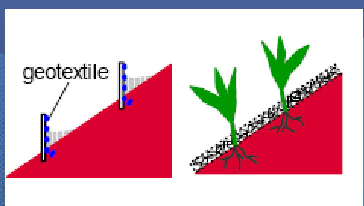
Geosynthetics Functions

- Fluid/Gas (barrier) containment: The geosynthetic acts as a relatively impermeable barrier to fluids or gases. For example, geomembranes, thin film geotextile composites, geosynthetic clay liners (GCLs) and field-coated geotextiles are used as fluid barriers to impede flow of liquid or gas. This function is also used in asphalt pavement overlays, encapsulation of swelling soils and waste containment.



Geosynthetics Functions

- Erosion control: The geosynthetic acts to reduce soil erosion caused by rainfall impact and surface water runoff. For example, temporary geosynthetic blankets and permanent lightweight geosynthetic mats are placed over the otherwise exposed soil surface on slopes. Geotextile silt fences are used to remove suspended particles from sediment-laden runoff water. Some erosion control mats are manufactured using biodegradable wood fibers.



Geosynthetics Functions

1.) Drainage (e.g. 6 - 8 oz/sy NP).

2.) Separation (e.g. 6 – 8 oz/sy NP).

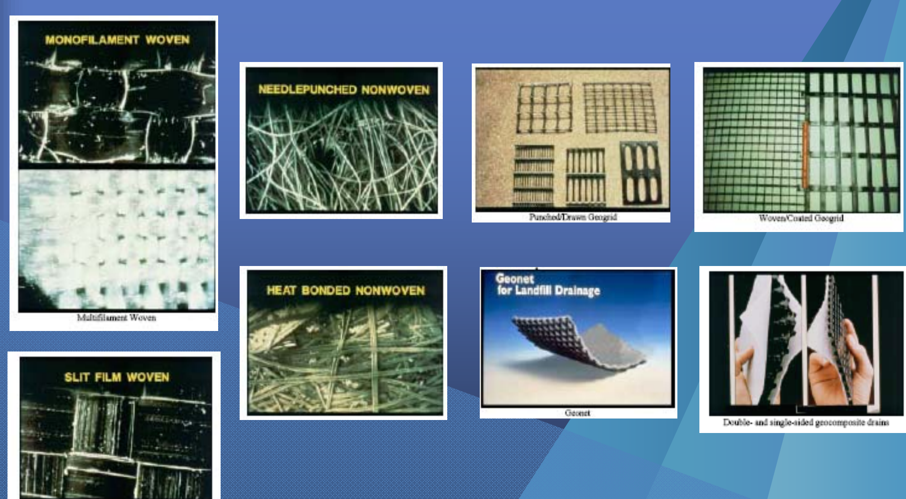
3.) Filtration (e.g. 4 – 8 oz/sy NP).

4.) Protection (e.g. 12 – 24 oz/sy NP).

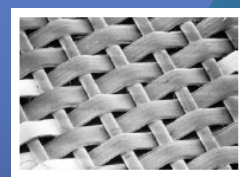
5.) Reinforcement (e.g. HS Wovens).

6.) Containment (e.g. HDPE, PVC, etc.)

Geosynthetic Fabric Illustrations



What are Kind of Geotextiles are These?



Geotextile Fabric Testing Standards

ASTM Specifications

Grab tensile	ASTM D 4632
Grab elongation	ASTM D 4632
Mullen burst	ASTM D 3786
Puncture	ASTM D 4833
Trapezoid tear	ASTM D 4533
UV Resistance	ASTM D 4355
Apparent opening size	ASTM D 4751
Permittivity	ASTM D 4491
Permeability	ASTM D 4491
Flow rate	ASTM D 4491
Weight	ASTM D 5261

Geotextile Fabric Testing Standards

<u>CEN/ISO Specifications</u>

▪ Tensile strength	EN ISO 10319
▪ Elongation	EN ISO 10319
▪ Puncture Resist (CBR)	EN ISO 12236
▪ Cone Drop	EN 918
▪ Protection Efficiency	WI 189066
▪ Opening size	EN ISO 12956
▪ Permeability	EN ISO 11058
▪ Flow normal to plane	EN ISO 11058
▪ Flow in the plane	EN ISO 11058
▪ Thickness	EN 984/1
▪ Weight	EN 965

Geotextile Properties

	English Units		X-Series				N-Series					Mirapave 400
			100X	500XL	500X	600X	140NL	140NC	140N	160N	180N	
REINFORCEMEI DRAINAGE/FILTRATIOI	Apparent Opening Size ASTM D 4751	U.S. Sieve	30	30	50	40	60	70	70	70	80	
	Percent Open Area COE-22125-86	%	1	1	1	1						
	Permittivity ASTM D 4491	sec^{-1}	0.1	0.05	0.05	0.05	2	1.9	1.8	1.4	1.2	
	Flow Rate ASTM D 4491	$gal/min/ft^2$	10	4	5	4	145	140	135	110	95	
	Wide Width Strength ASTM D 4595 lbs/ft	MD			100	175						
		CD			120	175						
	Creep Limited Strength ASTM D 5262	lbs/ft										
	Long Term Design Strength GRI GG-4 or GT-7	lbs/ft										
SURVIVABILITY	Grab Tensile Strength ASTM D 4632 lbs	MD	124	140	200	315	90	100	120	160	205	90
		CD	124	140	200	315	90	100	120	160	205	90
	Grab Tensile Elongation ASTM D 4632 %	MD	15	15	15	15	50	50	50	50	50	50
		CD	15	10	10	10	50	50	50	50	50	50
	Trapezoid Tear Strength ASTM D 4533 lbs	MD	65	45	75	120	35	45	50	60	80	35
		CD	65	45	75	120	35	45	50	60	80	35
	Mullen Burst Strength ASTM D 3786	psi	300	325	400	600	175	210	225	305	380	190
	Puncture Strength ASTM D 4833	lbs	60	65	90	120	55	65	65	95	130	55
	Roll Dimensions 1 width x length	ft	3 x 330	12.5 x 504	12.5 x 432	12.5 x 360	12.5 x 360	12.5 x 360	12.5 x 360	15 x 300	15 x 300	14.5 x 360
	Roll Dimensions 2 width x length	ft			17.5 x 309	17.5 x 258	15 x 360	15 x 360	15 x 360			12.5 x 360

Examples of Physical Properties of Woven Slit Film (X) and Nonwoven (N) Polypropylene Geotextiles.

Geotextile Properties

	English Units		Geolon® HP-Series							Geolon® HS-Series			
			HP370	HP470	HP565	HP570	HP665	HP670	HP770	HS400	HS600	HS800	HS1150
DRAINAGE/FILTRATIO	Apparent Opening Size ASTM D 4751 U.S. Sieve		30	20	40	30	40	20	30	40	20	20	30
	Percent Open Area COE-22125-86 %												
	Permittivity ASTM D 4491 sec $^{-1}$		0.52	0.2	0.001	0.4	0.26	0.5	0.23	0.026	0.32	0.2	0.32
	Flow Rate ASTM D 4491 gal/min/ft ^{2}		40	15	2	30	20	38	15	2	24	15	24
REINFORCEMEI	Wide Width Strength ASTM D 4595 lbs/ft	MD	3240	3600	4200	4800	4800	6240	7200	4800	7200	9600	13800
		CD	2700	3600	4800	4800	6600	4800	4800	4800	3600	3600	3600
	Creep Limited Strength ASTM D 5262 lbs/ft									2880	4320	5760	8280
	Long Term Design Strength GRI GG-4 or GT-7 lbs/ft									2277	3415	4553	6545
SURVIVABILITY	Grab Tensile Strength ASTM D 4632 lbs	MD	400	380	550	475	600	650	550	400	600	850	1150
		CD	250	350	550	440	700	450	450	350	500	550	600
	Grab Tensile Elongation ASTM D 4632 %	MD	15	10	15	12	18	15	12	8	8	8	8
		CD	6	6	6	6	6	6	6	8	8	8	8
	Trapezoid Tear Strength ASTM D 4533 lbs	MD	180	130	150	180	180	200	250	150	300	400	550
		CD	100	200	200	180	275	200	300	150	150	200	200
	Mullen Burst Strength ASTM D 3786 psi		800	1200	1200	1200	1200	1200	1200	1500	1500	1500	1500
	Puncture Strength ASTM D 4833 lbs		180	170	200	195	280	200	220	100	125	150	150
	Roll Dimensions 1 width x length ft		15 x 300	15 x 300	15 x 300	15 x 300	15 x 300	15 x 300	15 x 300	15 x 300	15 x 300	15 x 300	15 x 300
	Roll Dimensions 2 width x length ft												

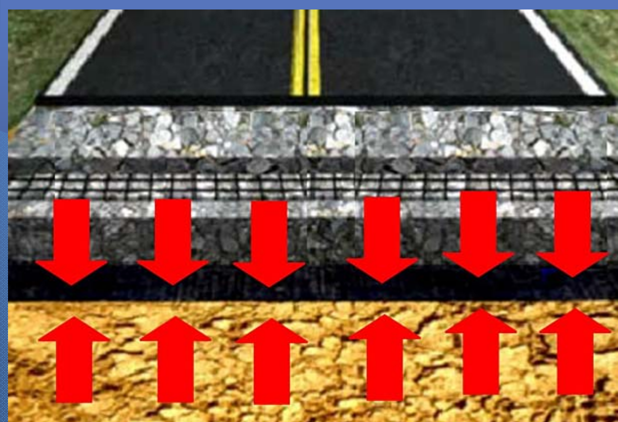
Examples of Physical Properties of Woven Polypropylene (HP) and Woven Polyester (HS) Geotextiles. 000

Functions of Geosynthetics for Road Construction

- Separation
- Reinforcement
- Confinement
- Filtration
- Drainage

Separation

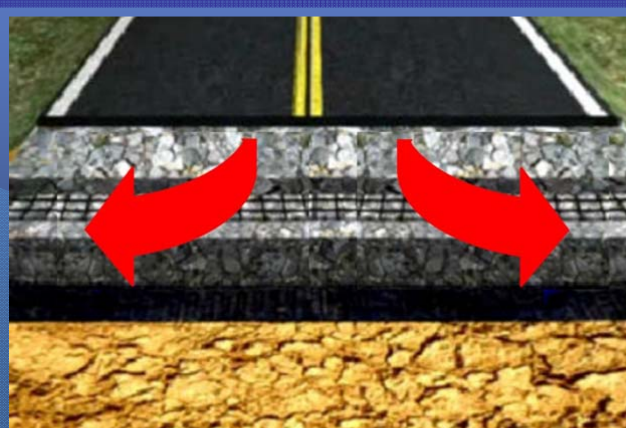
- Geotextile placed between dissimilar materials so that the integrity of both can remain intact or be improved.



Old adage:
"10 lbs. of stone placed on 10 lbs. of mud = 20 lbs. mud"

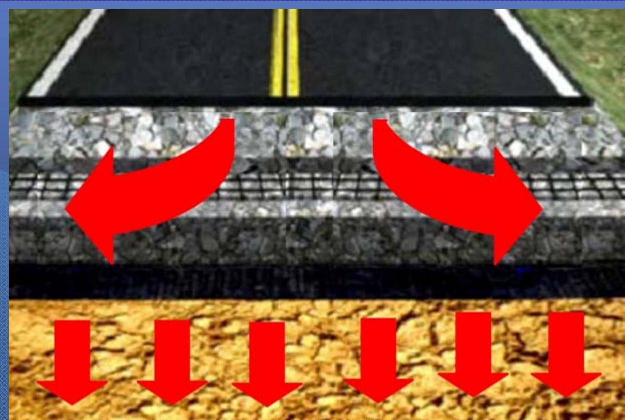
Confinement

- Geosynthetic improvement of the ability to resist lateral movement of the aggregate



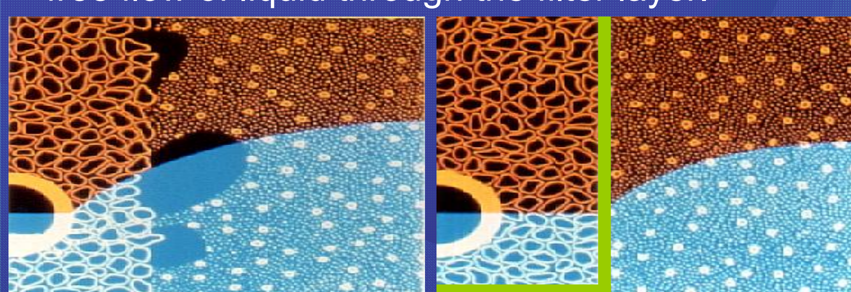
Reinforcement

- Improvement of the system strength created by the introduction of a geosynthetic into a soil/aggregate system



Filtration

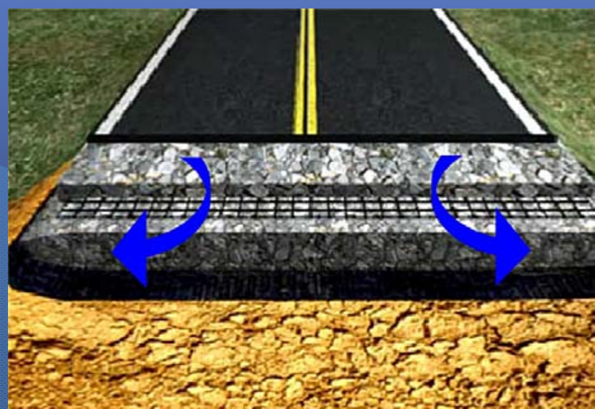
- The ability of a geotextile to prevent excessive migration of soil particles, while maintaining the free flow of liquid through the filter layer.



No Geotextile | With Geotextile

Drainage

- Fabric to soil system that allows for free liquid flow (but no soil loss) across or through the plane of the fabric over an indefinitely long period of time.



Roadway Stabilization & Reinforcement



Paving Fabric Applications

- Residential & commercial streets
- Roads & highways
- Airport runways & taxiways
- Parking lots

Paving Fabrics Features and Benefits

- Features
  - Absorbs stress
  - Retards moisture
- Benefits
  - Extends overlay life 3 to 7 years
    - Reduced maintenance costs
    - Increased pavement life
  - Equivalent to 1.2 inches of asphalt
    - Reduced installation costs
  - Retards reflective cracking and provides a permanent moisture barrier
    - Strengthens existing surface
    - Provide a smoother ride
  - Fast & easy to construct
  - Easily recycled

Geotextile Paving Fabrics

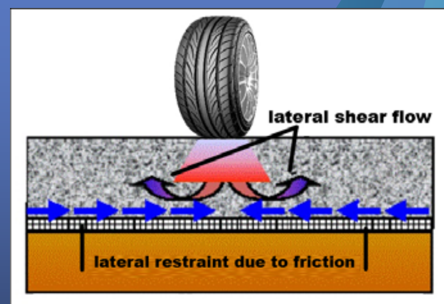
- Typically made from polypropylene staple fibers, needlepunched, heat set & calendared
- Standard weights of 3.5 & 4.0 oz/yd2
- Available in multiple widths & lengths to accommodate various lane widths
- Heavy cores and/or reverse roll-up often required
- Do not absorb water
- Natural affinity to petroleum products
- High chemical resistance (1<pH<14)
- Do not support fungus or mildew
- Stable up to 150°C
- Moderate strengths at low costs
- Expected lifetime of 200+ years

Geosynthetic Reinforcement Mechanisms

- Lateral Restraint
- Bearing Capacity Increase
- Tension Membrane Support

Lateral Restraint

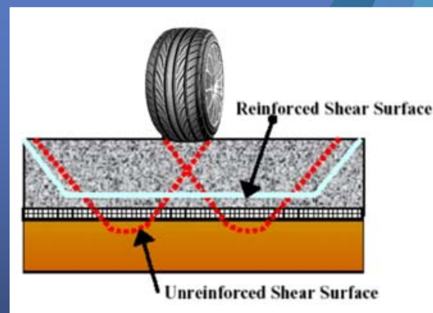
- Restraint of the lateral movement of base, or subbase, aggregate (confinement)
- Increase in modulus of base aggregate due to confinement
- Improved vertical stress distribution on subgrade due to increased base modulus
- Reduced shear strain along the top of the subgrade



Lateral Restraint

Bearing Capacity Increase

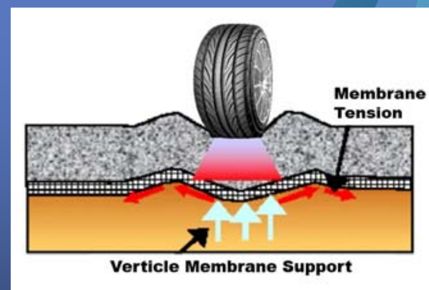
- By forcing the potential bearing capacity failure surface to develop along alternate, higher shear strength surfaces.



Bearing Capacity Increase

Tensile Membrane Support

- Mechanism mobilized under high deformation conditions.



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Tension Membrane Support

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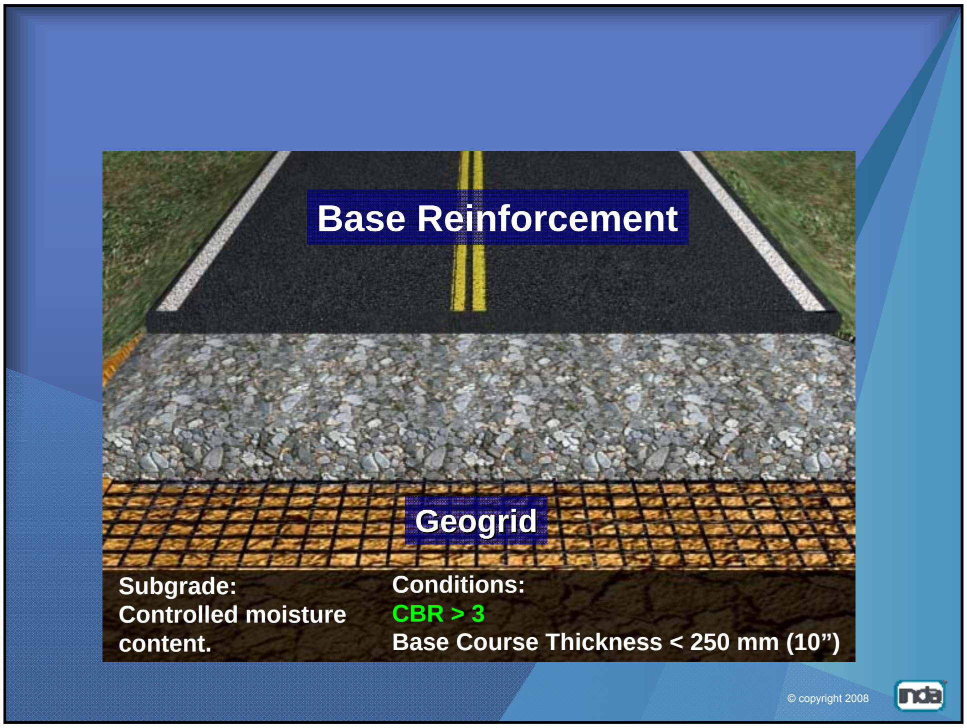
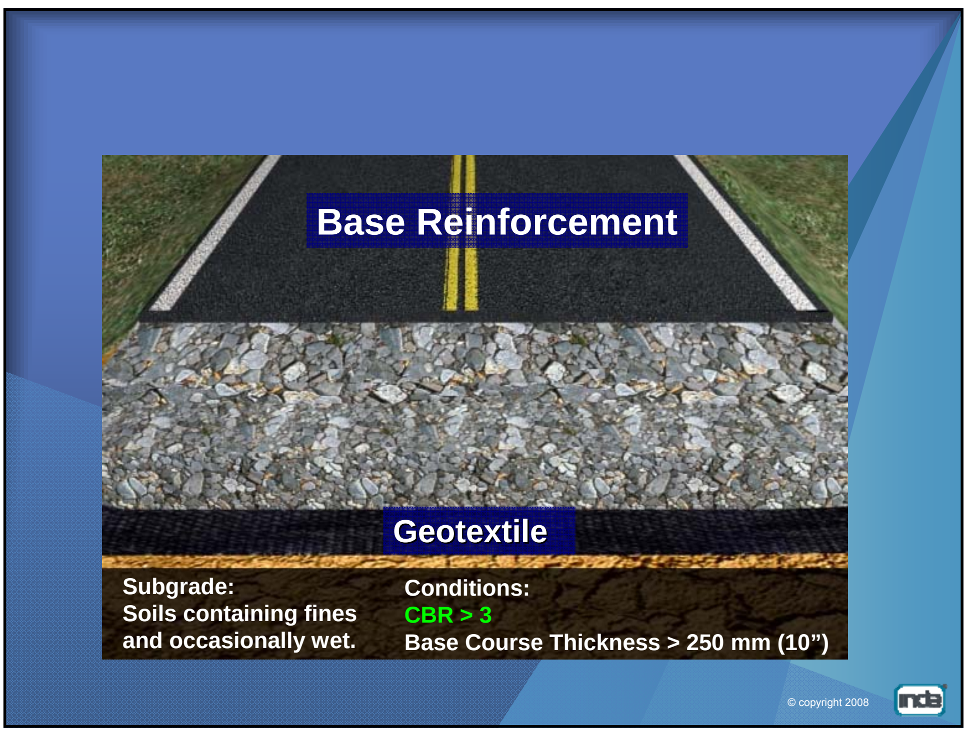
Geosynthetic Reinforcement Applications

- Base Reinforcement
- Subgrade Restraint (Stabilization)

Base Reinforcement

- "…results from the addition of a geosynthetic at the bottom or within a base course to increase the structural or load-carrying capacity of a pavement system…to
- improve the service life and/or
- obtain equivalent performance with a reduced structural section."


Base Reinforcement
Geogrid
Subgrade:
Controlled moisture
content.
Conditions:
CBR > 3
Base Course Thickness < 250 mm (10”)
© copyright 2008


Base Reinforcement
Geotextile
Subgrade:
Soils containing fines
and occasionally wet.
Conditions:
CBR > 3
Base Course Thickness > 250 mm (10”)
© copyright 2008

Base Reinforcement Benefits

- Geosynthetic placed as a tensile element at the bottom of or within a base / subbase aggregate
  - Improves service life
  - Obtains equivalent performance with reduced section
  - Reduces undercut, disturbance of subgrade
  - Reduces aggregate required for stabilization

Subgrade Restraint

- "..may occur when a geosynthetic is placed at the subgrade / subbase or subgrade/base interface to increase the support of construction equipment over a weak or low subgrade …is the reinforcing component of stabilization…"

Subgrade Restraint Benefits

- Geosynthetic placed as a tensile element at the bottom of a base or subbase aggregate
  - Improves service life
  - Obtains equivalent performance with reduced section
  - Reduces undercut, disturbance of subgrade
  - Reduced aggregate required for stabilization
  - Provides access & constructability over very soft soils
  - Helps to establish a well-compacted, non-yielding platform - uniform support

Pavement Restoration

Pavement Restoration

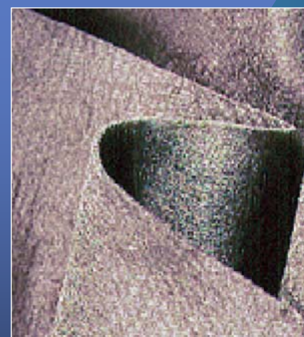
- The addition of a geosynthetic fabric onto existing pavement to form an impermeable membrane that prevents the penetration of surface water through the pavement and also provides a stress relieving layer which inhibits reflective crack growth.

Paving Fabric System

- A polypropylene non-woven fabric, heat bonded on the surface and designed to accept the optimum quantity of asphalt cement to provide a moisture barrier and stress relief membrane layer

Paving Fabric System

- Why Polypropylene?
  - Affinity for Asphalt.
  - Chemical Resistance.
  - Stability in Water.
  - Easy to Apply.
  - Withstands Hot Asphalt Temperatures.
  - Millable and Recyclable.
  - Sufficient Elasticity to be Installed Around Curves and Slopes.



Nonwoven Polypropylene Needle Punched Staple Fibers Heat Set

Pavement Fabric System

- Fabric - Asphalt Membrane
- Composed of a nonwoven polypropylene fabric and asphalt cement
- Fabric-Asphalt membrane deflects strain - retarding reflection crack

Fabric Core with Minimum Asphalt Thickness

Geosynthetic Functions Pavement Restoration

- Separation & Drainage
  - Moisture Barrier Between Surface and Subgrade
- Reinforcement
  - Deflects Strain – Retarding Reflection Crack

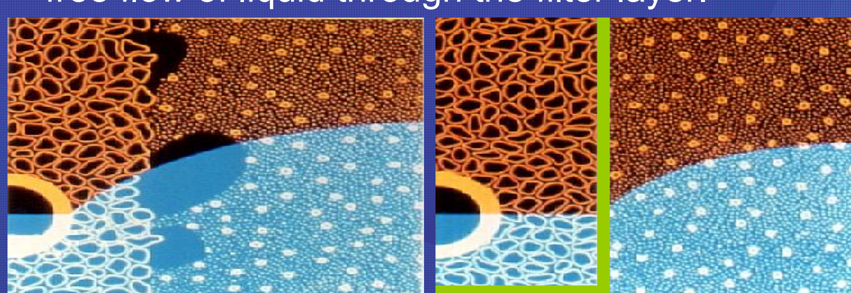
Drainage and Filtration

Drainage and Filtration

- Fabric to soil system that allows for free liquid flow across or through the plane of the fabric over an indefinitely long period of time, while preventing soil loss (filtration).
- *filtration - the ability of a geotextile to prevent excessive migration of soil particles

Filtration

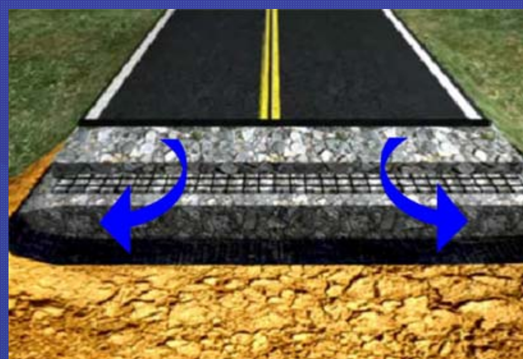
- The ability of a geotextile to prevent excessive migration of soil particles, while maintaining the free flow of liquid through the filter layer.



No Geotextile   With Geotextile

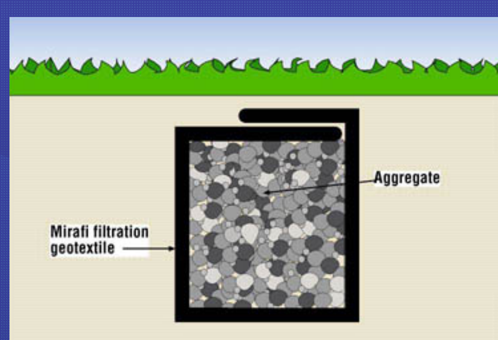
Drainage

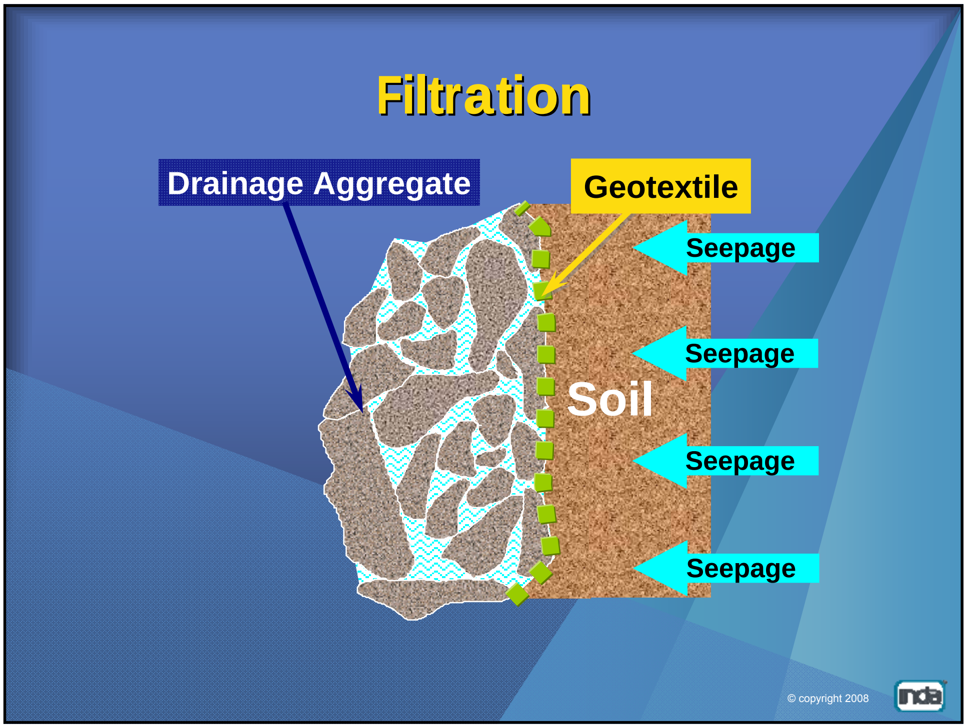
- Water drains along or through the plane of the fabric.

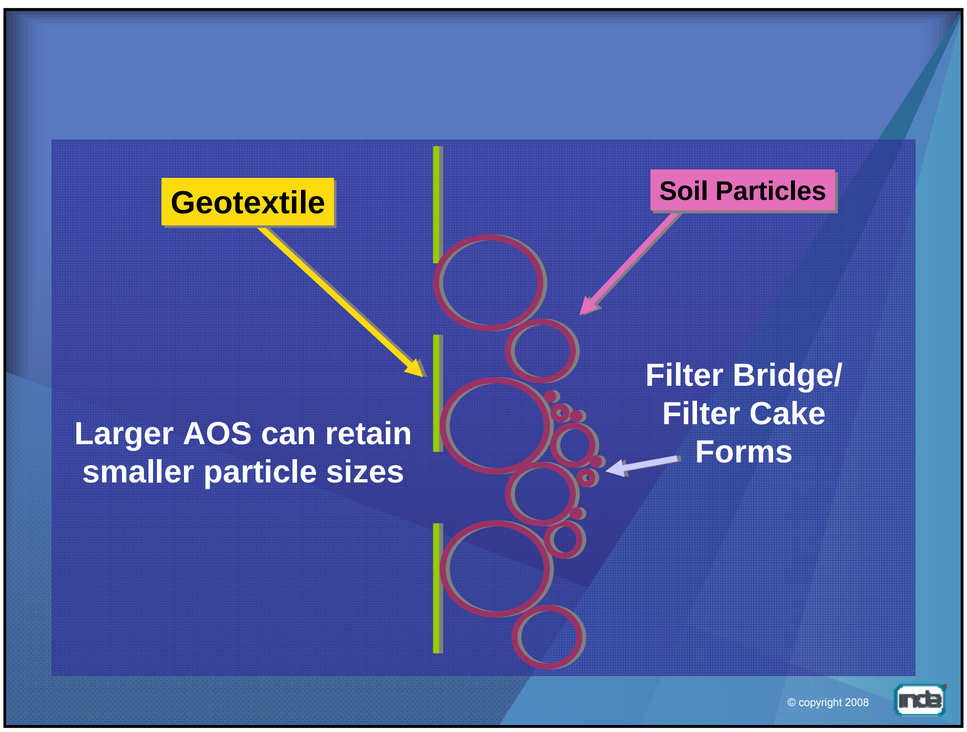


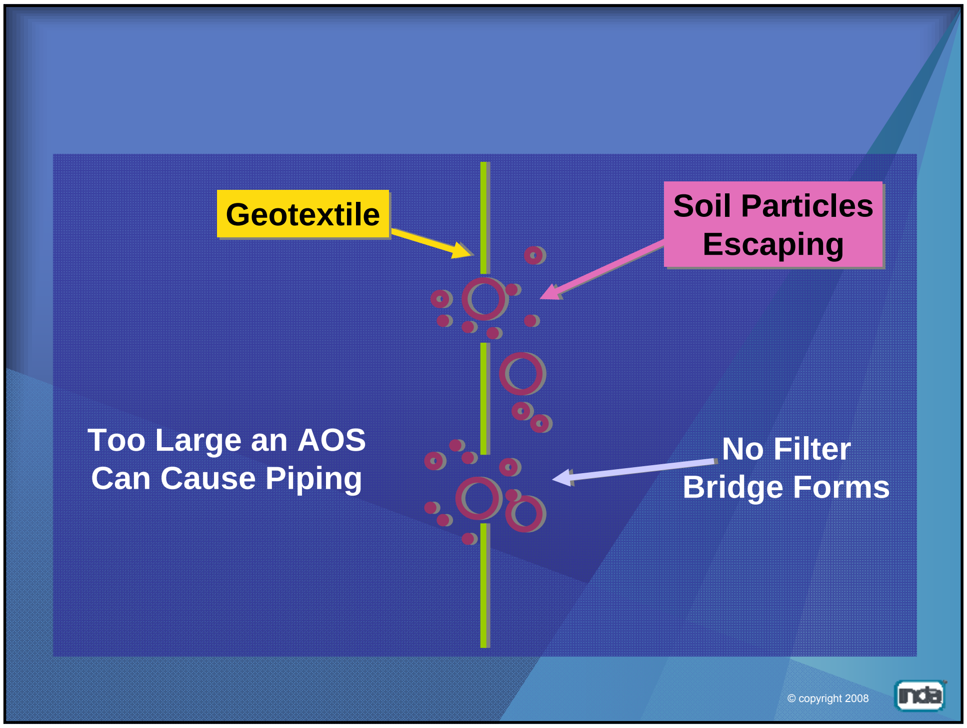
Basic Principle Pavement Drainage

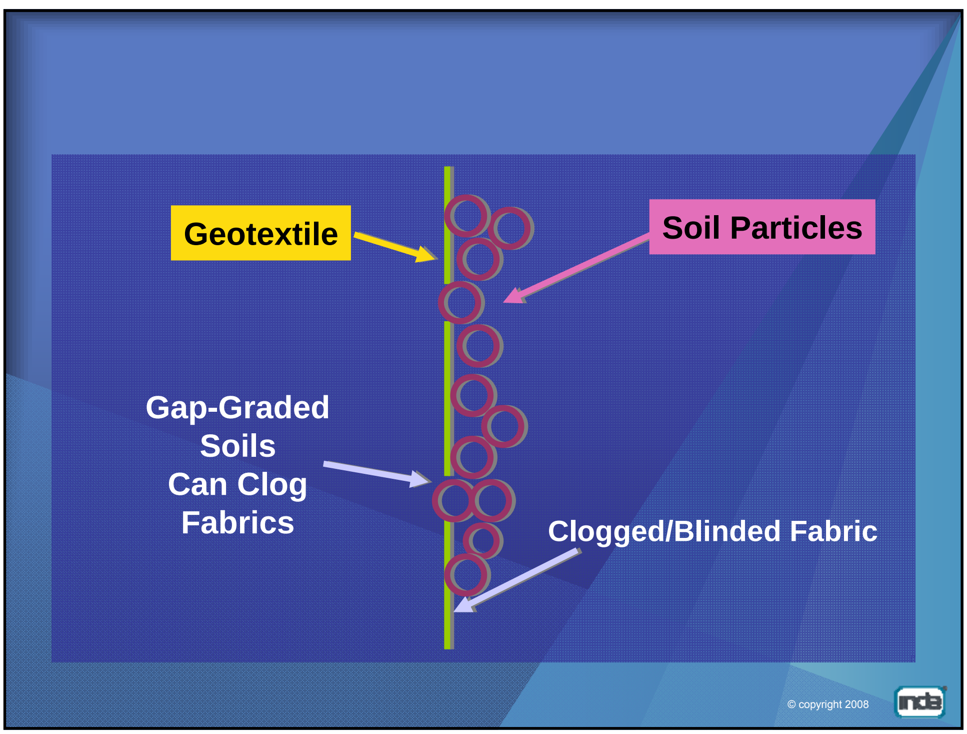
- Separation - between soil and aggregate while allowing free liquid flow




Filtration
Drainage Aggregate
Geotextile
Seepage
Seepage
Soil
Seepage
Seepage
© copyright 2008


Geotextile
Soil Particles
Filter Bridge/
Filter Cake
Forms
Larger AOS can retain
smaller particle sizes
© copyright 2008


Geotextile
Soil Particles Escaping
Too Large an AOS Can Cause Piping
No Filter Bridge Forms
© copyright 2008


Geotextile
Soil Particles
Gap-Graded Soils Can Clog Fabrics
Clogged/Blinded Fabric
© copyright 2008

Filtration

- Water flow through and along plane of fabric allows smaller particles to “fill in” gaps between larger ones, creating a strong “filter bridge.”

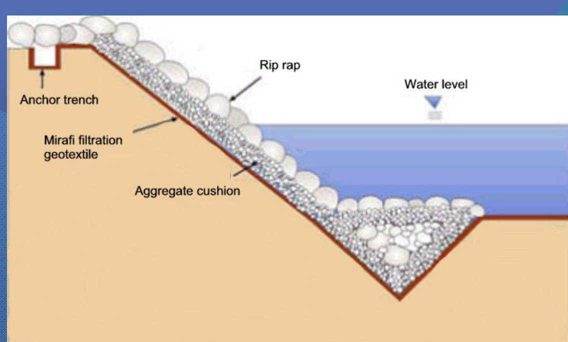
Erosion Control

Erosion Control

- The use of a geotextile to provide soil retention and clogging resistance under rip rap or armor systems.

Basic Principle
Erosion Control Geotextile

- **Separation - between soil and riprap/armor protection while allowing free liquid flow both directions**



Benefits of Geotextile Erosion Control

- Resists clogging while maintaining high flow rate in dynamic flow and high gradient conditions.
- Maintains separation of layers.
- High survivability in aggressive installation conditions.

Erosion Control

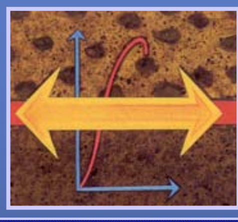
- Both Woven and Nonwoven Geotextiles are Used.

Erosion Control Illustrations

Benefits of Geotextile Erosion Control

- Resists clogging while maintaining high flow rate in dynamic flow and high gradient conditions.
- Maintains separation of layers.
- High survivability in aggressive installation conditions.

Geocomposite Benefits

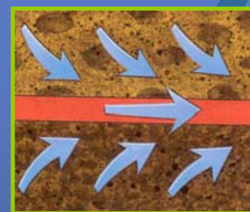


High tensile strength at low elongation

Mobilization of high strength at low strain. Specially suited to the reinforcement of fine grained soils (sandy clay).

High resistance to construction stress

The nonwoven component protects the reinforcing yarns against construction damage.



High in-plane drainage capability

Allows dissipation of pore water pressure through geotextile and therefore increases soil strength characteristics and soil/geotextile interface friction.

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Selecting the Optimum Nonwoven: Application of Gate Theory

Basic Financial Principles and Methods

Selecting the Optimum Nonwoven

Physical

Tensile Strength
Wet/Dry
Machine/Cross
Elongaton
Burst Strength
Tear Strength
Toughness
Impact Resistance
Tear Propagation
Seam Strength
Flex Fatigue
Shear Behavior
Abrasion Resistance
Compression Resist
Elasticity/Brittle
Surface Friction
To self
To other surface
Moisture Vapor
Air Permeability
Fluid Porosity
Water Repellency
Thickness
Density/Bulk
Bending Resistance
Surface Topography
Thermal Conductivity
Liquid Transport
Pore Size
Absorbency
Fluid Uptake Rate
Fluid Retention
Sewability
Wrinkle Resistance
Weight/Mass
Piling Resistance
Cutting Behavior

Chemical

UV Resistance
Thermal Behavior
Active/Inert
Polymer Properties
Flammability
Chemical
Resistance
Chem. Sensitivity
Hydrophobic/philic
Oleophobic/philic
Static Generation
Electric Charge
Adhesion/Cohesion
Bioactivity
Liquid Repellency
Dyeability
Biodegradability
Thermoplastic/Set
Dye Stability
Melting Behavior
Wetting Behavior
Absorbency
Cleanability
Color
Toxicity
Carcinogenicity
Printable
Sterilizable

Aesthetic

Soft/Stiff
Opaque/Transparent
Fragrance/Odor
Shiny/Dull
Fuzzy/Flat
Smooth/Rough
Pliable/Crunchy
Color
Surface Decoration
Surface Texture
Slick/Scroopy
Drape
Warm/Cold
Comfortable
Clammy
Stretchy
Bouncy/Dead
Fluffy/Hard
Bright/Dull
Reversible
Textile/Papery
Feminine/Masculine
Cute
Pretty
Sophisticated
Trendy/Classic
Quiet/Noisy
Fashionable

Commercial

Price
Cost Effectiveness
Quantity
Availability
Contract Terms
Width
Packaging
Put-Ups
Shipping
Exclusivity
Delivery Cycle
Tariffs
Liability
Patent Protection
Volume Breaks
Licensing
Royalties
Trademarks
Merchandising
Hot/Old News
Converting
Safety
Efficacy
Regulatory Rules
Unique
Disposable/Durable
Environmental
Impact

inda

Variables that Affect the Physical Properties of Nonwovens

Fiber Type
+
Method of Web Formation
+
Method of Bonding
+
Finishing Processes
+
Conversion
=
Nonwoven Fabric Properties

inda

Nonwoven Properties Affected by Fiber Type & Variant

- Tensile Strength
- Tear Strength
- Burst Strength
- Wet Strength Loss
- Hand
- Drape
- Wetability
- Washability
- Absorbency
- Resilience
- Aesthetics
- Crease Recovery
- Dispersability
- Sealability
- Printability

- Processability
- Soiling Properties
- Electrical Properties
- Electrostatic Properties
- Felting Properties
- Shrinkage Properties
- Barrier Properties
- Elongation
- Elasticity
- Specific Gravity
- Modulus
- Insulation Properties
- Flammability
- Heat Setability
- Thermal Softening Point

- Rot Resistance
- Heat Resistance
- Chemical Resistance
- Sunlight Resistance
- Abrasion Resistance
- Mildew Resistance
- Ageing Resistance
- Piling Resistance
- Permeability
- Porosity
- Durability
- Dimensional Stability
- Stiffness
- Price

Nonwoven Properties Affected by Method of Web Formation

- Tensile Strength
- Tear Strength
- Burst Strength
- Modulus
- Hand
- Drape
- Washability
- Absorbency
- Resilience
- Aesthetics
- Crease Recovery
- Abrasion Resistance
- Uniformity

- Ageing Resistance
- Processability
- Soiling Properties
- Durability
- Shrinkage Properties
- Barrier Properties
- Elongation
- Elasticity
- Fiber Orientation
- Loft
- Insulation Properties
- Flammability
- Density

- Permeability
- Softness
- Filtration Properties
- Wicking Properties
- Manufacturing Speed
- Compressibility
- Porosity
- Pilling Resistance
- Thickness
- Dimensional Stability
- Stiffness
- Price

Properties Affected by the Type of Binder Selected & the Method of Bonding

- Tensile Strength
- Tear Strength
- Burst Strength
- Curing Temperature
- Wet Strength Loss
- Sunlight Resistance
- Rot Resistance
- Heat Resistant
- Chemical Resistance
- Dermatitis Properties
- Abrasion Resistance
- Mildew Resistance
- Ageing Resistance
- Pilling Resistance
- Soling Properties

- Electrical Properties
- Electrostatic Properties
- Dimensional Stability
- Rewetting Properties
- Hand
- Elongation
- Elasticity
- Permeability
- Flammability
- Wetability
- Absorbency
- Dewatering
- Washability
- Aesthetics
- Delamination

- Sealability
- Processability
- Crease Recovery
- Binder Migration
- Fraying Properties
- Compressibility
- Barrier Properties
- Acoustical Properties
- Filtering Properties
- Drape
- Adhesion
- Modulus
- Warmth
- Stiffness
- Foaming

- Durability
- Tackiness
- Printing
- Laminating
- Porosity
- Pollution
- Price
- Loft
- Softness
- Toughness
- Pattern
- Uniformity

Properties Affected by Finishing Processes

- Tensile Strength
- Tear Strength
- Burst Strength
- Aesthetics
- Crease Recovery
- Sealability
- Printability
- Soiling Properties
- Electrical Properties
- Electrostatic Properties
- Shrinkage Properties
- Barrier Properties
- Ageing Resistance
- Permeability

- Durability
- Stiffness
- Repellency
- Softness
- Sterilization Properties
- Thickness
- Hand
- Drape
- Absorbency
- Elongation
- Elasticity
- Modulus
- Insulation Properties
- Flammability

- Heat Resistance
- Chemical Resistance
- Sunlight Resistance
- Abrasion Resistance
- Piling Resistance
- Porosity
- Dimensional Stability
- Price
- Pattern
- Color
- Dewatering
- Weight

Properties Affected by Conversion Operations

- Shape
- Packaging
- Size
- Form
- Additions
- Count
- Impregnation
- Absorbency
- Soiling Properties
- Insulation Properties
- Rot Resistance

- Chemical Resistance
- Abrasion Resistance
- Ageing Resistance
- Permeability
- Durability
- Application
- Dimensions
- Texture
- Thickness
- Materials
- Coating

- Laminations
- Aesthetics
- Barrier Properties
- Flammability
- Heat Resistance
- Sunlight Resistance
- Mildew Resistance
- Piling Resistance
- Porosity
- Price

Always Keep in Mind That

Fiber Type

\+

Method of Web Formation

\+

Method of Bonding

\+

Finishing Processes

\+

Conversion Process

=

Nonwoven Fabric Physical & Chemical Properties

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STAGE-GATE THEORY

Why New Products Fail

- Holes and omissions
  - Key activities are done poorly or not done altogether
- Lack of market information
  - In 77% of new product failures, project leaders chose not to do a detailed market study.
- Overlooked activities
  - lack of trial production and pre-commercialization business analysis.

Source: Robert G. Cooper, *Winning at New Products*, second edition

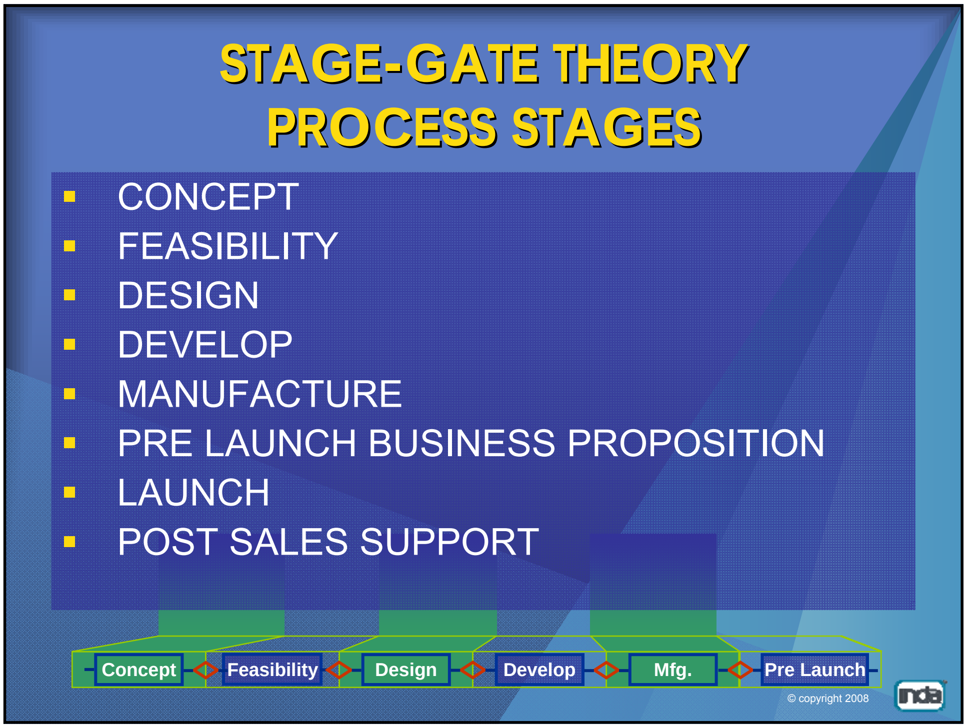
Thirteen Key Activities in the New Product Development Process

- Initial screening
- Preliminary market assessment
- Preliminary technical assessment
- Detailed market study
- Predevelopment financial analysis
- Product development
- In-house product testing
- Customer testing
- Trial production
- Trial sell
- Pre-commercialization business analysis
- Disciplined production start-up
- Market launch

Source: Robert G. Cooper, *Winning at New Products,* second edition

STAGE-GATE THEORY

- A systematic process - a blueprint or roadmap - for moving from new product ideas, through various essential stages and steps, to commercial sales.
- Characterized by a series of steps or processes (stages) separated by "gates."
- The gates define "required deliverables" before moving on to any step or process in the next stage.
- Companies usually adopt the system to fit their unique business or circumstances.


STAGE-GATE THEORY
PROCESS STAGES
CONCEPT
FEASIBILITY
DESIGN
DEVELOP
MANUFACTURE
PRE LAUNCH BUSINESS PROPOSITION
LAUNCH
POST SALES SUPPORT
Concept
Feasibility
Design
Develop
Mfg.
Pre Launch
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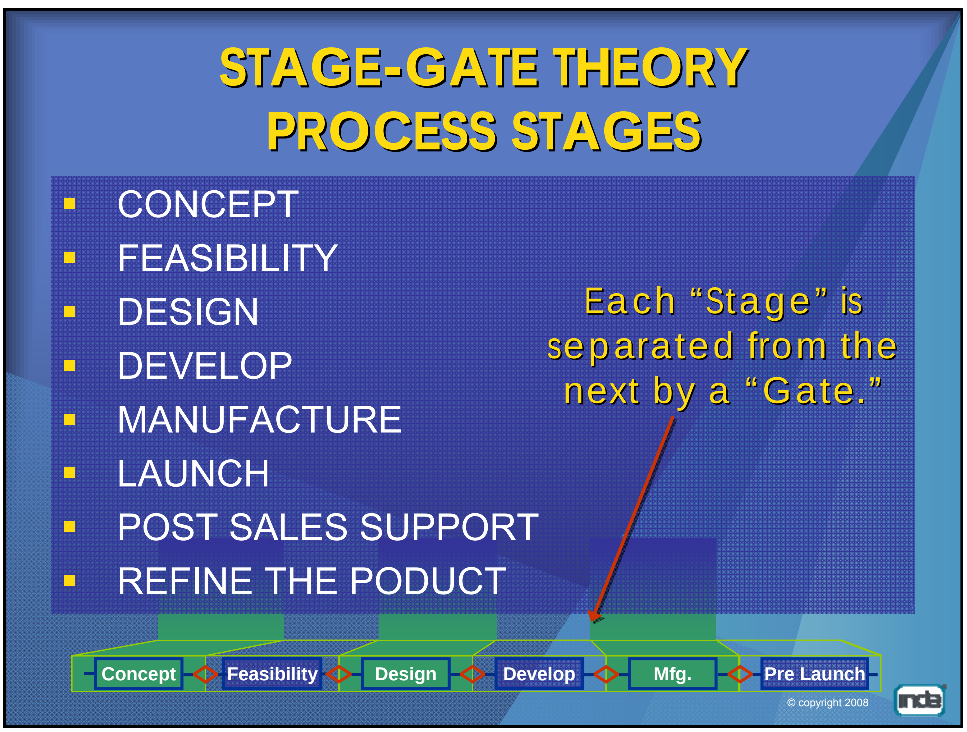
STAGE-GATE THEORY
PROCESS STAGES
CONCEPT
FEASIBILITY
DESIGN
DEVELOP
MANUFACTURE
LAUNCH
POST SALES SUPPORT
REFINE THE PODUCT
Each "Stage" is separated from the next by a "Gate."
Concept
Feasibility
Design
Develop
Mfg.
Pre Launch
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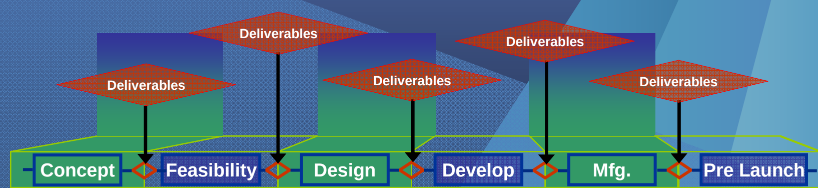
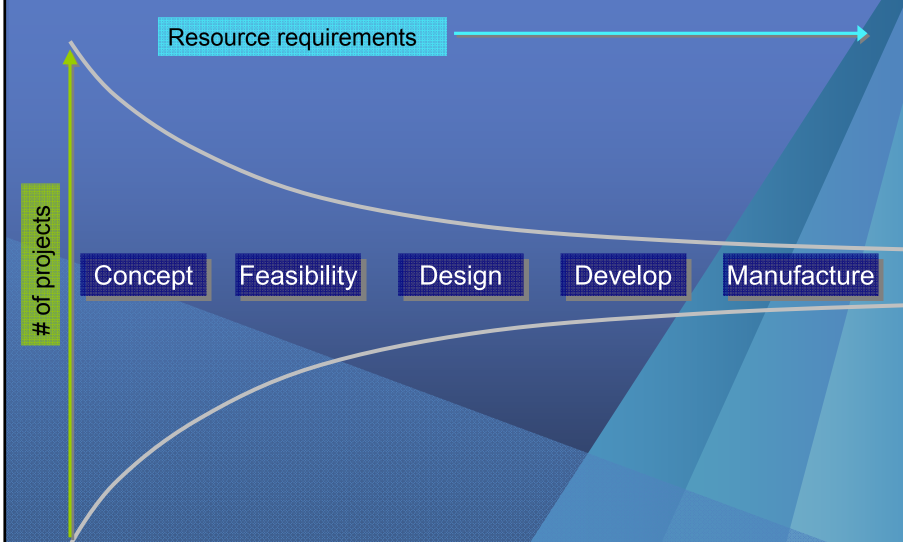
STAGE-GATE THEORY
PROCESS STAGES

- Passage through a Gate to the next Stage requires the development team provide “Deliverables.”
- The criteria for deliverables at each stage are determined in advance by the company.

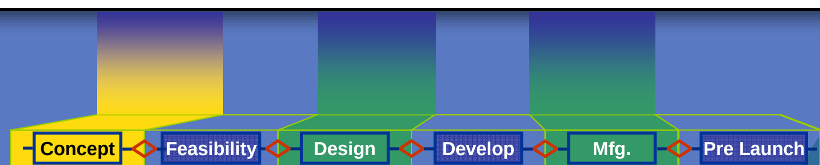


A well managed STAGE-GATE process will concentrate resources on a few good projects



Tools

- Multidisciplinary teams at each Stage
- Workable team process
- Prior homework
- Analytical methods appropriate to the product &/or market (Design for Six Sigma)



- IDEA GENERATION
- CUSTOMER(S)
- CURRENT SITUATION & MARKET NEEDS
- IN-HOUSE PRODUCT DEVELOPMENT CAPABILITIES
- BRAIN STORMING
- PROPOSED REQUIREMENTS
- INTELLECTUAL PROPERTY SITUATION
- ANTICIPATED COMPETITIVE RESPONSE
- SELECTION OF TARGET PRODUCT

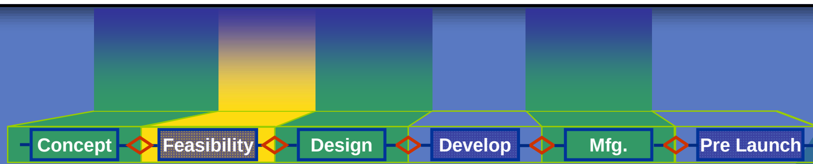
REVIEW PANEL

- MARKETING
- RESEARCH & DEVELOPMENT
- OPERATIONS
- FINANCE

Prioritize projects/concepts based on objective, best practice metrics to align project selection with the business strategy.

QUESTIONS AT FIRST GATE:

- Does this concept fit strategic or business plans?
- Is the concept customer driven?
- Is there a Marketing Champion? If not, who?
- Is there a Technical Champion? If not, who?
- Is the information from stage one sufficient to justify moving to the next stage?
- Can we obtain Intellectual Property rights to this new product or new application of an existing product?



- VERIFY REQUIREMENTS
- COMPETITIVE RESPONSES-"WAR GAMES"
- PROCESS/PRODUCT DEVELOPMENT PLAN
  - CUSTOMERS
  - EXPERIENCE
  - REQUIREMENTS
  - CAPABILITIES
  - ENGINEERED FABRICS
  - COST MODELS

FEASIBILITY MATRIX

NEW PROCESSES CURRENT MATERIALS (Moderate Risk)	NEW PROCESSES NEW MATERIALS (High Risk)
CURRENT PROCESSES CURRENT MATERIALS (Low Risk)	CURRENT PROCESSES NEW MATERIALS (Low Risk)

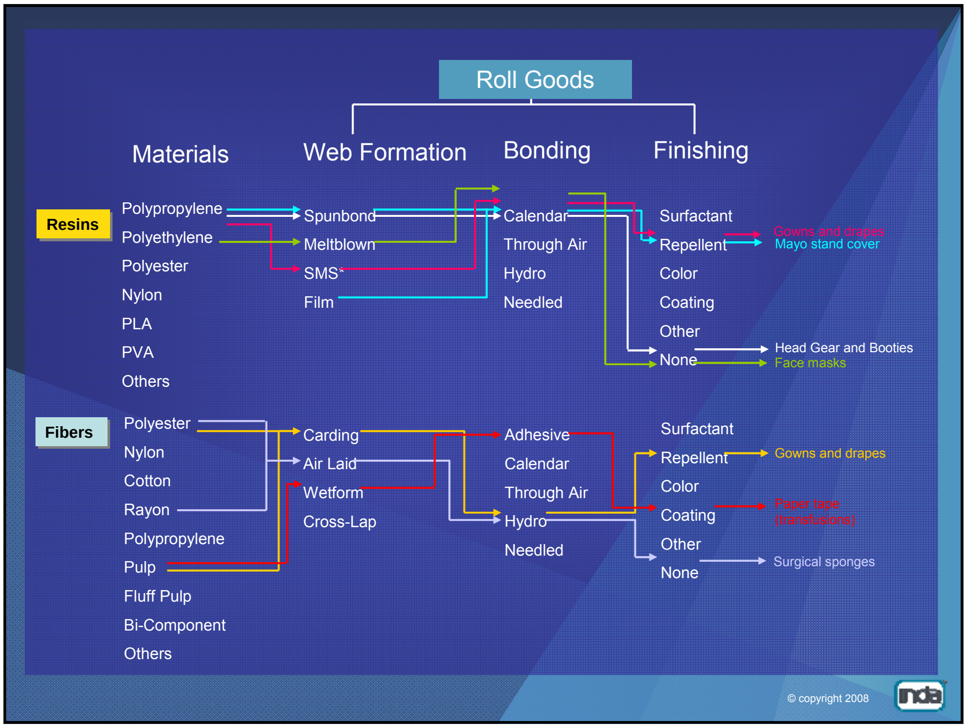
FEASIBILITY

Ten key factors in descending order of importance

1) A superior product
2) A well defined product prior to the development phase
3) Quality of execution in the technical phase
4) Technological synergy
5) Quality of execution in the predevelopment activities
6) Marketing synergy
7) Quality of execution in marketing activities
8) Market attractiveness
9) Competitive situation
10) Top management support.

Feasibility: Cost Model

- Manufacturing cost
  - Raw materials
  - Labor
  - Variable overhead (processing costs)
  - Fixed overhead (equipment, utilities, assets)
- Sales & General Administration costs
  - Sales & Distribution
  - Technical Service/R&D
  - Allocated overhead
  - Admin. Costs (Finance, HR, etc.)
- Total cost = Manuf. Cost + S&GA



QUESTIONS AT SECOND GATE:

- All the questions from the First Gate +
- Are Requirements known and understood?
- What are the product advantages?
- What are the characteristics of the target market/customer?
- Does the Development plan meet time frame?
- Is the estimated cost reasonable?
- Does the estimated cost/price produce acceptable profit margins?
- Are there synergies with current business?
- Have we identified the capital & resources needed?
- What will competition do?

DESIGN

- FACTORIAL DESIGN OF EXPERIMENTS (DOE)
- DUE DILLIGENCE
- RECORD KEEPING
- PRELIMINARY SPECIFICATION
- COST MODELS

RECORD KEEPING

- Laboratory Research Notebooks
  - Official record of invention & development
  - Numbered pages
  - Witnessed and dated
  - Hard bound so pages cannot be added
  - Permanent historical record

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SPECIFICATIONS

- Preliminary Targets based on Requirements
- Developed by Product Development
- Operations & Marketing must agree to Targets

QUESTIONS AT THIRD GATE:

- All the questions from Gates One and Two +
- Does the prototype meet requirements?
- Are there patent opportunities?
- Does the estimated cost/price produce acceptable profits?
- Does Operations believe they can produce the product at the estimated cost/volumes?
- Do we want to show this prototype to potential customers, now?

DEVELOP

- PHYSICAL PROPERTIES
- MANUFACTURING PROCESS DATA
- COST ESTIMATES
- PATENTABILITY & RIGHT-TO-MARKET
- CUSTOMER FACTORS
  - HOW PRODUCT WILL FIT IN LINE
  - HOW PRODUCT COMPARES TO CURRENT PRODUCT
  - HOW PRODUCT COMPARES WITH COMPETITORS PRODUCT
  - WILL PRODUCT BE CONVERTED AND HOW
  - HOW CONVERTED PRODUCT COMPARES WITH EXISTING

CUSTOMER EVALUATIONS

- Do you know the customer's needs?
- Do you know how the customer will use this product?
- Do you know how the product will fit within the customers line of products?
- Do you know how the product compares with the current product?
- Do you know how the product compares to the customer's competition?
- Do you know how the converted product compares with the customer's & competitor's current products?

QUESTIONS FOR FOURTH GATE:

- Do physical Properties meet requirements?
- Does estimated cost/price produce acceptable profits?
- Is the process/product/application patentable?
- Is there competing IP that would prevent "Right-to-Market"?
- Can we produce this product on a commercial basis?
- Do we want to show this prototype to more customers?

MANUFACTURE

- HAVE SUFFICIENT PRODUCTION BEEN RUN AND QUALIFIED?
- CUSTOMER FEEDBACK IS BASIS FOR ACTION
- ARE THESE MINOR MODIFICATIONS vs REDEFINITION
- SHOULD WE RETURN TO FEASIBILITY GATE?

QUESTIONS FOR FIFTH GATE:

- Is customer feedback understood and actionable?
- Is the "fix" simple to implement?
- Does the product require complete redefinition?
- Should additional production runs be scheduled and evaluated?
- Should we cancel or return process to Feasibility Gate?
- Do we have commitment from the customer(s)?

PRE LAUNCH BUSINESS PROPOSITION

- PRODUCT FEATURES & BENEFITS
- CUSTOMER BASE
- PATENT OPPORTUNITIES
- RIGHT-TO-MARKET APPROVAL
- COMPETITIVE RESPONSE
- MANUFACTURING COSTS
- PACKAGING & DISTRIBUTION
- PROFITS
- LAUNCH PLANS

QUESTIONS FOR THE SIXTH GATE:

- Is the Business Proposition complete?
- What are competitive responses?
- Have specifications been signed by all parties, including customers?
- Has Operations run sufficient product to confirm process parameters and actual costs?
- Have patents been filed?
- Are regulatory submissions required and filed?
- Who is in charge of launch?

LAUNCH

- PULL THE TRIGGER!

- How will progress be measured?
- How soon will modifications to product be made?
- What is the customer/market response?
- Is there a second generation product concept?
- How soon do we start, again?

Credits

- *Winning at New Products Accelerating the Process from Idea to Launch*, Second Edition, Robert G. Cooper
- Sopheon Inc. (www.sopheon.com)
- Edward Cerne, Freudenberg Nonwovens, retired

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COST MODELS

COST MODEL COMPONENTS

- RAW MATERIALS
- LABOR
- VARIABLE OVERHEAD
- NON-VARIABLE OVERHEAD

RAW MATERIALS

- BASIC INGREDIENTS OF PRODUCTS
- INCLUDES WASTE
- VARIANCES TO STANDARD
- YIELD

LABOR

- DIRECT LABOR
- INDIRECT LABOR
- BENEFITS

VARIABLE OVERHEAD

- UTILITIES
- MAINTENANCE
- OPERATING REPAIR MATERIALS

VARIABLE MANUFACTURING COST

- SUM OF:
  - RAW MATERIALS
  - LABOR
  - VARIABLE OVERHEAD

NON-VARIABLE OVERHEAD

- DEPRECIATION
- UTILITIES
- ALLOCATED OVERHEAD
  - PLANT MANAGEMENT
  - HUMAN RESOURCES
  - ENGINEERING
  - FINANCE

GENERIC COST MODEL

- GUIDE FOR ESTIMATING MANUFACTURING COSTS
- FLEIXIBLE FOR VARIOUS PROCESSES
- CALCULATES THE SUM OF THE 4 PORTIONS OF MANUFACTURING COSTS

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International Geotextile Suppliers
Past, Present and Future

Needlepunched Geotextile Fabric Providers

- Bidim - France
- Fibertex – Denmark
- Ten Cate – the Netherlands
- Polyfelt – Austria
- Bonar Technical Fabrics – Belgium
- Fritz Landolt AG- Switzerland
- Huesker – Germany
- Naue GmbH – Germany
- GSE – USA
- Geosistemas Pavco – Colombia
- Geotechnics BV – the Netherlands
- Propex - USA

Needlepunched Geotextile Fabric Providers

- Taiyo Kogyo Corp Sun – Japan
- Tenax – Italy
- Cetco – USA
- Maeda Kosen – Japan
- Mitsubishi – Japan
- Mitsui – Japan
- Tanaka - Japan
- Dae Han – Korea
- Geofabrics – UK
- ABG – UK
- Geofelt – Austria
- Juta – Czech Republic
- Mirafi – USA
- Emas Kiara - Malaysia

Needlepunched Geotextile Fabric Providers

- DeGussa Construction – Spain
- Hui Kwang – Taiwan
- Engepol – Brazil
- Punzonados Sabatell – Spain
- Edilfloor – Italy
- Greenvision – Italy
- Vigano Pavitex - Italy

Geotextiles on the Web
A Reasonable Starting Point

- http://www.tencate.com/
- http://www.thraceling.com
- http://www.propexinc.com/
- http://www.terram.com/
- http://www.fiberweb.com/
- http://www.usfabricsinc.com/
- http://www.coloradolining.com/
- http://www.geotextiles.com/
- http://www.techfabindia.com/

Increased Geotextile Usage in India
Interactive Discussion

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CD CONTENTS

CD CONTENTS (continued)

CD CONTENTS (continued)

Test Methods and Procedures

First Edition: Harmonized Nonwoven Standard Test Methods

Table of Contents of All Methods Revised in 2005
ASTM Standards on Geosynthetics (Committee D35), 5th Edition, 2000
Table of Contents
Flammability Test Methods and Terminology

Highloft Nonwovens: A Difficult Market to Define (E.A. Vaughn)

Highlot Nonwovens – Another Definition (George Jordan)

Guidance Document: WSP 4.0 (05) List of Useful Addresses

Listing of Equipment Vendors WSP 6.0 (05)

Geotextiles

Glossary of Geosynthetic Terms (E. A. Vaughn)

An Early Review of Geotextile Products and Markets (J. E. Fluet, Jr. and R. Denis)

Recommended Descriptions of Geosynthetics Functions, Geosynthetics Terminology,
Mathematical and Graphical Symbols (International Geosynthetics Society)

Geosynthetic Classification (International Geosynthetics Society)

Geosynthetic Functions (International Geosynthetics Society)

Needled Felts (Peter Stevenson)

Conversion of Nonwovens into Finished Products

Major Nonwoven Converted Products

- Diapers
- Fem-hygiene
- Wipes

Wipes Packaging

Wipe Packaging

Unwind Stands

Full-width Reels

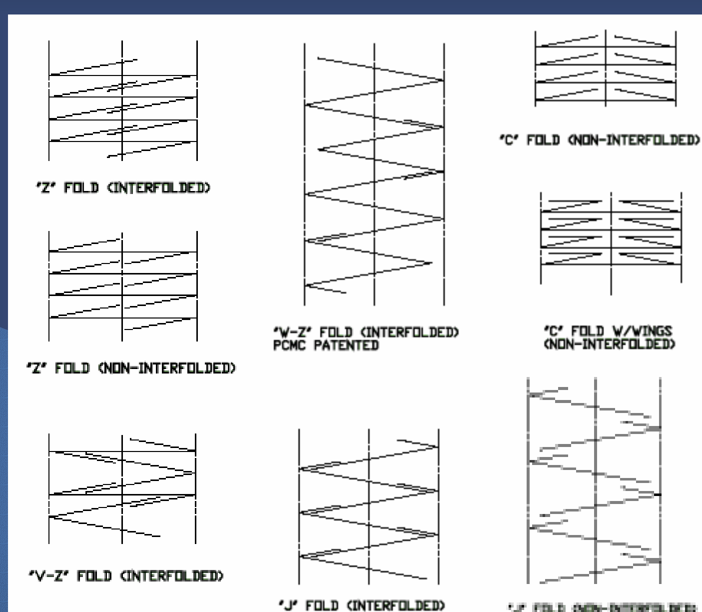
Lap-Splice Unwinds

Pre-slit Reels

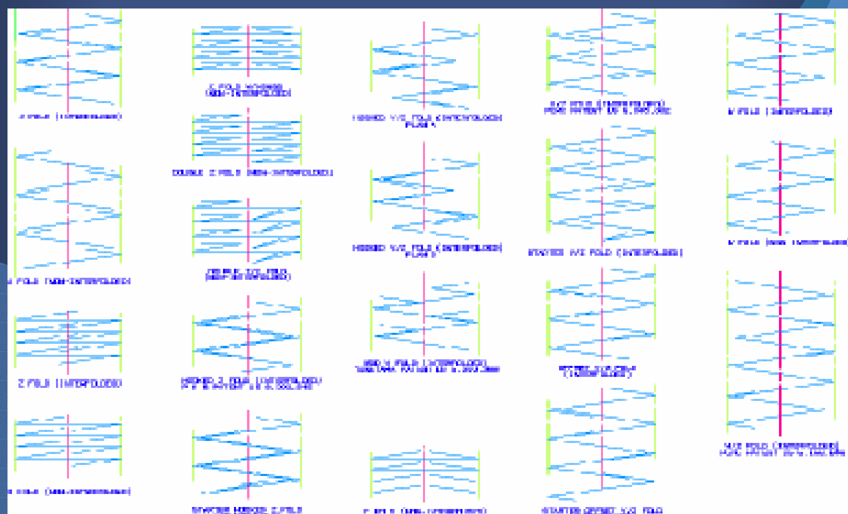
Wetting Process

Folding Process

Fold Geometry



Fold Geometry



Substrate Developments In Wipes

- **Laminates**
  - **Shared properties of unlike substrates**
  - **Enhanced performance**
- **Dual Texture Media**
  - **Enhanced performance**
- **Specialty Fiber/Specialty Process/Specialty Fiber**
  - **Dispersible, Antimicrobial-Coated, Micro, Bi-Co**
- **Patterned/Printed media**
  - **Differentiation through aesthetics**

Formulation Developments in Wipes

- **Water Soluble Emulsions (ready-made formulations)**
- **Micro-encapsulation**
- **Micro-Particle Delivery Systems**
  - **Laurel Methacrylate/Ethylene Glycol Dimethacrylate Cross-polymer (Delivery of oils/fragrances)**
  - **Combination Hydrophilic/Lipophilic Delivery Systems (adsorption of aqueous + polymeric actives) – Allyl Methacrylate Crosspolymer**
- **Multi-functional Formulations (clean/exfoliate, clean/adsorb sebum/deliver active, clean/disinfect, etc.)**
- **Point-of-use Timed Delivery of Actives**

Formulation Development in Wipes

Characteristics of Micro-Particle Delivery Systems

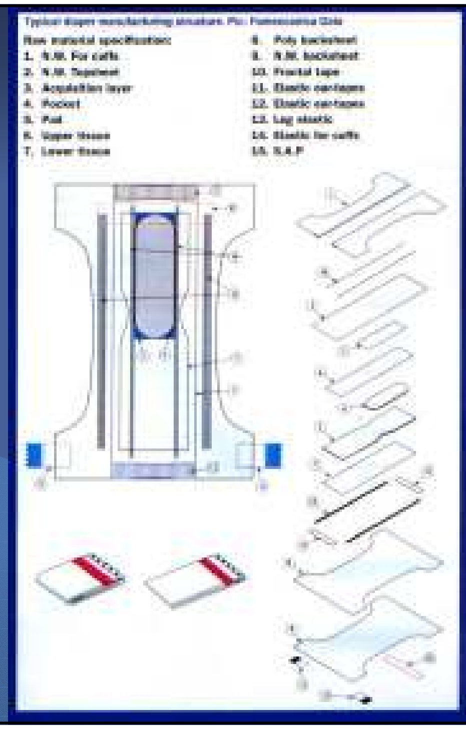
- Highly cross-linked, non-swelling polymeric particles
- Adsorbs and delivers up to 5 times its weight in functional ingredients
- 20 – 100 µm for delivery systems
- Currently used in cosmetic and personal care applications
- Examples of functional ingredients:
  - Benzoyl peroxide -> Acne care
  - Silicones -> Skin protection
  - Organic Sunscreens -> Skin protection
  - d-Limonene -> Surface cleaning
  - Perfluoropolyethers -> Surface modification

Wipes Packaging and Consumer Needs

- Sheet Sizing and Count
- Fold Type and Ease of Access
- Dispensing Consistency and Ease of Handling
- Integrity of Package/Life of Product
- Compatibility Between Product and Packaging Elements
- Stability of Product (Independent & as a whole)
- Cleanliness of Product (Preservatives)
- Storage of Package

Summary

- The Wipes Market – Positive Growth and New Opportunities
- Unique/Specialty Products Are Growth Drivers – Required for Continued Growth
- Each Product Component Requires Attention To Develop a Unique Product
- Consumer Needs/Desires Are Critical



Products Driving Growth