Asten

PAPER MACHINE CLOTHING

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Foreword

Colonial papermakers would truly be amazed at the technological achievements that the paper industry has attained. Asten is fortunate to have had a major role in ensuring the success of those achievements.

Starting more than 120 years ago with simple weave structures manufactured from metal, wool, and cotton, Asten has evolved its paper machine clothing into sophisticated products made from synthetic fibers with highly engineered properties for distinct paper machine applications. These new products and technologies, combined with modern and advanced manufacturing techniques, have offered tremendous opportunities for sophisticated paper machine clothing products to meet the demanding needs of today's paper machines.

Asten has played an instrumental role in the technological shift from the art of papermaking to the science of papermaking. As papermaking processes have become more sophisticated and demanding, Asten has continually demonstrated its leadership by providing the highest quality, innovative products and services available anywhere in the paper machine clothing industry. Today our dynamic organization is providing a full range of paper machine clothing in every major global market.

The management of Asten is proud to present the first edition of *Paper Machine Clothing*. We are delighted and fortunate that the book is authored by a former Asten associate, Dr. Sabit Adanur. Also, we are grateful to all Asten associates who contributed significantly to the publication of this book.

Dr. Adanur holds a Ph.D. in Fiber Polymer Science and an M.S. degree in Textile Engineering and Science from North Carolina State University, as well as a B.S. degree in Mechanical Engineering from Istanbul Technical University. Currently a professor in the Textile Engineering Department at Auburn University, Dr. Adanur spent three years at Asten as manager of Research and Development.

This first edition of *Paper Machine Clothing* is designed as a comprehensive resource for managers, engineers, professionals and production specialists who work directly or indirectly with the papermaking process. The book contains the latest technology available in the profession.

Asten is proud to be part of an alliance with the industry it serves to help introduce these new paper technologies that have kept our industry on the leading edge of a global and competitive paper industry.

We hope you will find this book educational and informative. Furthermore, we truly hope that it will be used to further advance the science of papermaking.

WILLIAM A. FINN
Asten, Inc.
President and CEO



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Introduction

The first two basic necessities of *civilization* are textiles and paper. Assuming that a person's stomach is full (food is a *must* for survival not a *necessity* for civilization), his next need is a piece of cloth to cover his body to look more civilized to the eye and protect himself from the adverse effects of the environment. The second necessity to be further civilized is a piece of paper to write on or to read from to communicate and to extend his knowledge as well as to record history. There has been a direct correlation between a nation's standard of living and the amount of textiles and paper used.

Although textiles and paper are in general different products, they have some interesting commonalities between them. They both use fibers in their final products. Both of their manufacturing processes are a mixture of science and art, two of the most ancient arts, indeed. Neither textile nor paper manufacturing processes are positively controlled. That is, in either case it is hardly possible to control the individual fiber which is the smallest meaningful building block in the structure. Moreover, there are some products that may be classified as both nonwoven textiles and paper, depending on which industry you are in. These products link the two industries together. There are of course some differences between a textile product and paper. Textiles in general use longer fibers than paper. Paper uses mostly wood and other plant fibers; textiles use both natural and man-made fibers. Nonwoven paper and textile products mostly use synthetic fibers. In a textile product, frictional and mechanical forces are the major forces that hold the textile fibers together giving the structural integrity to the product. In paper, relatively short fibers are chemically bonded together with hydrogen bonds.

Another link between the textile industry and paper industry is paper machine clothing. The paper machine clothing industry involves both textile and paper aspects which makes it fascinating. Paper machine clothing is an integral part of the papermaking process. Paper and related products such as books, newspapers, magazines, tissue, towels, bags and currency, etc., cannot be made without a textile fabric with today's technology. Therefore, textile fabrics are essential to the well being of the paper industry. Textile fabrics are also essential in the manufacture of other textile products such as nonwoven textiles.

Although this book is mainly about paper machine clothing, it also has some concise information about papermaking, paper structure and properties. Therefore, this book may serve as a bridge between the textile industry and the paper industry. Paper topics related to paper machine clothing are included for convenience to the reader. Highly sophisticated structures and properties of paper machine clothing cannot be fully comprehended or appreciated without some knowledge of pulp and paper technology, structure and properties. A further similarity between textiles

to the furnish in stock preparation to obtain different properties. Fillers are added to improve printing properties, smoothness, brightness and opacity. Sizing agents make the paper stronger and more water resistant. Sizing can also be done on the paper machine, by surface application to the sheet.

Step 8: Finally, more water is added to the pulp to form a slurry that is ready to be pumped to the forming fabric through the headbox.

Although the properties of the original wood fiber are partially destroyed during the pulping process, the original characteristics are at least in part retained in the fiber [5]. Therefore, the properties of the resultant paper to a great extent depend on the fiber that is used. However, special properties such as improved strength, softness, moisture absorption, moisture resistance, etc., can be imparted to the paper by special treatment during the manufacturing process of the paper [1].

Important properties of pulp for good papermaking are ease of refining, dewatering ability, wet web strength, and dry strength. The pulp should be easily formed into paper on a paper machine which is called runnability.

1.2 Paper Manufacturing

Paper is a network of fibers. The principle of papermaking is relatively simple. The basic necessary ingredients of sheet forming are fiber (wood or other), water and a drainage medium. The mixture of fibers and water (called slurry), is filtered through a porous fabric. Water is drained through the fabric and wood fibers, fillers and fines are collected on the surface of the fabric; thus the sheet is formed (Figure 1.9 on page 13). After formation, the sheet is pressed and later dried to remove excess water. Although the main structure of paper is fibrous, nonfibrous components such as clays and other mineral fillers, dyes, polymers and bonding agents are added to improve formation, sheet structure and optical properties such as brightness and opacity.

Papermaking is a process that can be manually done in a lab or at home with the basic necessary equipment. However, current papermaking technology is a highly sophisticated and continuous process which requires state-of-the-art machinery and equipment. Various chemicals, finishing and coating agents are used to help with the formation and improve the sheet properties and characteristics. There is a constant search to improve texture, print quality, control of ink bleeding, optical and other properties of papers. Nevertheless, like most textile manufacturing processes, papermaking is still a combination of art and science. The main reason for this is that the exact control of individual wood fibers during formation is hardly possible. Besides, as a natural product, there is inherent variation in wood fibers.

1.2.1 *History of Papermaking*

Papermaking is an ancient art. Approximately 4000 BC, Egyptians developed the first paper for writing purposes from a plant called papyrus. In fact, the word *paper* may have come from the word "papyrus." The stems of papyrus were thinly sliced and layers of slices were beaten into hard thin sheets and coated with glue-like material. However, the individual fibers were not separated which is different from modern papermaking principle [1].

Table 1.2 (page 23) shows a chronology of papermaking. The actual art of making paper was invented by Ts'ai Lun in China in the year 105 AD. He beat the water and mulberry tree bark mixture into a pulp. Using a screen, he collected the fibers and dried them in the sun which resulted in the first sheet of paper made from wood. With the invention of printing press by Johann Gutenberg of Germany in 1450, the demand for paper increased. In the mid 18th century, Rene de Reaumur, a French scientist, observed the pulp made by paper wasps by chewing bits of wood and mixing it with saliva which they use to make nests. Therefore, he suggested that the same procedure could be used to make paper. Despite this discovery, rag pulp remained the principle raw ingredient of paper for a long time.

Modern paper machines as we know them were invented by Nicholas Louis Robert, an

Englishman in 1798. He designed a hand-cranked machine that produced paper in a continuous roll which was a big improvement over the hand-dipping method. The Fourdrinier brothers of London bought the patent, improved and developed a machine that is named after them and still in use today. The machines, even the earliest Chinese method, all used wire meshes to form the paper on. In 1879, C. F. Dahl, a Swede, invented the kraft process by cooking the wood chips with sodium hydroxide and sodium sulfide under pressure which is a widely used process resulting in stronger paper.

Since the introduction of the first paper machine, there has been continuous increases in machine speeds and widths. Improvements and innovation in paper machine design and paper machine clothing played a key role in this progressive development. In early paper machines, woolen felts in the press and cotton felts in the dryer section were used along with the metal wires in the forming section. However, those types of fabrics were a limiting factor for higher machine speeds and new paper machines. The development of synthetic forming fabrics allowed the machine builders to design and develop twin-wire forming units which improved the sheet quality.

Today, paper is formed on polyester and nylon fabrics compatible with increased machine width and speed. In the press section, the development of all synthetic needled press fabrics allowed heavy press loadings which increased the efficiency of water removal. The increased stability of synthetic press felts met the demands of faster and wider machines. Similar improvements were made in the dryer section in speed and width with the introduction of polymeric dryer fabrics. Drying rate was increased along with the fabric life.

1.2.2 *Papermaking Process*

The five basic steps of the sheet forming process on a paper machine are:

- fiber dispersion and distribution onto a forming fabric
- drainage of water
- consolidation of the sheet
- compaction of the sheet
- drying

Coatings can be applied to the sheet during or after these processes. A typical paper machine has three distinct sections as shown in Figure 1.10 (page 13): forming, pressing and drying. The fabrics that are used in these sections are called forming fabrics, press fabrics (felts) and dryer fabrics (felts), respectively. Each fabric type performs specific functions. Therefore, each fabric type must be designed, engineered and manufactured differently depending on the paper grade, paper machine position and size.

Modern papermaking is a fast and massive process. For example, up to 100,000 liters of paper pulp are evenly spread within one minute onto a 7 m wide fourdrinier paper machine. Finished paper is wound on the rolls at the end of the paper machine only a few seconds after the high water content material has reached the forming fabric [7].

Forming

The fabrics that are used in the forming section are called forming fabrics. The term "forming" comes from the formation of paper. Pulp slurry, which is a mixture of approximately 99% water and 1% fiber, is pumped through the headbox evenly across the forming fabric. The forming fabric travels along the forming section of the machine like a porous conveyor belt. As the fabric moves, water is filtered through the forming fabric and wood fibers are retained on the fabric surface, thus forming the sheet (i.e., a wet paper web at this stage) as shown in Figure 1.9. At the end of the forming section, the sheet has a consistency of approximately 20% fiber and 80% water. Figure 1.11 (page 13) shows the typical sheet and water ratio through the fourdrinier machine. The forming section of the paper machine is also called the "wet-end."

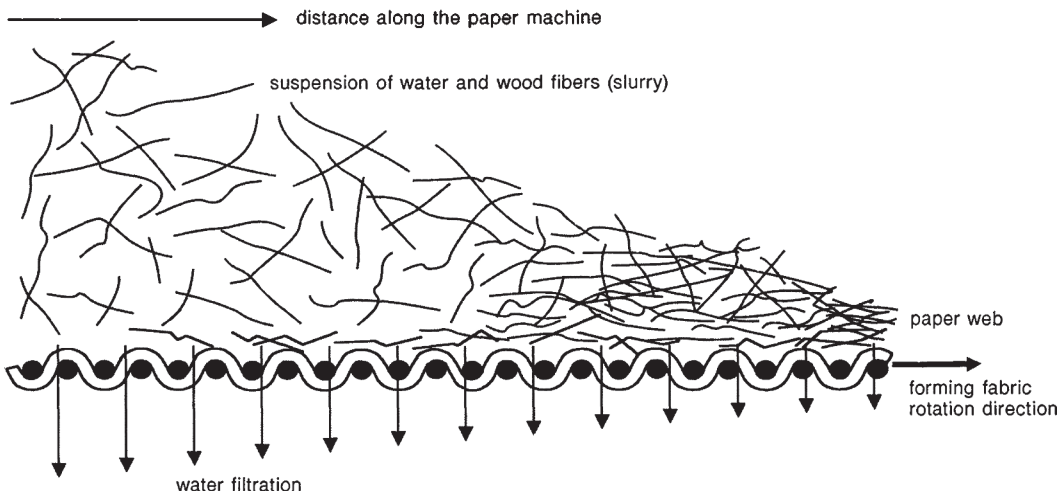


FIGURE 1.9. Schematic of sheet formation (courtesy of Wellington Sears Company).

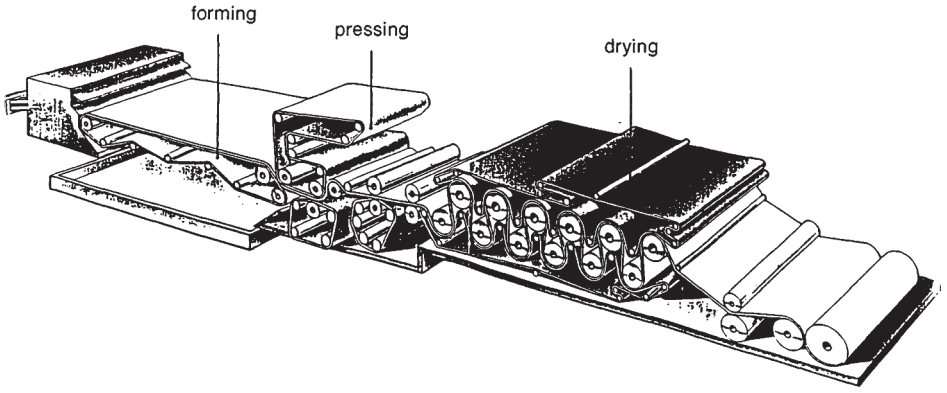


FIGURE 1.10. Schematic of a fourdrinier paper machine.

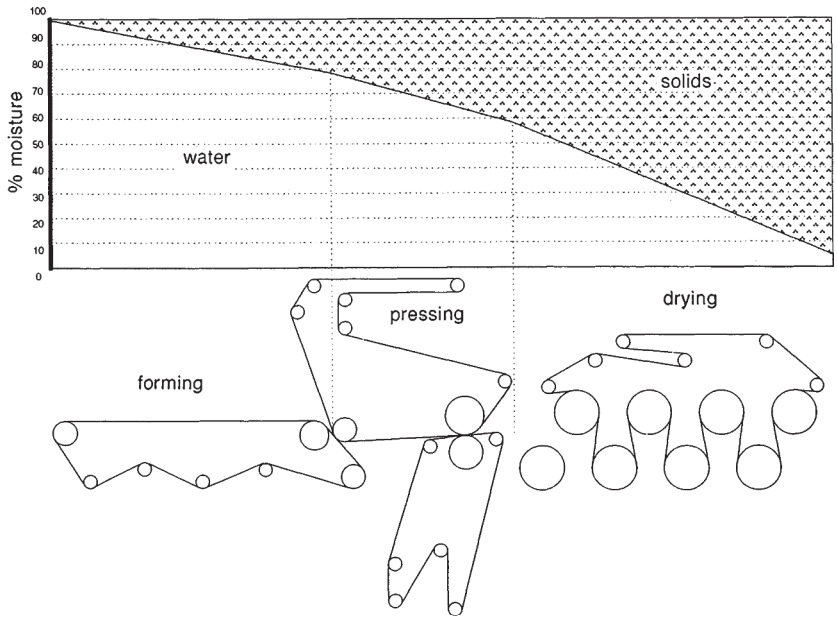


FIGURE 1.11. Sheet and water ratio through the fourdrinier machine.

TABLE 1.2. A Chronology of Papermaking [1,3,4,6].

BC	4000	Papyrus for writing purposes developed in Egypt
AD	105	Ts'ai Lun credited for invention of paper in China
	600	Mayans of Central America made paper from bark
	751	Arabs learned papermaking after battle of Semerkand
	800	Paper reportedly made by Arabs in Baghdad
	868	Wang Chieh printed first book in China
	900	Paper made in Egypt
	1085	Crusaders took over paper mill located in Toledo, Spain
	1102	Paper produced in Sicilia
	1268	Papermaking started in Italy where watermark was introduced
	1348	Paper mill established in France
	1450	Invention of printing press by Gutenberg to print the Bible; this invention increased demand for paper
	1576	First paper mill established in Russia
	1609	First newspaper with a regular publication date in Germany
	1637	Sung Ying-Hsing noted the use of waste paper for making paper in Northern China
	1690	Rittenhouse establishes a paper mill in Germantown, Pennsylvania which was the first mill in North America
	1719	Reamur, a French naturalist, suggested using wood as a fiber source
	1774	Chlorine was used with lime to bleach paper
	1798	Nicholas Louis Robert invented the first paper machine
	1800	Matthias Koops received patent for process using straw, wood and deinked waste paper which was the initial form of recovery and recycle system
	1803	Bryan Donkin developed the first successful paper machine for Fourdrinier brothers
	1805	Joseph Bramah invented cylinder machine which was patented by John Dickenson in 1809
	1807	English patent issued to Fourdrinier brothers for improved paper machine
	1817	Thomas Gilpin installed the first paper machine, which was a cylinder type, on Brandywine River near Wilmington, Delaware; Dickinson invented size press for paper machine
	1821	T. B. Compton, England, received patent for drying paper on the machine. Cloth was used for protection and better appearance
	1823	Crompton used steam dryers in England
	1826	John Marshall invented dandy roll; vacuum pumps on the fourdrinier machine
	1827	First fourdrinier paper machine installed in America at Saugerties, New York
	1844	Pulp is made by grinding
	1850	Ebart invented a flame retardant paper
	1852	Turner developed endless wire for paper machine
	1863	Patent issued to J. F. Jones of Rochester, USA for multicylinder machine with seven or more vats
	1866	First groundwood pulp mill in the United States established at Curtisville, Massachusetts
	1875	Multiply paper machine with two separate fourdrinier sections
	1879	C. F. Dahl invented the kraft process
	1909	First kraft pulp mill in the United States established at Roanoke Rapids, North Carolina
	1953	Daniel Webster of Consolidated Paper invented modern twin-wire former
	1965	Blade and roll formers introduced
	1970	Multiple combined fourdriniers
	1980	Multiple fourdrinier with top station or top wire
	1985	Roll/blade former
	1990	Retrofit blade former with adjustable drainage

Compared to pressing or drying, forming is the most critical stage in papermaking. Forming fabrics affect the final sheet properties more than press or dryer fabrics. If the sheet structure is not formed properly in the forming section, it would hardly be possible to correct it later on the paper machine [8]. Therefore, forming fabric properties must be carefully engineered. Although it depends on the type of formation, the average life of a forming fabric is three months. Forming and forming fabrics are the subject of Chapter 2.

Pressing

After the sheet is formed, it is transferred to the press section (Section 2.7). The function of pressing is to continue the water removal process that started in the forming section, consolidate the sheet, give texture to the sheet surface, support and transport the sheet. During pressing, the sheet web is compressed in the nip formed by two press rolls, one or both of which may be felted. Water is moved from the sheet into the felt(s) and may be expressed at the nip, or carried away for removal by felt vacuum boxes. Figure 1.12 (page 14) shows this process in a plain press nip. There is a considerable amount of pressure at the point of contact. Increased compression increases water removal [8–11]. Since most of the paper web is still water when entering the press section, the paper surface finish is influenced by the press fabric design. Although it depends on sheet grade and paper machine, typical sheet consistency at the end of press section is 40% fiber and 60% water. At the end of the press section, the sheet is transferred to the dryer section. The average running life of a press felt is about 30–90 days. Pressing and press fabrics are the subject of Chapter 3.

Drying

After pressing, most of the residual water in the sheet is removed by evaporation (mass transfer) in the dryer section by using steam (heat transfer). The fabrics in this section are called dryer fabrics or dryer felts. The paper sheet travels around heated cylinders where most of the remaining water is evaporated. The consistency after this section is on the order of 95% fiber and 5% water which is the typical consistency of regular paper. The dryer end of the paper machine is also referred to as "dry-end."

The drying zone can be considered as a "black box" into which wet paper, steam and air enter. The dried paper, the moist and heat-laden air, and the condensate leave the box [12]. Typically, large volume of drying cylinders evaporate more than 17,000 litres of water per hour from the paper. Figure 1.13 (page 14) shows the arrangement in the drying zone. Dryer fabric presses the sheet tight against the heated cylinder. Most of the energy used to make the sheet is consumed in the dryer section and the dryer fabric has a significant effect on drying efficiency. Dryer fabrics typically last 6–15 months. Drying and dryer fabrics are the subject of Chapter 4.

Coating and Calendering

Coating of the paper surface may be done to impart different surface properties. In calendering, paper is passed through the nip(s) of two or more rolls (Figure 1.14 on page 14). Calendering increases the smoothness and uniformity of the paper and makes it thinner. After calendering, the paper is wound onto a large roll which may be cut into smaller rolls in a winder machine.

Converting Process

After paper is manufactured, it usually goes through a converting process before it is sold to the consumer. The converting operation is critical for the function or performance of the paper. Quality deficiencies in the paper are usually revealed in the converting plant or in the printing press [5].

1.3 Paper Machines

Although the principle of papermaking has not changed since the introduction of fourdri-

is considered the premium pulp grade because of its long fiber length and strength. U.S. pulp statistics include about 2 million tons of fluff pulp production used in diapers and other absorbent hygiene products. Dissolving and mechanical pulp are excluded from the statistics. Canada has about 1.6 million tons of mechanical pulp capacity, mainly bleached chemithermomechanical pulp (BCTMP).

1.4.12 *Newsprint*

Newsprint is uncoated paper used for the printing of newspapers. Not less than 65% of the total fiber content of newsprint consists of wood fibers obtained by a mechanical process, with other standards addressing smoothness, weight and ash content. Virtually all U.S. and Canadian newsprint capacity is on a nominal 30 lb basis weight standard, and a typical sheet falls into the 58 to 60 brightness range.

1.4.13 *Nonwovens*

A nonwoven product is a manufactured sheet, web or batt of directionally or randomly oriented fibers, made by bonding or entangling fibers through mechanical, thermal or chemical means. The fibers may be of natural or man-made origin. Nonwoven products form a bridge between paper and textile products. Nonwoven manufacturing processes are explained in Chapter 2.

The application areas of nonwoven products are ever increasing. Some examples are medical products, diapers, interlinings, shoe components, wipes, floor coverings, mattress covers, disposable clothing, filters, insulation, soil stabilization, luggage and automotive components.

1.4.14 *Specialty Papers*

This category is for grades that do not neatly fit the previously mentioned grades. Specialty papers are often used as a carrier for polyester, foil or other applications such as computer paper, thermo imaging papers, etc. The specialty paper market is characterized by smaller machines. Physical properties vary greatly. Plastics are a major competitor for these grades.

1.5 End-Use of Paper

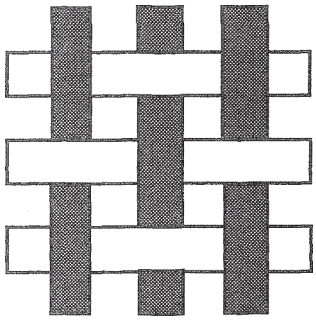
The United States is the world's largest manufacturer of pulp, paper and paperboard. The production capacity of the United States is approximately equal to the combined capacity of the next four largest producing nations (Figure 1.18 on page 18). Although the United States has only 5% of the world's population, with 12% of the world's paper and paperboard mills, it has 30% of the world's paper and paperboard production and with 16% of the world's pulp mills, it has 35% of the world's wood pulp production [13]. The U.S. pulp and paper industry is one of the nation's top ten manufacturing industries. There are approximately 550 facilities in the United States making paper, paperboard and building products. Since 1980, the U.S. pulp and paper industry invested more than $110 billion to increase productivity and capacity. Over $40 billion of this investment is done since 1990. In 1992, the U.S. pulp and paper industry produced over 82 million tons of paper and paperboard and 10 million tons of market pulp. Figure 1.19 (page 18) shows the world demand for paper and paperboard.

Paper is critical to life today. Americans use more than 90 million short tons of paper and paperboard every year. Paper can be used in three different ways:

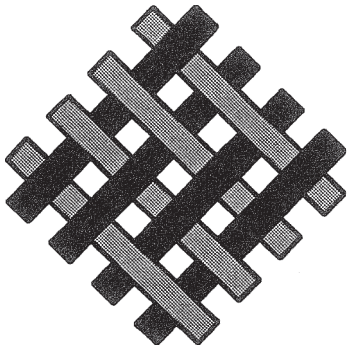
(1) As a structural material for load-bearing and other applications; e.g., grocery bags, paper boxes, construction materials, etc.
(2) As a printing and communication material, e.g., books, newspapers, notebooks, etc.
(3) As a material to absorb liquids (e.g., tissue, paper towel) or resist moisture (e.g., paper plates and cups).

Sometimes, paper has to perform more than one function at the same time. Table 1.8 lists various types of papers according to end use.

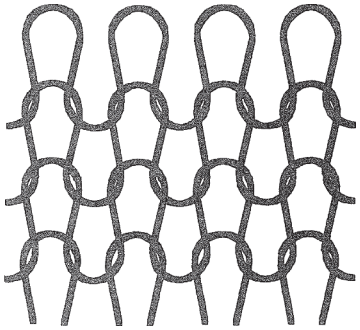
plain weave (top view)



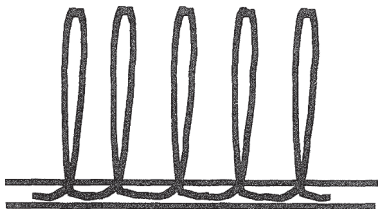
regular braid (top view)



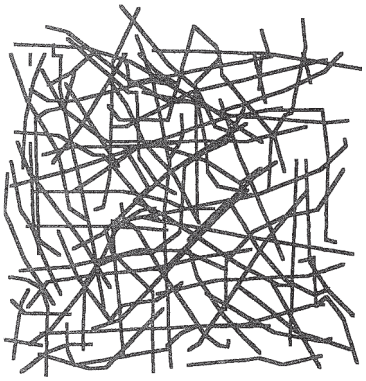
weft knit (top view)



tufted (cross-section)



nonwoven (top view or cross-section)



paper (cross-section)



FIGURE 2.2. Schematics of textile and paper structures.

stretch and increase the volume of yarn available to wear away. This is the opposite of the type of yarns we need to improve sheet quality by better fiber support.

The total fabric structure contributes to the ability of the fabric to act as a drainage medium. On the machine, the fabric has the capability to drain the headbox flow in a very short time, provided the flow consists only of water, as is the case during the initial start-up. It is only when the other parts of the furnish are added to the flow that the fabric appears to show significant drainage resistance. Once the fiber mat is deposited on the top of the fabric, the mat becomes the major source of drainage resistance. In the early part of the forming process, the way in which the fiber mat is built up governs the drainage. In the later part of the table, the ability to generate a pressure drop from the top of the sheet to the bottom of the fabric governs the drainage.

Mechanically a forming fabric must have:

- good wear resistance
- resistance to stretching, narrowing, skew, puckering, ridging and wrinkling
- guide-ability
- drive-ability
- resistance to high pressure shower and other damages
- the ability to be cleaned and have the sheet knocked off

A forming fabric should give the papermaker:

- good first pass retention
- good formation
- reduced power consumption
- reduced offset linting
- less two sidedness
- good strength properties
- proper surface topography to achieve desired paper properties

To achieve these tasks compromises are necessary. Forming fabrics are highly complex structures. A detailed understanding of each paper machine is needed to be sure that the right fabric is designed and used.

2.2.1 *Forming Fabric Designs*

Forming fabrics have more effect on the final sheet properties than press or drying fabrics which makes their design very critical. As a result, the design and manufacturing of forming fabrics require very special considerations and careful engineering.

There are basically three types of forming fabric designs used in the papermaking industry: single layer, two layer and three layer. Before we discuss these designs, a clarification needs to be made concerning manufacturing and installation of paper machine fabrics. A fabric can be woven in two ways as shown in Figure 2.3:

(1) Flat weaving
(2) Endless weaving

Flat woven fabrics have to be joined (seamed) to make an endless fabric for use on the paper machine. Warp direction on the weaving machine becomes machine direction (MD) on the paper machine and filling direction on the weaving machine becomes the cross machine direction (CD) on the paper machine. In endless weaving, the fabric is woven as an endless belt. The warp direction on the weaving machine becomes the cross machine direction (CD) on the paper machine and the filling direction on the weaving machine becomes the machine direction on the paper machine.

During weaving of the fabric, cross machine direction yarns are also called "shute" yarns. The term "shute," which is extensively used in the paper machine clothing industry, comes from the "shooting" of the yarn across the weaving machine with a shuttle. Another term for the filling yarn is "weft" which is commonly used in the textile industry.

Single Layer Designs

Single layer fabrics have one layer of warp yarns and one layer of weft yarns. Most single layer fabrics are woven with two to eight harnesses. Figure 2.4 shows warp profiles of some single layer fabrics.

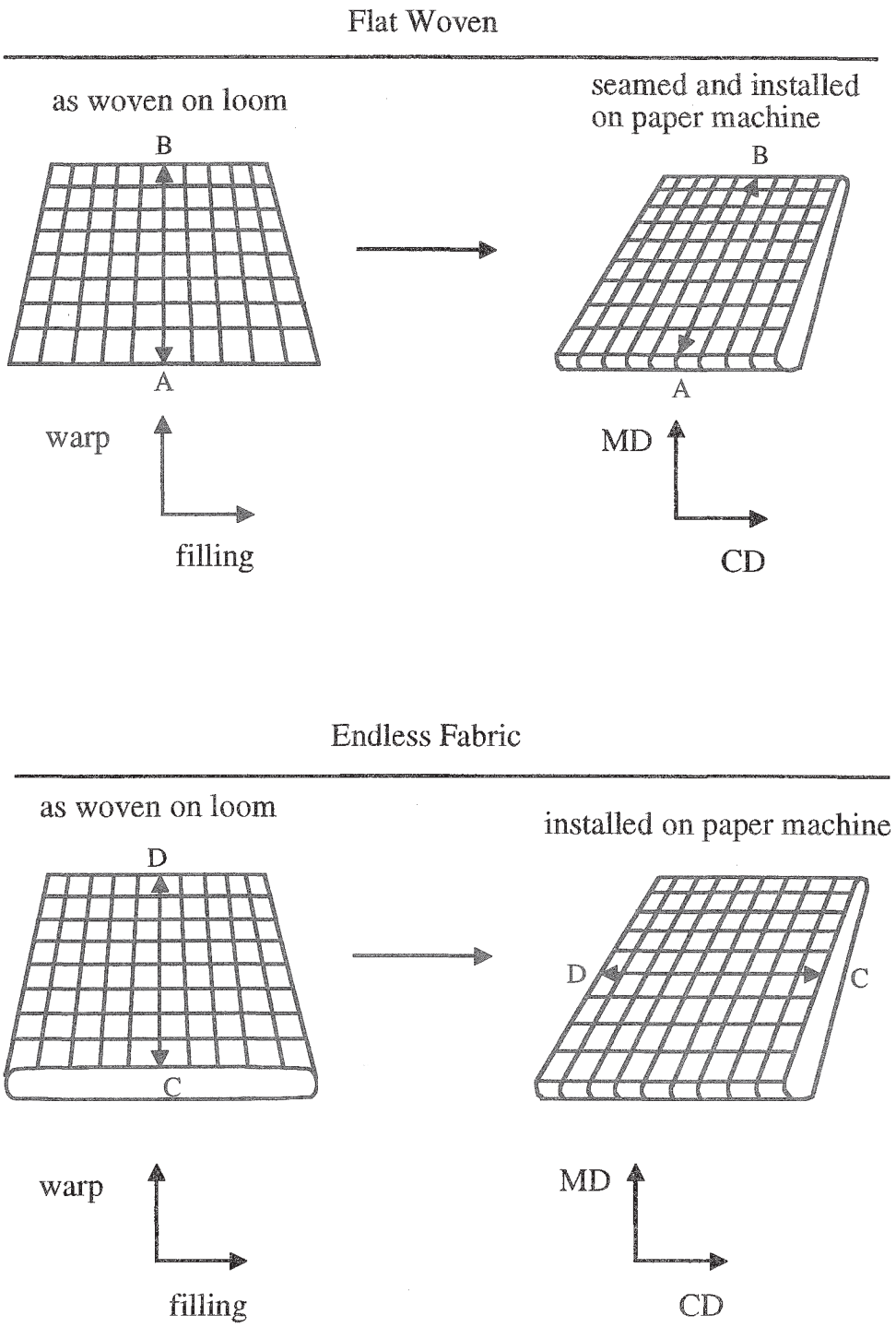


FIGURE 2.3. Flat and endless fabric weaving and installation.

Plain weave design requires a minimum of two harnesses ("sheds") to weave. Paper machine clothing manufacturers use the term "shed" instead of "harness" to indicate the number of yarns in a repeat unit of the fabric. A "shed" is the opening between the warp yarns during weaving. A harness is a mechanical device to which warp yarns are attached. Machine direction (warp) yarns pass over and under alternate cross machine direction yarns.

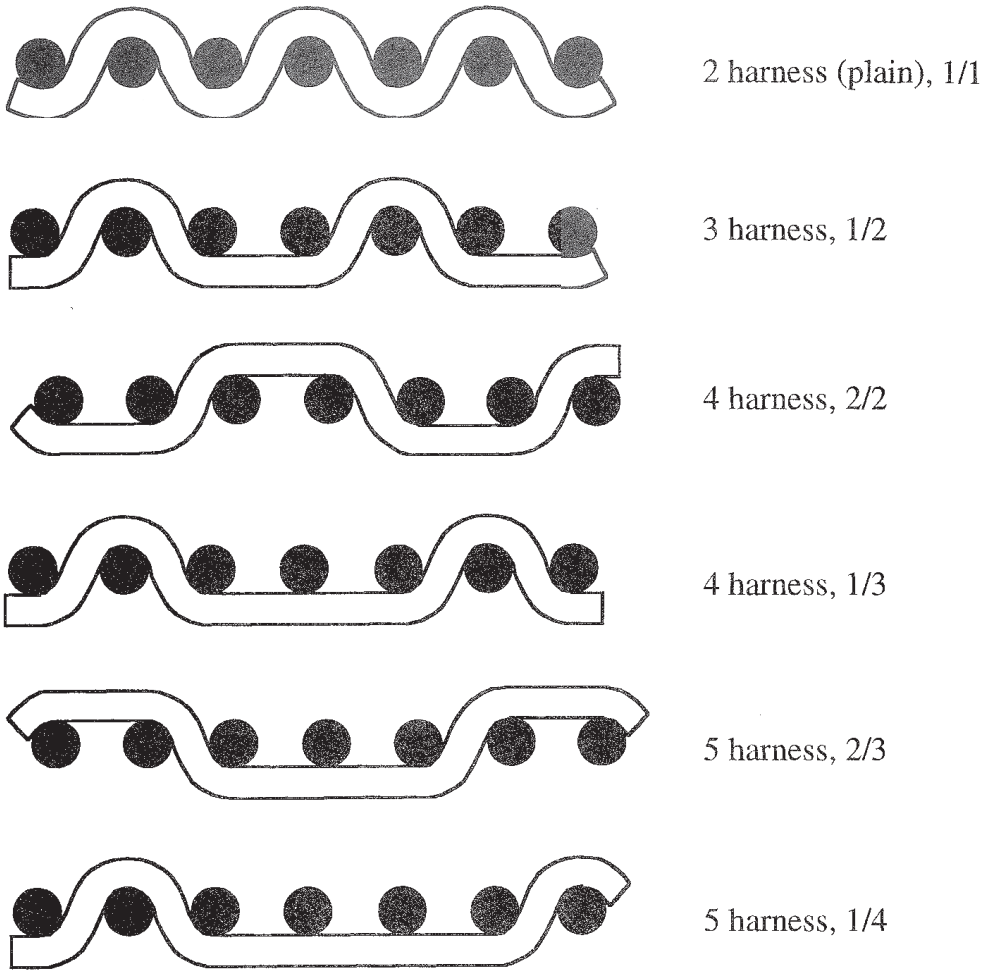


FIGURE 2.4. Warp profiles of typical single layer forming fabrics.

The meshes are usually coarse and used primarily in board, pulp and industrial cloth applications. During operation, single layer fabrics wear on both machine direction and cross machine direction yarns. Figure 2.5 shows a plain weave fabric. Plain weave gives minimum sheet marking but it is not a practical single layer fabric for normal papermaking.

Three harness (1/2 twill) designs are woven with the machine direction yarn passing over one cross machine direction yarn then under two cross machine direction yarns. The crossover is offset by one yarn each time, which forms a diagonal pattern in the fabric. This imaginary line is called twill line. This type of fabric is not utilized in many applications today.

Four harness designs can be achieved in different ways. Four harness twills are woven with the machine direction yarn passing under one cross machine direction yarn then over three cross machine direction yarns. The crossovers are offset by one, to form a diagonal pattern in the fabric similar to three harness but with longer yarn surfaces. This type of fabric is generally not used in paper manufacturing today.

Four harness broken twill is similar to the four harness twill, however, the crossovers are offset in a broken pattern. This type of pattern is sometimes referred to as a crowfoot pattern. The coarse mesh fabrics in this design are used in brown paper and are generally run with the long cross machine knuckle toward the sheet for better release. The medium mesh fabrics are used in the newsprint industry and are run with the long cross machine knuckle toward the machine

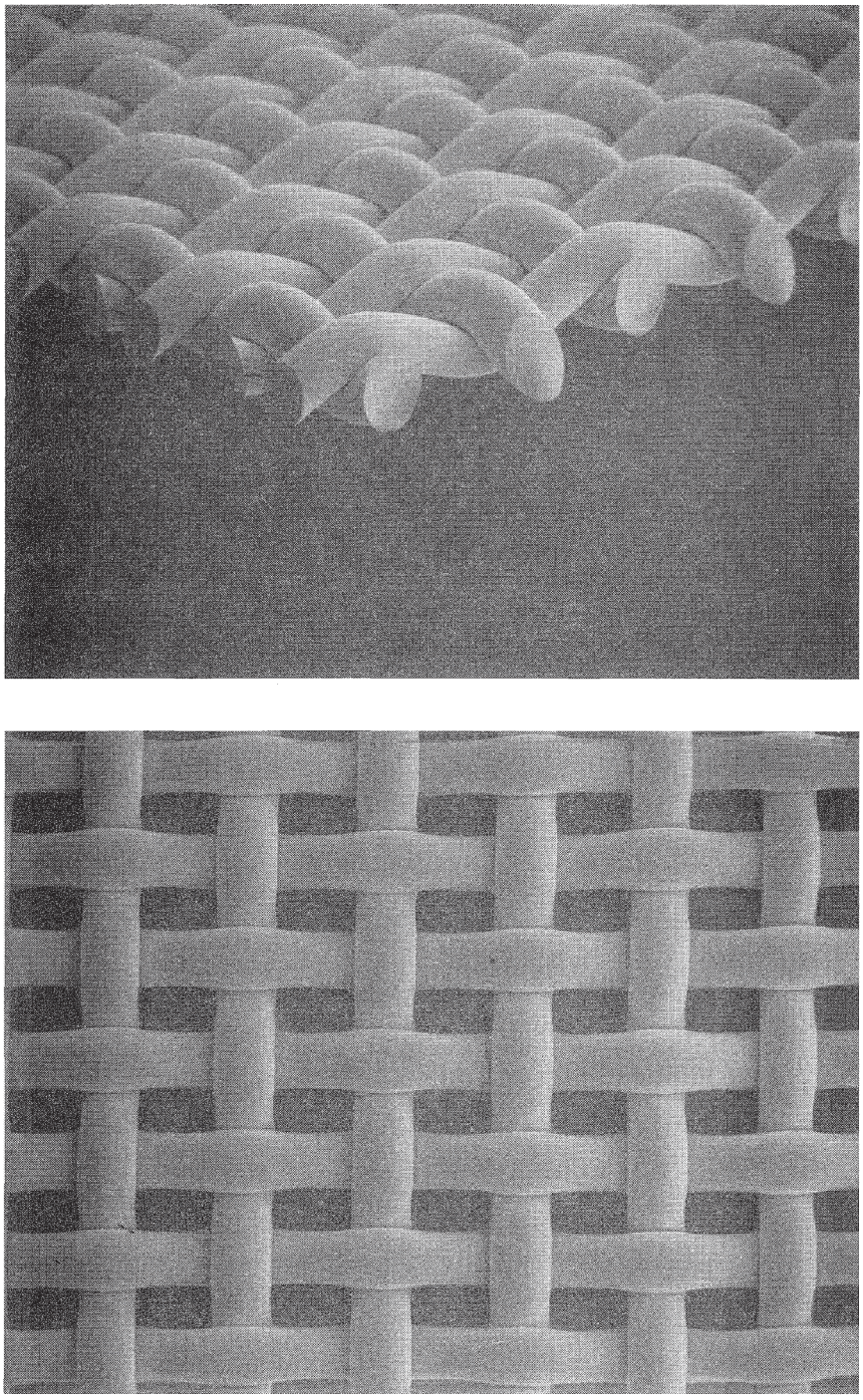


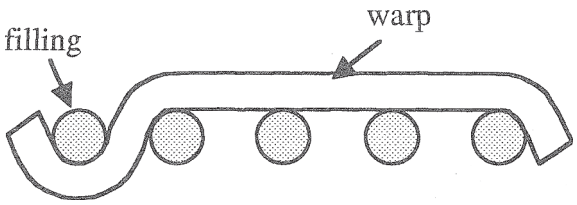
FIGURE 2.5. Photomicrograph of a plain weave fabric.

for better wear. The finer meshes in this weave are also run with the long cross machine knuckle toward the machine and are used for high quality printing, copying and writing papers.

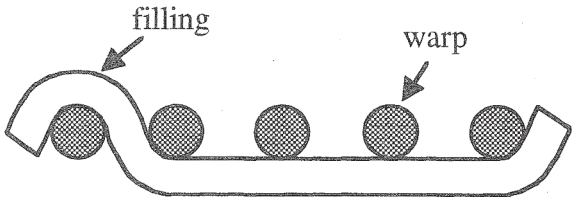
In four harness double twill the machine direction yarn passes over two cross machine direction yarns then under two cross machine direction yarns. The crossovers are offset by one to form a twill pattern.

Five harness design also has different combinations. Figure 2.6 shows schematic of a five harness, 1/4 twill design. The warp yarn passes over 4 and under 1 weft yarn. The

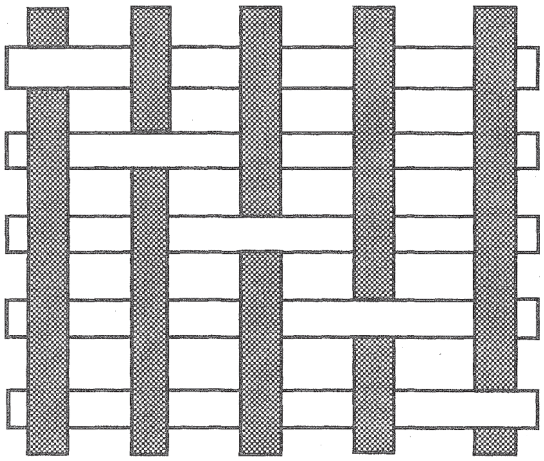
warp profile:



filling profile:



top view:



bottom view:

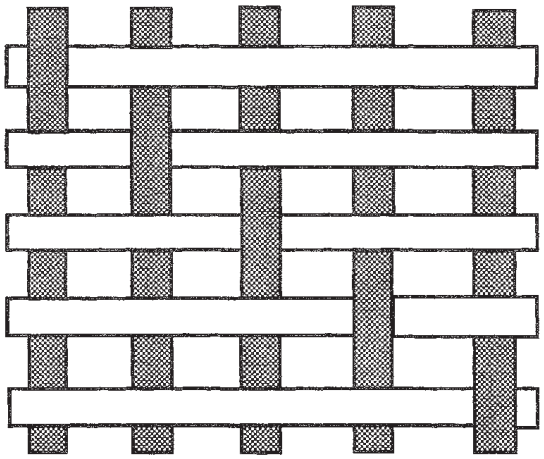


FIGURE 2.6. Schematics of five harness (1/4) twill single layer fabric design unit cell.

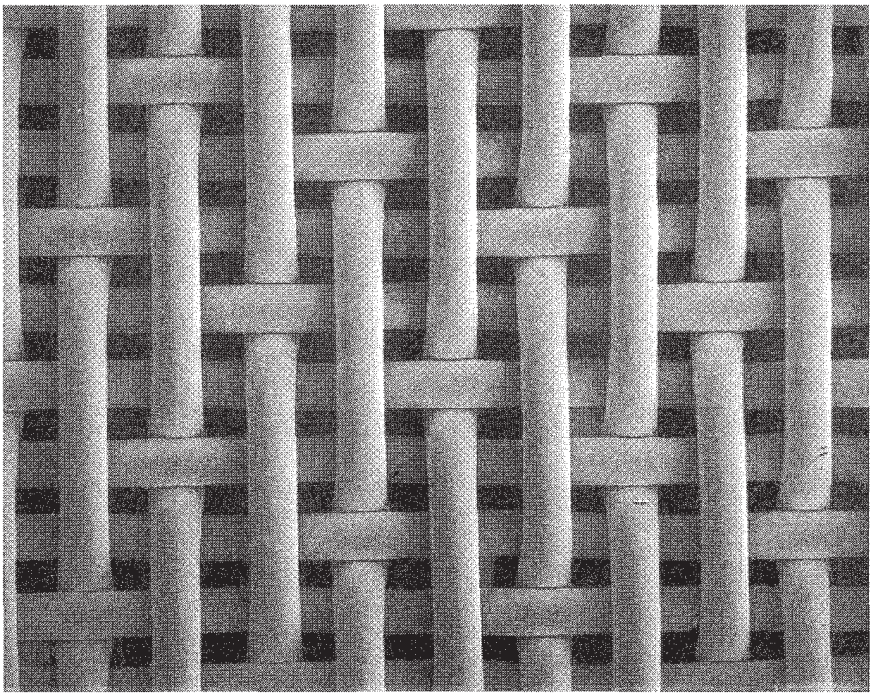


FIGURE 2.7. Top view of a five harness single layer broken twill fabric.

crossover points are adjacent so that they form a twill line.

Five harness broken twills are also woven with the machine direction yarn passing over four cross machine direction yarns then under one cross machine direction yarn. However, the crossovers are staggered to prevent a twill pattern as shown in Figure 2.7. These fabrics have low profile knuckling and smoother surfaces. Fabrics in this weave can be run with long machine direction knuckles to the sheet or long cross machine direction knuckles to the sheet depending on the grade of paper to be run. Suitable for a variety of paper grades, it is more easily adaptable for optimizing fiber retention than other designs.

Five harness 2/3 twills are woven with the machine direction yarn passing over three cross machine direction yarns and under two cross machine direction yarns (Figure 2.8). The crossover is offset by one yarn to form a twill pattern. This weave is used primarily in brown paper of all grades from lightweight linerboard, corrugating medium and bag to heavy weight linerboard. It offers good wear and release characteristics. These fabrics are normally run with the longer machine direction knuckles to the sheet, but also can be run with the longer cross machine knuckles to the sheet for better release without sacrificing much life.

Two Layer Designs

In two (double) layer forming fabrics, there is one layer of warp yarns and two layers of filling yarns. There are two major variations of two layer fabrics: a) standard two layer and b) two layer extra designs.

a) Standard Two Layer Design

Figure 2.9 shows schematics of various standard two layer designs. There are several different weave patterns available in both seven and eight harness two layer weave patterns. These weaves can be used for all grades of paper as well as for industrial applications.

Four harness two layer fabrics have the wear knuckles in the machine direction. These fabrics generally employ heavyweight yarns. This weave is suitable for pulp, some brown

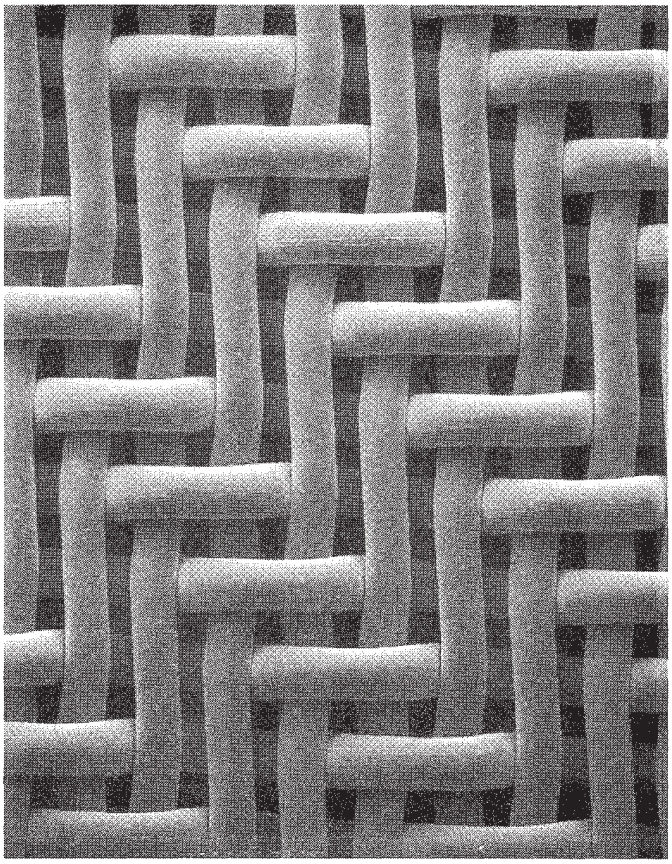


FIGURE 2.8. Five harness 2/3 twill.

paper and industrial applications such as fiberglass mat. Seven harness two layers offer a smooth surface and higher guiding efficiency over other double-layer weaves. This design is suitable for all grades of paper. Eight harness two layers are used on all critical finish grades.

Two layer designs offer high fiber support. The top filling diameters, coupled with the larger bottom fillings give the fabric unique properties. The result is improved formation, retention and life. Figure 2.10 shows a photomicrograph of an eight harness two layer fabric. Figure 2.11 shows warp and filling profiles of a four harness two layer fabric.

Advantages of two layer fabrics versus single layer:

(1) Greater dimensional stability and resistance to stretching
(2) Greater resistance to wear and damage
(3) Improved formation

- higher drainage capacity but at a lower rate (slower initial drainage)
- more uniform fiber distribution
- more fiber support
- more fiber retention
- less fiber deflection—less linting
- less two sidedness

Fabric stability is enhanced as a result of an increased number of MD yarns coupled with the beam-like structure developed by stacking the CD yarns. This provides for a forming surface with increased cross directional support, while at the same time maximizing the wear surface and reducing the load on the paper machine elements. This type of fabric is considerably less susceptible to deformation caused by the constantly changing tension, as it runs its course around the machine.

The unique potential of a two layer offers a long CD knuckle on both the sheet side and wear side. This offers two advantages. Larger

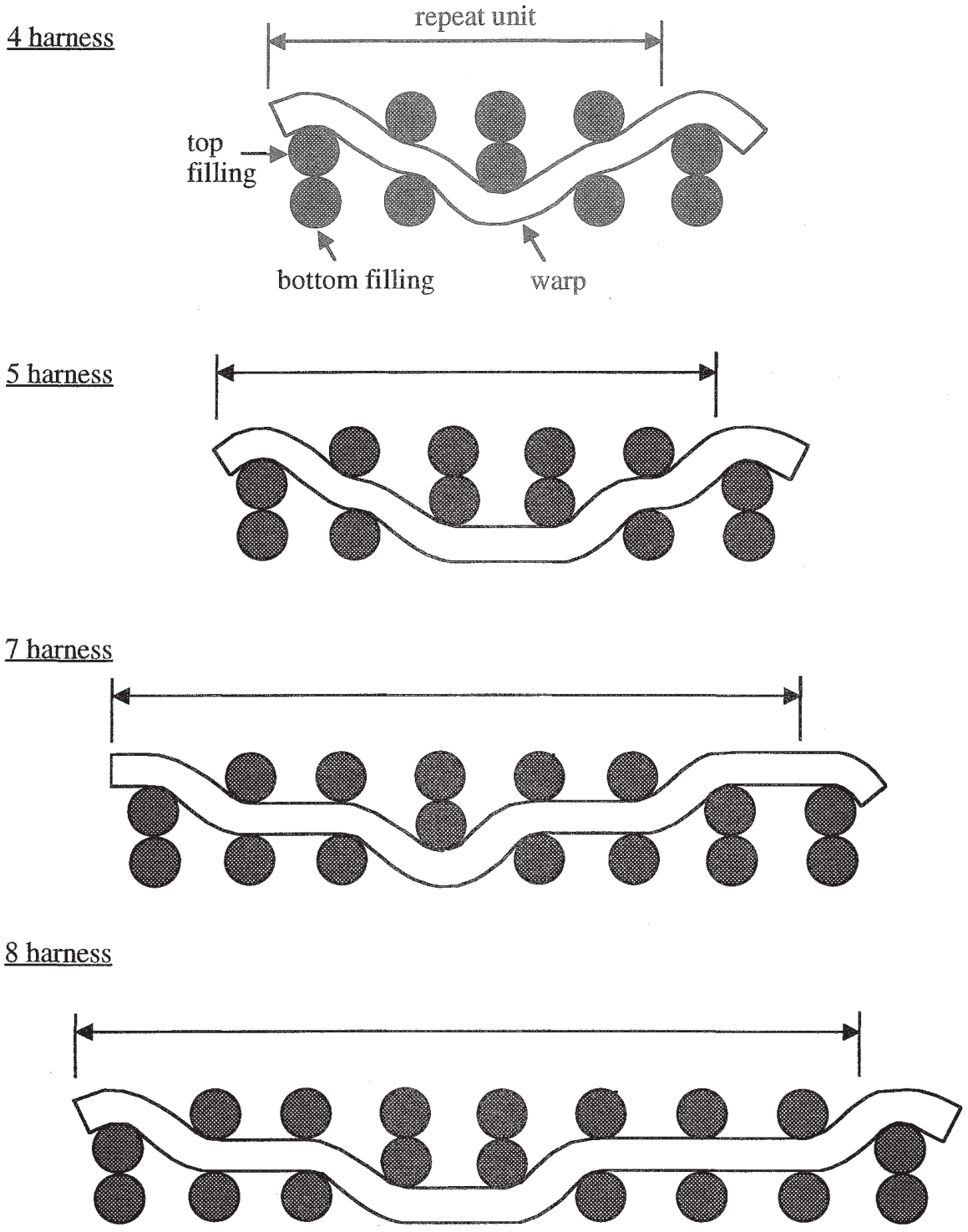


FIGURE 2.9. Standard two layer fabric warp profiles.

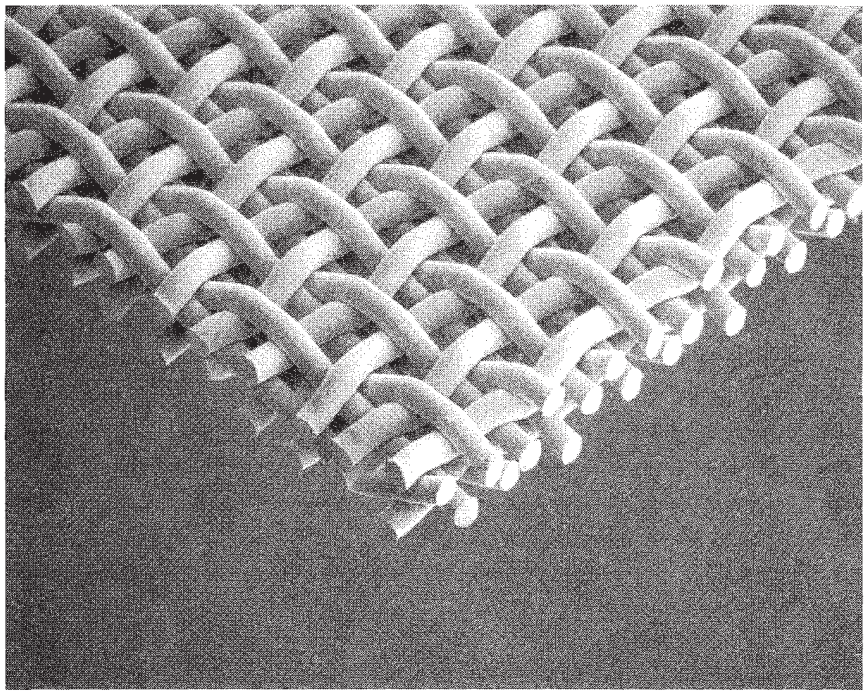


FIGURE 2.10. Photomicrograph of an eight harness two layer fabric.

yarn diameter is generally more effective in reducing wear. The long CD knuckle down shows the lowest wear rate. Two layers are generally designed with a smaller CD yarn on the sheet side for sheet quality and a larger CD yarn on the machine side for wear resistance.

The overall drainage capacity of a two layer design is greater than the comparable single layer. The two layer actually reduces the drainage rate in the initial forming zones where whitewater losses are the most dramatic. Water and solids must change direction of travel several times; reducing the velocity minimizes the amount of solids lost in the forming process. The increase in fiber support also reduces the penetration of the mat into the fabric mesh, which normally would retard drainage capacity and adversely affect fabric hygiene. Drainage capacity, which is directly proportional to the caliper of the forming fabric, is substantially increased. The stacking of the CD yarns affects the drainage capacity (void volume) of the fabric. This explains why a two layer with no projected open area is as effective as a single layer having a 20% open area or more.

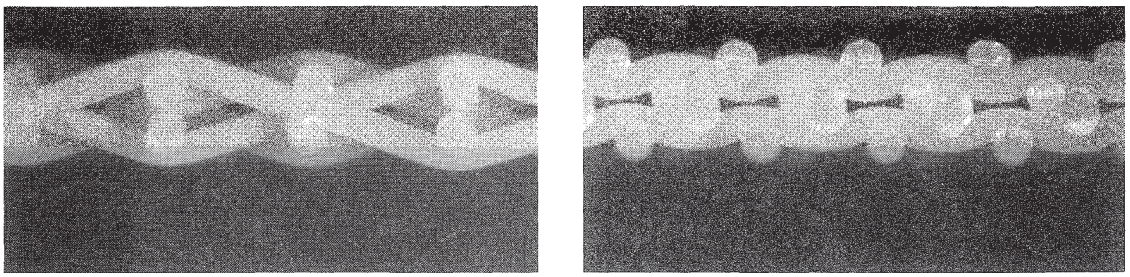


FIGURE 2.11. Warp and filling profiles of a four harness two layer fabric.

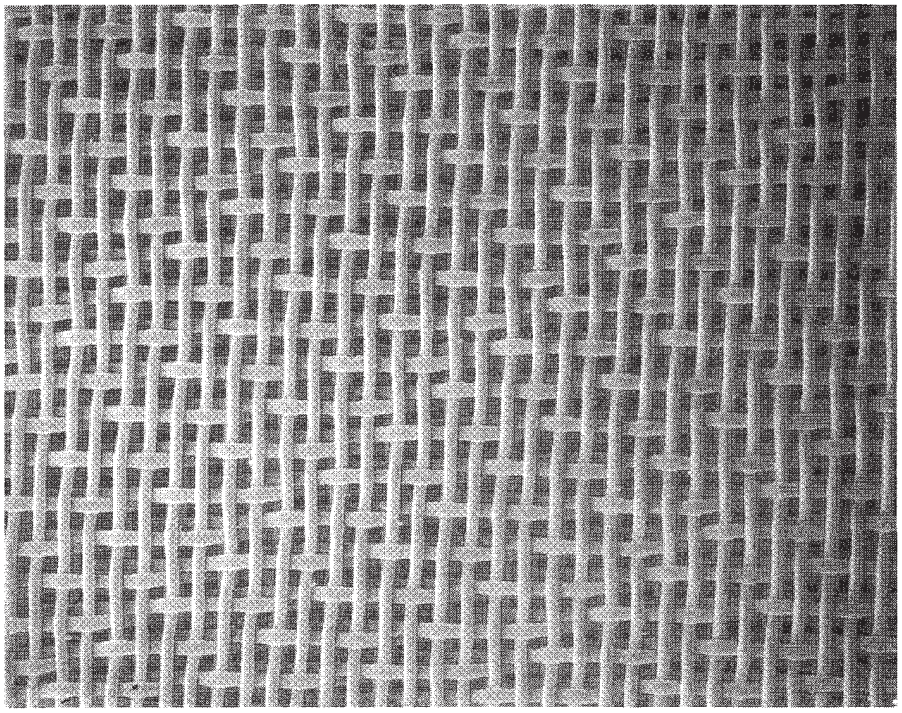


FIGURE 2.12. Top surface of a seven harness two layer fabric.

It is a well established fact that fibers tend to orient in the machine direction particularly at the bottom portion of the jet. Due to the hydrodynamic effect in the headbox, the fibers leaving the headbox are oriented in the jet direction before hitting the forming fabric. Therefore, the run attitude of the knuckles in the CD direction will dramatically improve the random distribution of fibers by turning the flow. The two layer design increases the number of CD yarns to improve this random distribution, while at the same time increasing the fiber support. Two layer fabric designs offer increased fiber support (Section 2.2.4) by substantially increasing the yarns per unit area and reducing the penetration of the fiber mat into the forming fabric surface. The fiber support of a two layer is approximately 20% greater than that of a single layer. Figure 2.12 shows the top surface of a seven harness two layer fabric. The two layer design offers greater weave variation than a single layer and hence better chances to enhance overall sheet appearance through desired sheet side surface characteristics.

An essential consideration in dealing with fiber support is knuckle area and height. The shape, number and location of knuckles have a dramatic effect on the fabric operating characteristics and machine performance. The two layer design allows optimization of fiber support in the forming zone. Running the long CD knuckle on the sheet side enhances formation and reduces fiber penetration. Two layer fabrics can be surfaced on the sheet side to increase the fiber support surface area (Section 2.2.3). The enhanced sheet release is an advantage of the two layer structure.

Wire marking is the result of optical and physical characteristics of the sheet caused by point to point density and surface differences of the fabric topography. Two layer designs minimize this point to point density difference by reducing the MD knuckle height above the plane of the fabric, utilizing small diameter MD yarns. This transfers a substantial amount of crimp from the MD yarns to the CD yarns, which reduces wire marking. Figure 2.13 shows crimp levels of yarns in a two layer fabric. Surfacing two layer fabrics enhances the monoplane characteristics of the fabric, thus further reducing wire mark.

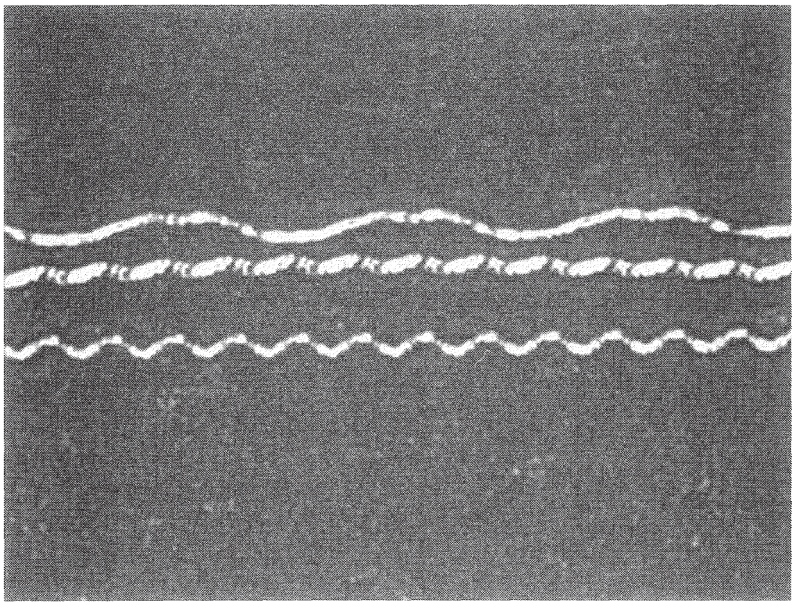


FIGURE 2.13. Crimp levels in a two layer fabric (top: warp, middle: top filling, bottom: bottom filling).

Explanation of X-Diagrams

X-diagrams are graphic representations of weave patterns. Figure 2.14 shows the X-diagram of a typical seven harness two layer design. Boxes in the vertical direction represent warp or machine direction (MD), boxes in the horizontal direction represent filling or cross machine direction (CD).

The X's show where outer warp knuckles are located on both the top and bottom sides of the fabric and the positions of the top and bottom warp knuckles in relation to one another, when observing the fabric from the top layer through to the bottom layer.

The blank boxes show where the filling is exposed in both layers. The following is shown in the top diagrams:

- The fabric is a seven harness repeat.
- In the machine direction, a warp knuckle is formed at a first pair of filling yarns in the top layer and at a fourth pair of filling yarns in the bottom layer for each warp yarn as shown by the warp profile.
- Warp knuckles are formed in a 1, 3, 5, 7, 2, 4, 6 filling sequence. This is a broken weave in a two step offset with the prominent diagonal running right.
- In the cross machine direction, the filling is exposed over six of the seven warp yarns in both layers, that is, over six, under one as shown by the filling profile.

For filling yarns of equal size, stacking is obtained by exact positioning of the cross machine direction yarns in the top layer over those of the bottom layer as shown in Figure 2.15(a). For filling yarns of nonequal size, stacking means good vertical positioning of the cross machine direction yarn whereby the top layer yarn (smaller) is 100% over the bottom layer yarn (larger) as shown in Figure 2.15(b).

Nonstacking is the nonvertical positioning of the cross machine direction yarns in a two layer fabric design [Figure 2.15(c)].

Low Density Two Layer Fabrics

The original designs of two layer fabrics were successfully run on many newsprint and fine paper applications. Most of these applications have required special showering to clean the fabrics. For other applications, such as tissue and brown paper, this same type of fabric has not proved very successful for several reasons:

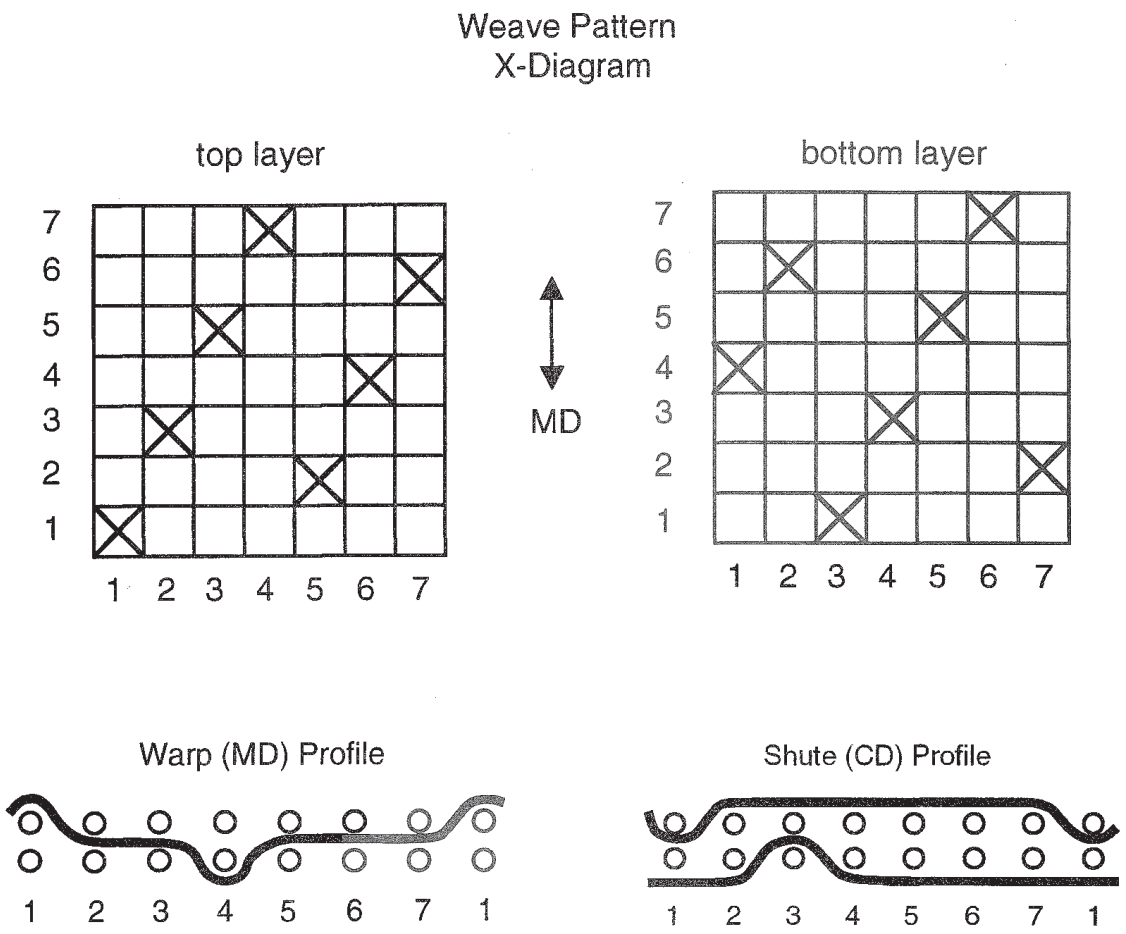


FIGURE 2.14. Analysis of a seven harness two layer fabric design.

- drainage too slow resulting in poor formation
- inability to knock off the sheet or edge trim
- inability to clean heavy soil causing fabric to plug up

To overcome these problems, two layer fabrics were developed that had characteristics more similar to single layer so far as drainage and flow characteristics are concerned. These fabrics were called low density double layer (LDDL) fabrics. The advantages of low density two layer fabrics were:

- faster drainage
- easier to clean
- easier to knock off the sheet

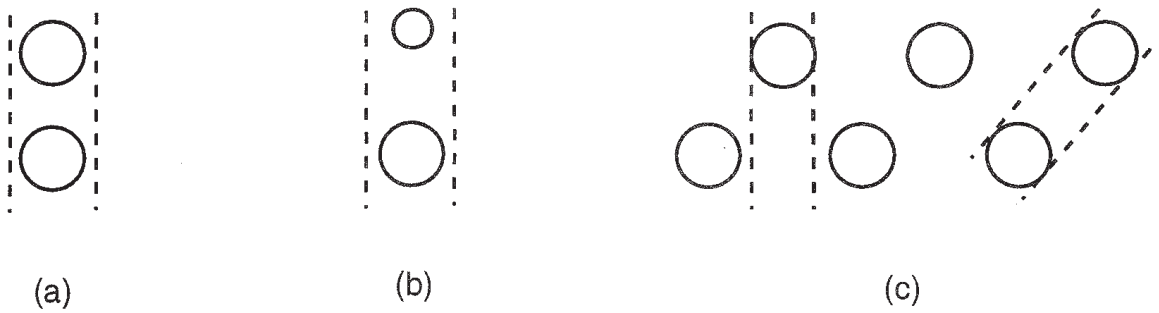


FIGURE 2.15. Stacking versus nonstacking.

- special showering not required in most cases
- improved wear over single layer
- dimensional stability
- damage resistance

The drainage index of a low density two layer design is approximately 5% greater than comparable single layer designs. Unlike traditional double layer designs, the low density two layer structure has projected open area so that sheet knock-off and fabric cleaning functions can be performed with the showering of a standard single layer.

On average, the fiber support of the low density two layer is 25% greater than that of normal single layers. This design gives substantial life increase compared to single layer fabrics, due to the uniqueness of the high plane difference between the CD and MD yarns. This difference results in the wear being transferred to the CD yarn. Thus, low density two layer design protects the load bearing yarn (MD yarn) to resist wear and increase fabric life.

b) Two Layer Extra Design

This is a two layer design consisting of two cross machine direction (filling) yarns on the sheet side for every cross machine direction yarn on the wear side (Figure 2.16). The two top filling yarns are designed to increase the fiber support index of the fabric (Figure 2.17). The bottom filling yarn is of an increased diameter to ensure long life.

There are several operating advantages of two layer extra design over conventional single and double-layer designs. Improvement in sheet formation is the main advantage. The high filling yarn count ensures fabric stability. This reduced tendency towards ridging improves life. The unique relationship of the filling yarns in the vertical plane ensures ease of cleaning. Figure 2.18 shows the warp and filling profiles of a typical two layer extra fabric.

The high fiber support, coupled with the reduction in crossover points improves sheet smoothness and reduces wire mark. These two physical properties are major considerations for the papermaker. Two layer extra forming fabrics incorporate additional CD yarns into the fiber support area or sheet side of the fabric. Each of these yarns alternates with a pair of stacked cross-direction yarns in the fabric construction. This construction results in increased fiber support and helps to eliminate fiber deflection without sacrificing drainage capability. Typically, standard two layer fabrics for fine paper and newsprint have 50–65 yarns per inch on the sheet side whereas two layer extra weave would have around 90.

Drainage characteristics are similar to two layer designs. The two layer extra drains the same as a standard two layer of the same permeability initially, but more efficiently later on due to the higher drainage index. Water and solids must change direction of downward flow several times; thereby reducing the velocity, under conditions of high hydraulic pressure. This reduces the amount of solids lost in the forming process. The two layer extra has double the drainage index of a standard two layer.

The two layer extra fabric gives improved sheet appearance and quality. Field results have shown that most cases of linting problems previously experienced with single layer and regular double layer designs are significantly reduced with two layer extra type designs. Formation problems caused by weak dimensional stability in single layers are eliminated with the two layer extra as a result of the enhanced number of MD and CD yarns per unit area. Two sidedness of the paper is also reduced to a minimum with the two layer extra fabric.

In a recent development of two layer extra designs, all top side yarns are the same size and woven into the fabric structure to maximize sheet quality and process stability. This design is especially suitable when maximum water is removed at low consistency. This design offers very high retention, formation and sheet runnability. In some two layer extra designs, finer double warp yarns are used against machine elements instead of a single large warp yarn.

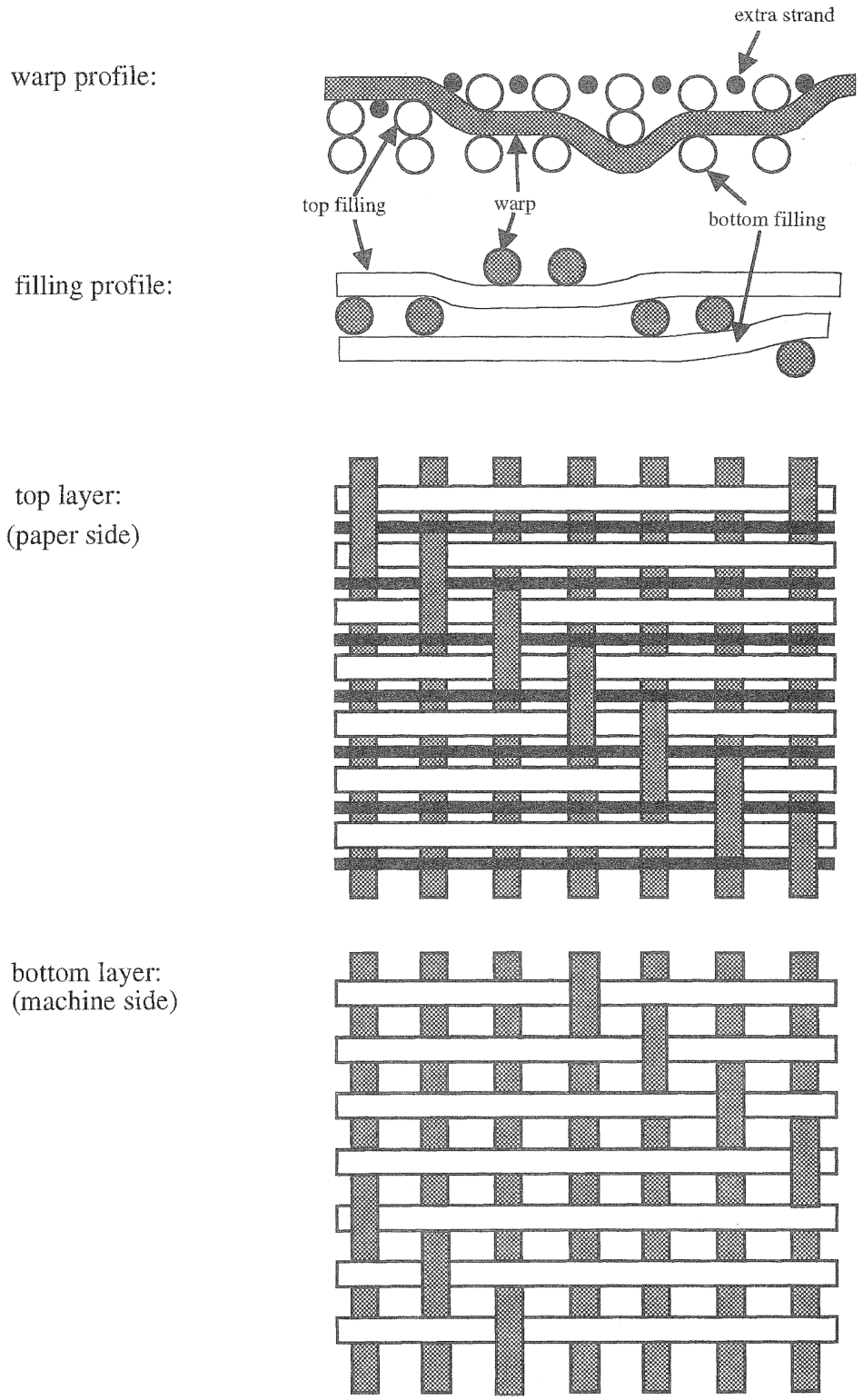


FIGURE 2.16. Schematic of a seven harness two layer extra fabric design.

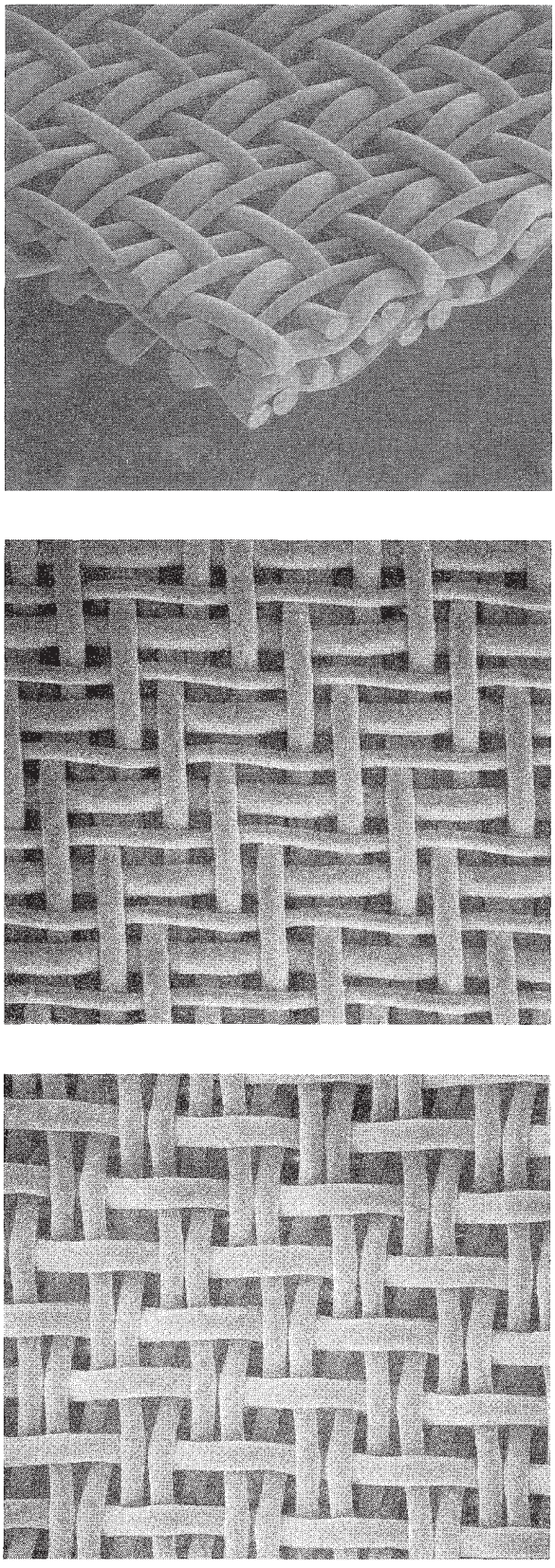


FIGURE 2.17. Photomicrographs of a typical two layer extra design; middle: top view, bottom: bottom view (magnification: 18×)

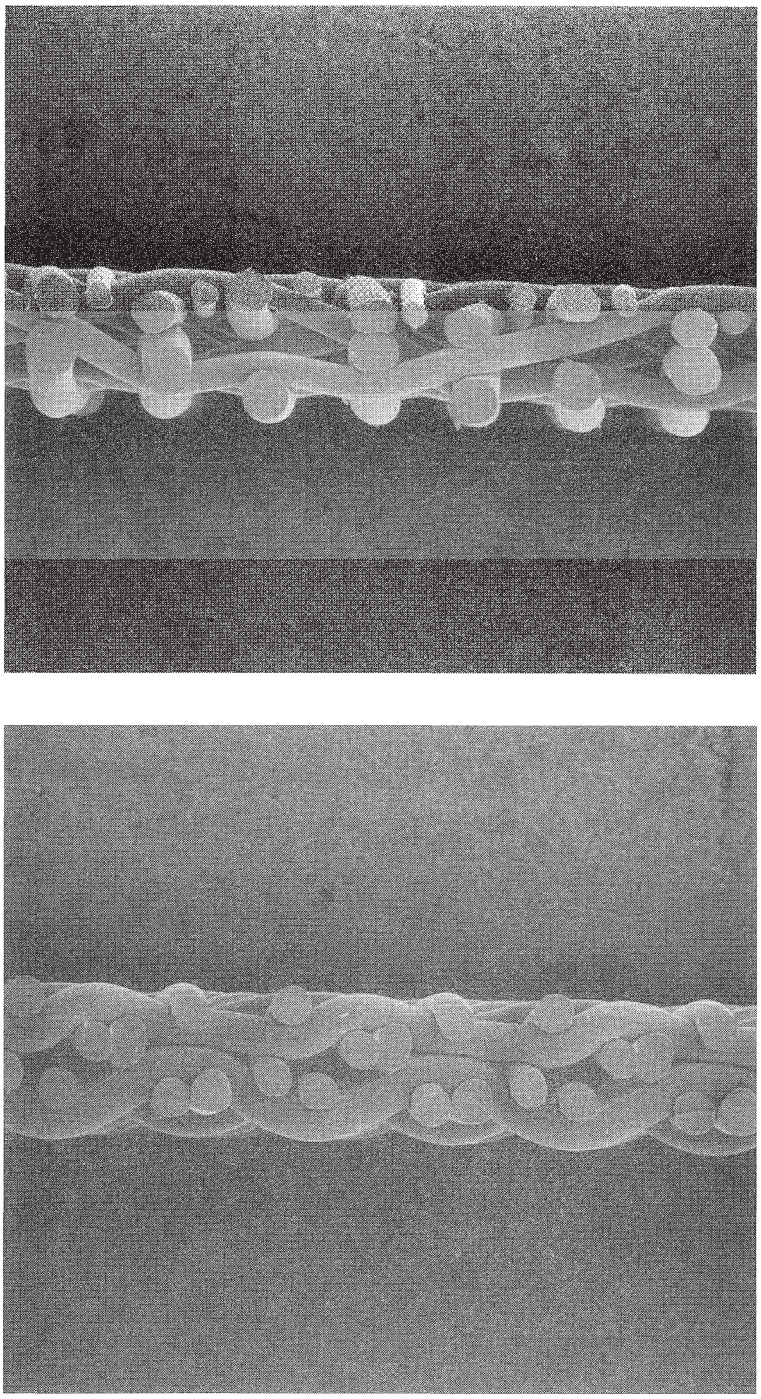


FIGURE 2.18. Warp (top) and filling profiles of a typical two layer extra fabric.

Three Layer Designs

Three layer fabrics have two separate fabrics—top and bottom—connected with a binder yarn (stitch) as shown in Figure 2.19. The fine top side of the fabric improves formation and fines retention. It also reduces wire mark, which is a major consideration in fine papers. The coarse bottom layer is specifically engineered to ensure long fabric life (Figure 2.20). The large filling and warp yarns allow decreased running loads.

The stitch yarn can be an additional yarn or part of the top or bottom layer fabrics. The additional stitch yarn is generally placed in a location where it is protected from wear by the large bottom yarns. Wear of stitch yarn can cause delamination of the two layers and failure of the forming fabric. Figure 2.21 shows X-diagram and warp and filling profiles of a typical three layer design.

Advantages of three layer designs:

- improved sheet support: a fine sheet side provides over 5000 fiber support points per square inch. On average, the fiber support of a three layer is 25% greater than that of standard double layers.
- improved formation and stability
- reduced two-sidedness
- increased flexibility in design by allowing each layer to be optimized independently
- longer life due to larger diameter wear yarn

The three layer fabric has improved sheet appearance and quality. Field results have shown that many cases of two sidedness previously experienced with double-layer designs are significantly improved with three layer designs. Formation problems caused by weak dimensional stability and the MD frame length with double layers can be eliminated with the three layer. This reduction in MD frame length (MD length is defined as the spacing between adjacent rows of CD directional yarns) has led to higher retentions due to less surface area open to embedment of the fiber from the stock jet. The three layer has a noticeable shorter MD hole, thus providing significant improvement in both fine and fiber retention.

The uniqueness of the three layer offers the opportunity to design each layer independently. The three layer fabric is designed with a fine mesh top layer to provide the ultimate sheet support. This equates to improved formation, increased fines retention and reduced two sidedness. The increase in fiber support means that the sheet releases easier, thus reducing machine draws. The rugged bottom fabric provides a durable base for increased fabric life and dimensional stability. Three layer fabrics are used for all grades of paper.

The unique potential of the three layer offers a long CD knuckle on both the sheet side and wear side. Three layer fabrics are generally designed with smaller CD yarn on the sheet side for papermaking and a larger CD yarn on the machine side for wear resistance. This offers two advantages: (a) larger yarn diameter is generally more effective in increasing life, and (b) The long CD knuckle down shows the lowest wear rate.

Finally, it should be noted that although three layer designs offer these potential advantages, in actual practice many are outperformed by two layer extra designs in retention, smoothness, wear and ring crush on brown grades. Therefore, the two layer extra design is a major competitor of three layer designs, which, in many cases, is replacing three layer applications. Cost is another factor that is on the side of the two layer extra fabrics.

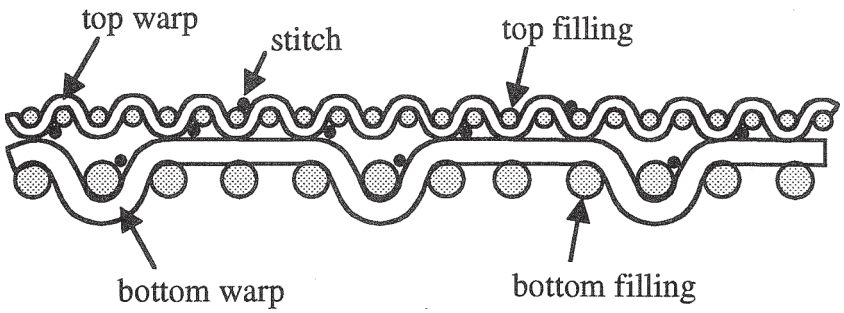
Other Designs

Other forming fabric designs are also possible. In one design variation, there are three layers of weft yarn and one layer of warp yarn as shown in Figure 2.22(a). An extra fine yarn may also be used on the top layer as shown in Figure 2.22(b).

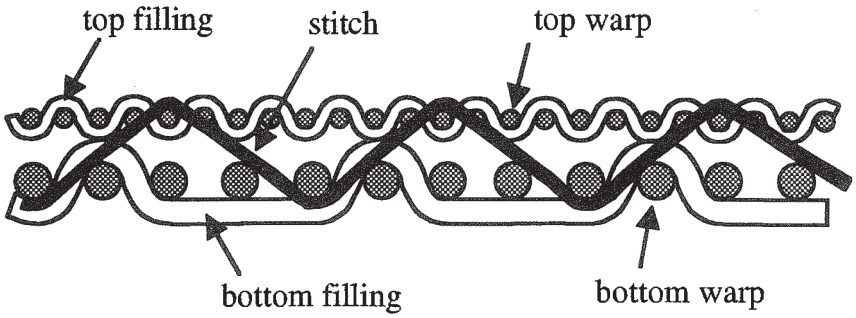
2.2.2 *Forming Fabric Design Variables*

The yarns used in warp and filling directions in forming fabrics have different properties. The rule of thumb in a forming fabric is

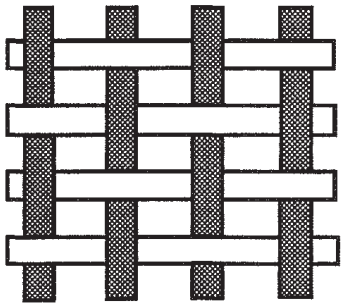
warp profile:



filling profile:



top layer:
(paper side)



bottom layer:
(machine side)

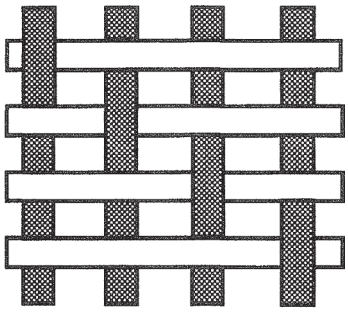
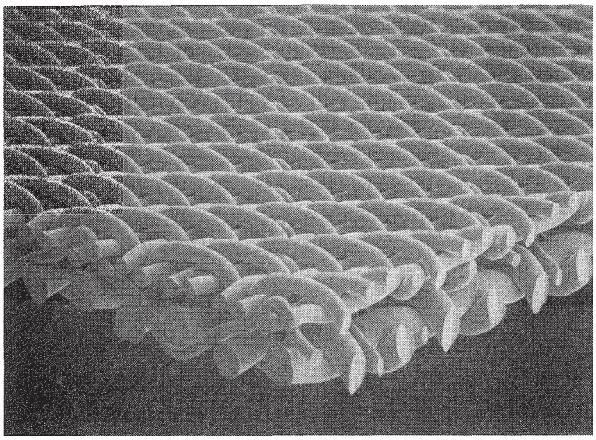
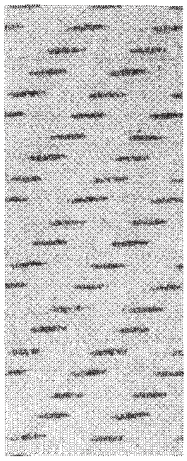
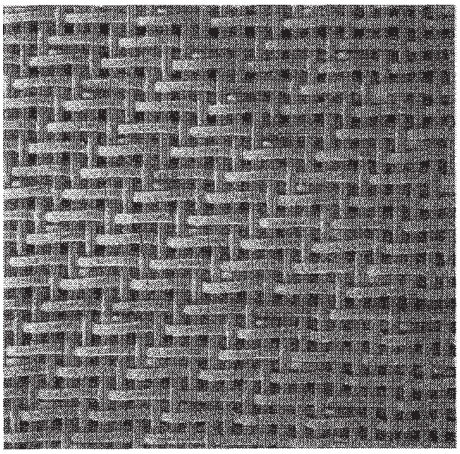


FIGURE 2.19. Schematic of three layer fabric design.

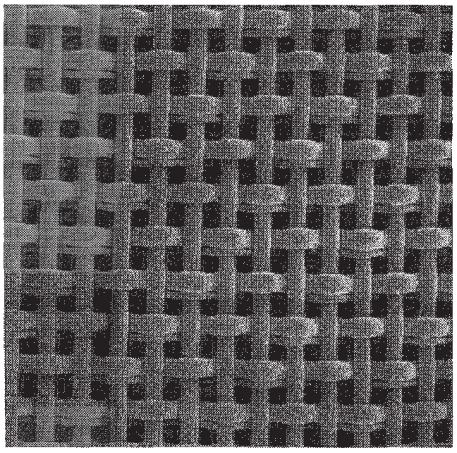




top surface impression



four harness top layer



plain bottom layer

FIGURE 2.20. Photomicrograph of a three layer fabric.

that CD yarn is for wear and MD yarn is for load bearing on the paper machine. Therefore, higher modulus yarns are used in MD direction to reduce stretching on the paper machine.

The fiber support and drainage characteristics of most fabric designs can be varied by changing yarn diameter, mesh count, weave and yarn predominance.

By proper selection of yarn diameter and mesh, it is possible to obtain a variety of hole sizes and open areas to meet the required machine conditions. If, for example, it has been determined that the hole size of a fabric is adequate, but a different percent open area is needed, a change in MD yarn diameter and mesh will change the percent open area [7]. Figure 2.23(a) illustrates this situation.

Similarly, if the percent open area is satisfactory but more sheet support is required, a similar change can be made to give a greater number of smaller holes with the same percent open area. In Figure 2.23(b), an additional MD yarn is brought into the picture. By proper selection of the additional number of MD yarns, the percent open area could be held constant.

As the fabrics get finer with increasing mesh count and smaller yarns, the bridging

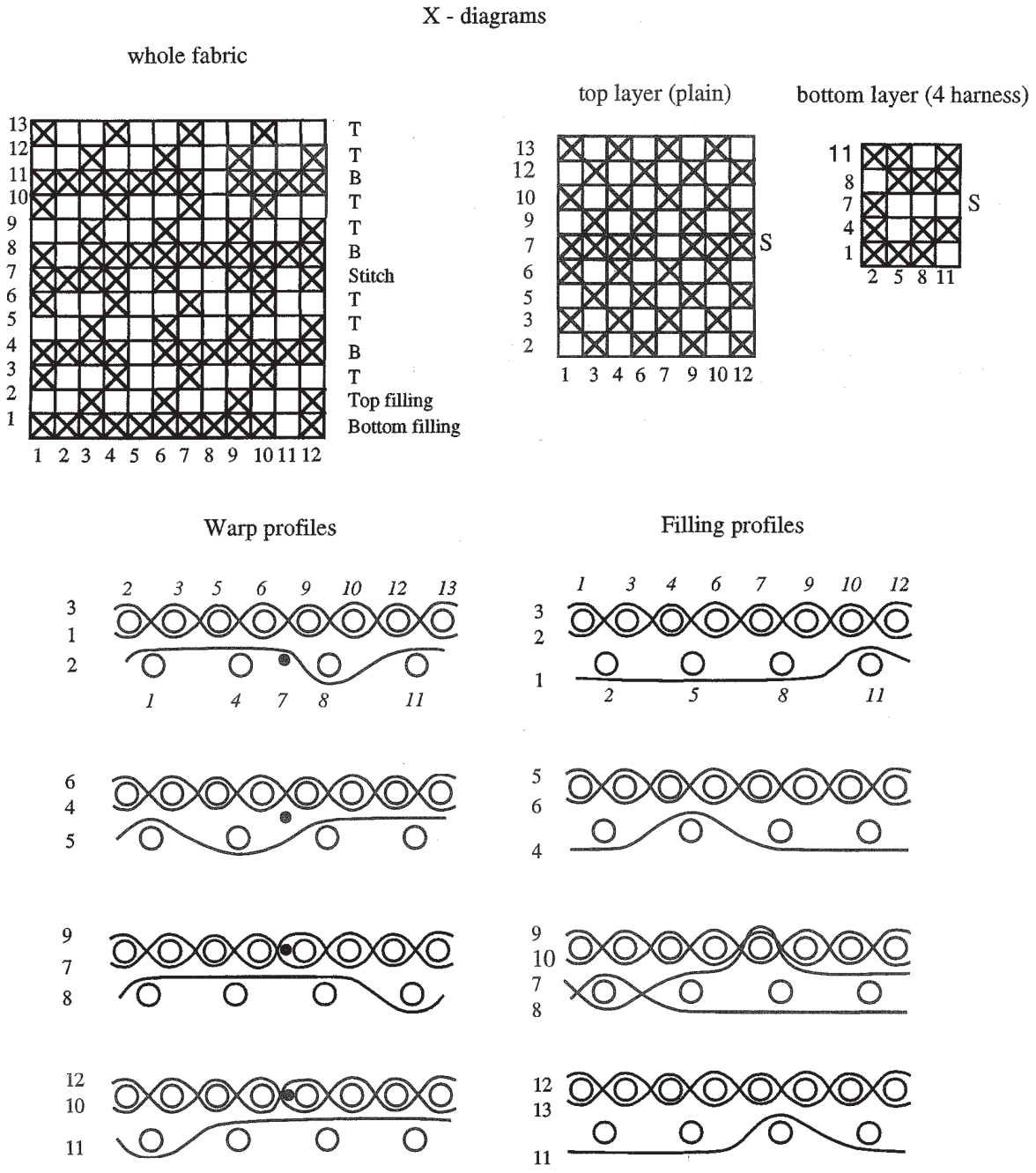
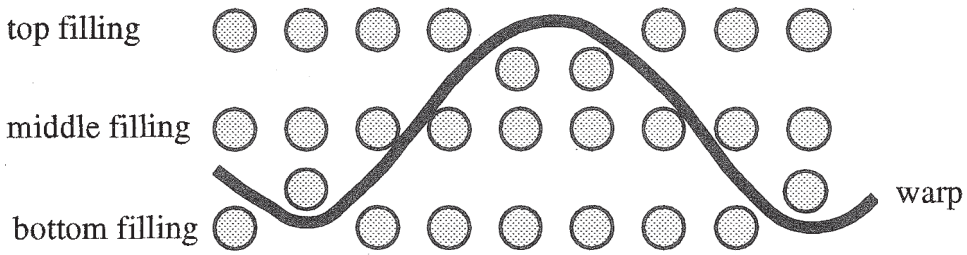


FIGURE 2.21. X-diagram and warp and filling profiles of a typical three layer design.

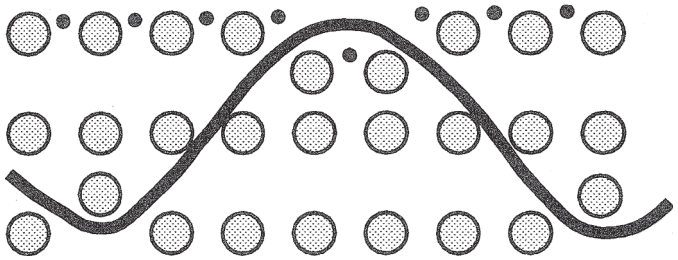
location moves higher in the structure of the fabric (Figure 2.63 in Section 2.3). Depth of penetration of the knuckle becomes more favorable, and at the same time the location of the bottom of the fiber-filler-fines plug moves upward.

The crowding of the MD yarns by the CD yarns increases with increasing MD yarn count. Because of finishing and operating tensions at the points of crossover contact, the MD yarn tends to ride up the side of the CD yarn knuckle. This results in a lower height of the knuckle.

The closely spaced MD yarns in the span between CD yarns and the climbing effect of the MD yarn at the knuckle combine to give



(a)



(b)

FIGURE 2.22. Triple shute weave.

a fabric with a sheet side surface that is smooth compared with the surface of a fabric with a lower MD yarn count. This smoother sheet-side surface will improve the surface smoothness and density uniformity of the final sheet.

Fabric warp profiles are used to determine whether a multilayer design is symmetric or nonsymmetric. Consideration must be given to a full warp cycle. Two layer symmetry or non-symmetry is determined by the warp path between the filling layers as referenced from the short warp knuckle. Symmetric designs have equal division or arrangement on either side of a common reference plane or division line as shown in Figure 2.24. There is a balance of opposite corresponding parts in size, shape or position.

Nonsymmetric designs have unequal division or arrangement on either side of a common reference plane or division line as shown in Figure 2.25. Opposite corresponding parts are disproportionate in size, shape or position.

2.2.3 *Manufacture of Forming Fabrics*

The design and manufacture of a forming fabric for a paper machine is a complex task. In general, forming fabrics are paper machine specific, i.e., quite often a forming fabric is custom designed for a particular position on a particular paper machine. Papermakers demand a long-lasting forming fabric which will enable them to produce high quality paper products. Forming fabrics are manufactured to meet various demanding requirements which include stability, wear resistance, proper drainage capacity, uniform fiber distribution, no wire marking and proper retention. Figure 2.26 shows the flow chart for manufacturing of forming fabrics.

Forming Fabric Materials

Until the 1950s, fabrics used for forming were made of phosphor bronze or stainless

preliminary heatsetting. Although the woven pick count is changed by heatsetting because the fabric is stretched, the pick count difference remains constant. Moreover, if the fabric pick count is not constant, it will make seaming more difficult.

Yield

The second attribute that can be controlled during weaving is yield. Yield is defined as the ratio of warp yarn length to the woven fabric length. Yield affects the fabric modulus. The modulus is a measure of fabric strength and stability, in that it measures how much a fabric will stretch when a given tension is applied to it.

Older paper machines were designed to run metal wires, which had a modulus of approximately six times more than the current polyester fabrics. Thus, they were built with very small adjustments for tensioning the wires or fabrics, sometimes as little take-up as a few inches on machines designed to run fabrics one hundred feet long. Today, if the fabrics are made too short, the mill cannot even get the fabric on the machine; if they are too long, the mill cannot put enough tension on the fabric to take out all the slack and provide drive friction.

The yield, along with fabric design, material type, weave, caliper, warp size, and preliminary heatset tension, determines how much a fabric will stretch in the heatsetting operation. This will affect the fabric modulus and the fabric final sizing to achieve the proper length. This in turn determines fabric stability.

As with pick count, the uniformity of the yield is also important because of the interaction between the fabric properties. Changes in yield can cause differences in fabric thickness, air permeability, stacking in two layers, pick count, fabric width and appearance, as well as in fabric modulus. Yield change during weaving causes stacking to change.

Yield can be measured with a simple method. Make a mark on the warp yarns and on the fabric at the same time. After, say, 10 cm of warp has come off the warp beam then make a mark again on the fabric and the warp. Measure the amount of fabric which was made in 10 cm of warp and divide this by 10 which gives the percent yield in the fabric.

Fabric Consistency

The importance of fabric consistency in the areas of pick count and yield control is mentioned earlier. Papermaker fabrics, as shipped, are effectively an endless belt. Modern paper machines run at speeds around 2000 meters per minute (6562 feet per minute). If a fabric is 30 meters long, that means that a little defect comes around on the paper machine 66 times every minute! It can mean hundreds of blemishes in every roll of paper.

Defects have a tendency to project above the plane of the cloth, even after they are repaired. They, therefore, have less resistance to wear on the machine and can quickly turn into holes. The wood fibers can no longer be evenly distributed, the spacing may not be the same as the rest of the fabric and fiber support differs in this area. As a result, the repaired area will tend to leave a wire mark on the paper sheet.

Preliminary Heatsetting

After weaving, fabrics are subjected to heatsetting at high temperatures. The purposes of heatsetting are to relieve the internal stresses in the flat woven fabric, to increase fabric modulus and to improve dimensional stability of the fabric. For heatsetting flat woven fabrics, the fabric ends are temporarily seamed and the fabric is rotated around rolls on heatsetting machines (heatsetting "tables") as shown in Figure 2.45.

Typical loads during preliminary heatsetting are 0.4–0.8 gram/denier. During heatsetting, the forming fabric is stretched in the MD direction and also tentered along the CD direction as shown in Figure 2.46.

As the fabric is woven, the filling has very little crimp compared to the warp. During heatsetting, warp crimp decreases and filling

Air Permeability

It is a measure of air flow through a forming fabric at the standard pressure drop. The standard conditions are cfm/sq ft at 0.5 inch water column pressure.

Air permeability is of considerable value in predicting drainage characteristics of a fabric. It is, however, an air flow measurement, whereas the papermaker is interested in water flow. Within a given weave pattern and mesh range, air permeability, as a drainage indicator, may not correlate with actual machine data as sheet support characteristics also influence water handling capability. Nevertheless, air permeability is one of the most important properties of forming fabrics.

Air permeability is also a good indicator of fabric to fabric uniformity as long as weave and yarn diameters are constant.

Void Volume

Void volume, by definition, is the amount of space in a volume of fabric that is not occupied by solid material (Figure 2.61). Most single-layer and two layer fabrics have void volumes ranging from 60–70%. Both fabric thickness and internal structure affect absolute void volume.

Some studies have shown that having a high level of interconnected internal void volume could enhance dewatering over vacuum augmented boxes. On the other hand, a fabric with too high a void volume can lead to a wetter than normal sheet off the couch, due to the fabric having a high volume of air carried in the fabric.

Within a forming fabric, the void volume is not evenly distributed; some areas are more closed and it is the most closed area that best describes the water handling capabilities of a particular fabric. This area, called the "Minimum Average Hole Area (MAHA)" or "bottleneck," can be found by physically sectioning the fabric and measuring percent open area at the different planes through it.

The passage of water through a fabric is limited by the least permeable plane of a bottleneck within the fabric structure, but not by the projected open area. This bottleneck changes in shape and location when the material used to make the fabric is changed. It can also be altered by using different weave patterns. Void volume can be calculated as follows:

$$\text{Total volume} = \text{length} \times \text{width} \times \text{caliper}$$

$$\text{Calculated void} = \text{total volume} - (\text{weight of sample/density of material})$$

$$\%\ \text{void volume} = (\text{calculated void/total volume}) \times 100 \quad (2.6)$$

Fiber Support Index (FSI)

The concept of fiber support index was developed by Beran [13]. His work, based on a statistical model, predicts the fiber support characteristics of forming fabrics based on

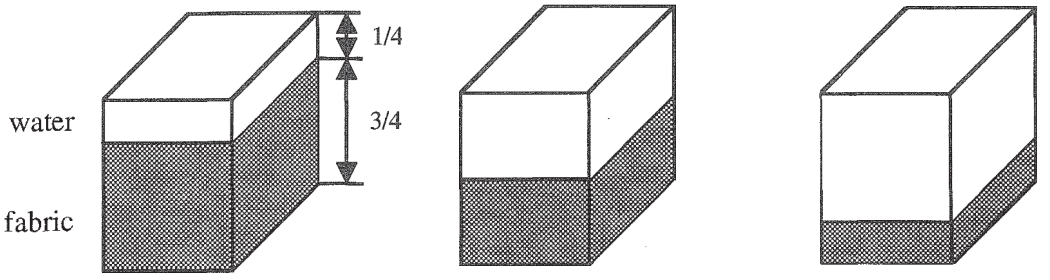


FIGURE 2.61. Void volume.

3

Pressing

The press section is the next part of the paper machine after the forming section. The function of pressing is to continue the water removal process which started in the forming section, consolidate the sheet, give texture to the sheet surface, support and transfer the sheet. The fabrics in this section are called press fabrics or press felts. The term "fabric" has a broader meaning; "felt" is a type of fabric which is made of individual fibers only, i.e., no yarn in the fabric structure. Nevertheless, the terms "press fabric" and "press felt" are used as identical terms in the papermaking industry. Although it depends on sheet grade and paper machine, typical sheet consistency at the beginning of the press section is 20% fiber and 80% water and at the end of the press section is 40% fiber and 60% water. At the end of the press section, the sheet is transferred to the dryer section.

During pressing, the sheet is compressed between one or two fabrics and two rolls in the press nip to squeeze water from inside the web and out of the felt fibers. Figure 3.1 shows this process in a plain press nip. Increased compression increases water removal [1–3].

The main functions of a press fabric are water removal from the sheet, sheet support and transportation, providing uniform pressure distribution, and imparting proper surface finish to the sheet. The fabric should provide proper protection for the sheet to resist crushing, shadow marking and groove marking. Other functions include transferring the sheet from one position to another in case of closed draws, driving the undriven felt rolls and cylinder formers. The amount of water that the felt can absorb and the water flow resistance are affected by the void volume (volume that is not occupied by fibers or yarns) and air and water permeability of the fabric. Low flow resistance and ability to maintain void volume under load are important during operation. Important press fabric properties include strength, adequate void volume, required permeability, low compressibility, batt/base ratio, compaction resistance, abrasion resistance, contaminant resistance, heat and chemical resistance.

3.1 Water Removal Theory

The basis weight of the sheet and its drainage characteristics are critical factors in determining the mechanism for water removal. There are basically two types of nips that define the water removal process.

3.1.1 *Flow-Controlled Nips*

In these nips, water removal is primarily influenced by water flow resistance in the sheet. In flow-controlled nips, the resistance to fluid flow within the mat of fibers controls the rate at which water can be pressed. These

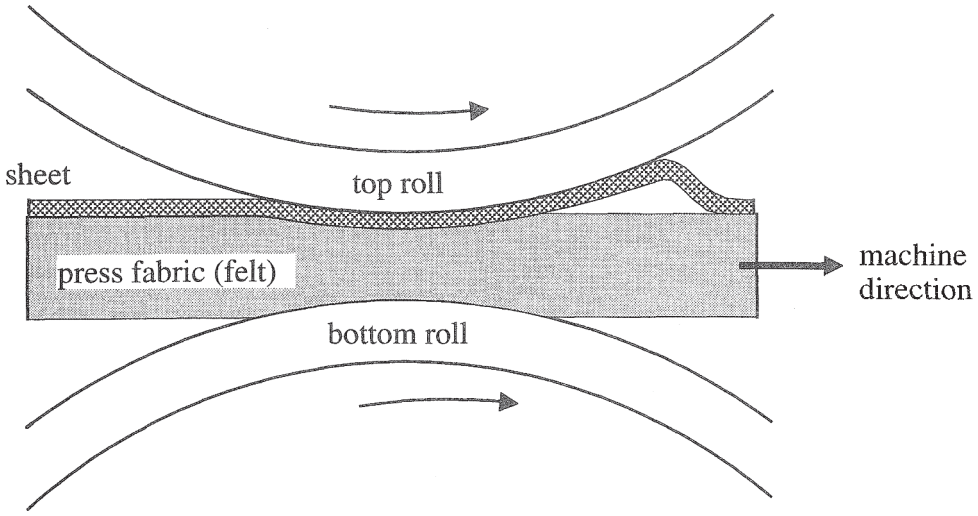


FIGURE 3.1. Schematic of simple press nip.

nips are characterized by high water loads, heavyweight sheets, slow draining and low freeness stocks.

Major symptoms of problems in flow-controlled nips are crushing and hydraulic flow mark. Water removal is aided by:

- soft roll covers
- large diameter press rolls
- double felting
- high sheet temperatures

Design Considerations

(1) Low flow resistance: In flow-controlled nips, it is very important that flow resistance be minimized. Typically, coarser batt deniers and higher permeability fabrics are used to facilitate water removal without crush or hydraulic mark.

(2) High void volume: Because of the higher water loads, high void volume structures are usually required. Generally multilayer or laminated fabrics are used to handle the water flow in the nip.

(3) Flow-controlled nips, where the sheet structure restricts water flow, may occur with lightweight, low freeness sheets, such as carbonizing, condenser and glassine: In this case, coarser batt denier would not be applicable, and void volume requirements would be less.

3.1.2 *Pressure-Controlled Nips*

In pressure-controlled nips, the mechanical resistance to compression within the sheet controls the rate of water removal. These nips are characterized by low water loads, lightweight sheets, fast draining and high freeness stocks.

Major symptoms of problems in pressure-controlled nips are vibration, poor consistency and physical impression mark. Water removal is aided by:

- hard roll covers
- small diameter press rolls
- pressing uniformity
- high sheet temperatures

Design Considerations

(1) Base pressure uniformity: Higher sheet contact during pressing is very important. High contact base designs are preferred.

(2) Mass uniformity: Because of the higher nip intensity and peak nip pressures, press bounce and vibration are potential problems.

(3) Batt stratification: Finer deniers are used to improve the pressure uniformity of the fabric. These are usually needled over coarser fibers for permeability control and resistance to filling.

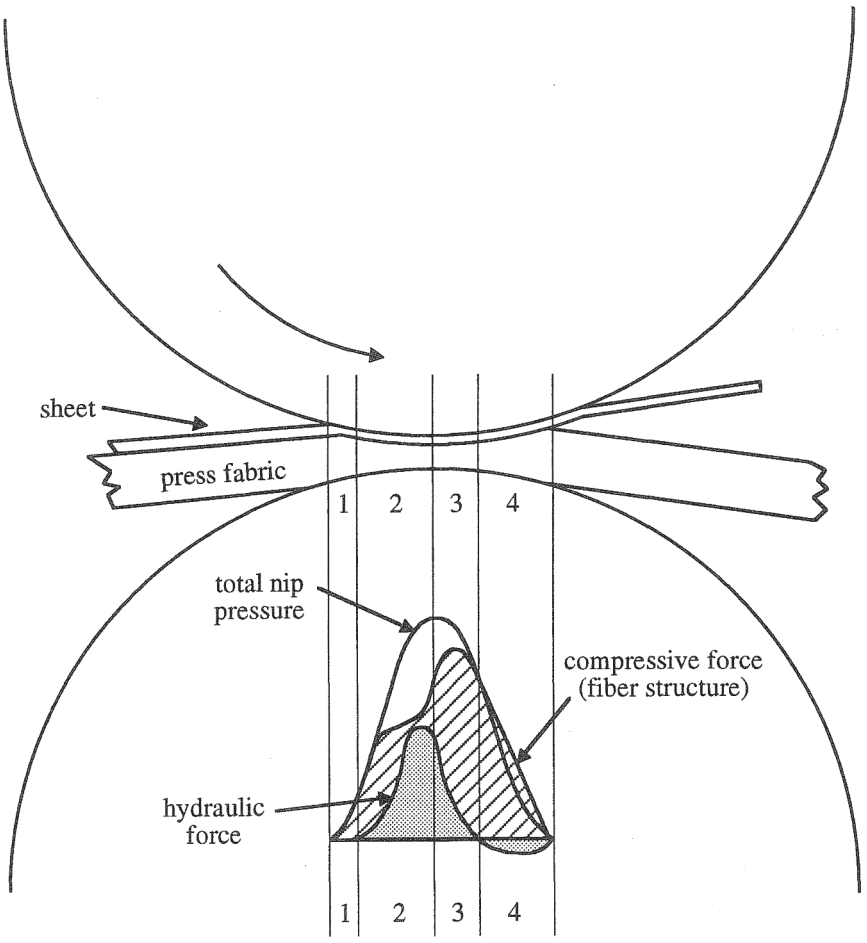


FIGURE 3.2. Transversal flow nip.

An understanding of the fundamentals of transversal flow pressing is necessary to optimize press and press fabric design. Figure 3.2 shows a typical transversal flow press nip in which press operation has been broken down into different phases based on mechanisms involved in water transfer. The nip is defined by two solid rolls with paper and fabric passing through the nip. Both the press fabric and paper are unsaturated entering the nip.

Phase 1 starts at the entrance of the nip where pressure develops in the sheet structure and continues until the sheet is saturated. There is no hydraulic pressure generated in this phase.

Phase 2 begins when the sheet becomes saturated and hydraulic pressure develops. Water is pressed from the sheet into the press fabric. If the press fabric becomes saturated, hydraulic pressure causes flow of water into the voids of the roll (grooves, holes, etc.). This phase extends to the mid-nip or the point of maximum pressure.

Phase 3 extends from the point of maximum total pressure to the point of maximum dryness. Maximum dryness occurs at maximum structure pressure and where the hydraulic pressure in the paper reaches zero.

Phase 4 begins where the paper and press fabric start to expand resulting in negative hydraulic pressure. Both the fabric and paper became unsaturated and rewetting occurs due to capillary forces and pressure differences between the press fabric and paper. During the expansion phase, the sheet and fabric compete for the boundary water.

The press fabric is a necessary component of this water removal mechanism. The press

fabric provides a porous structure to which the water can flow from the paper in the ingoing nip and it should retain this water in the expansion phase of the nip. The ideal fabric should provide perfectly uniform pressure distribution, lowest possible flow resistance, and smallest rewet in the outgoing nip.

An analysis of nip conditions using Walstrom's model [4] can help identify the terms of our compromise. The following equation represents a model for outgoing moisture ratio for a nip.

$$MR_{out} = k - f_1 - f_2 - f_3 - P - RW - R_1 - R_2 \qquad (3.1)$$

where

MR_{out} = outgoing moisture ratio
k = moisture ratio of maximum paper dryness at zero flow resistance and uniform pressure distribution determined by compression characteristics of the paper
f_1 = increase in moisture ratio due to flow resistance in the fiber wall
f_2 = increase in moisture ratio due to flow resistance in the paper structure
f_3 = increase in moisture ratio due to flow resistance in the press fabric
P = increase in moisture ratio due to nonuniform pressure application
RW = increase in moisture ratio due to rewetting, redistribution of water between paper and fabric
R_1 = increase in moisture ratio due to rewetting of the press fabric from the pressure structure
R_2 = increase in moisture ratio due to rewetting after the nip

A closer look at this model suggests how press fabric properties influence water removal.

f_3, the effect of fabric flow resistance, is dependent on speed, capillary structure, incoming moisture, moisture change, temperature, and basis weight. It is worth noting that open press fabric structures, to reduce flow resistance, are in direct conflict with the property of uniform pressure distribution.

P, the effect of uniform pressure distribution, is likely determined primarily by the press fabric. The fabric should bridge the grooves, suction holes, etc., to exert a uniform pressure to the paper.

RW, R_1 and R_2 concern rewet and are dependent on press nip conditions, paper and fabric structure and their dryness.

The relative importance of each factor and the direction of fabric design compromise are determined by the following:

- water load
- nip pressure and width
- speed or nip dwell time
- sheet properties; freeness, furnish and weight
- temperature

At low basis weights, free sheets, and low speeds, flow resistance in the paper or fabric (f_2, f_3) is relatively negligible; P and rewetting dominate. Smooth, dense fabrics are preferred. At the other extreme—high basis weights, low freeness, and high speeds—flow resistance is highly important. Double felting and/or high-void volume fabrics can be of benefit. Pressure distribution and rewetting continue to be important.

In between the two extremes, all press variables need to be considered. Also it should be noted that the relative importance of each of these variables changes with water load. First presses with high water loads tend to behave more as flow-controlled nips, even on lightweights. Last presses have lower water loads and move toward pressure-controlled conditions. Table 3.1 shows the relative importance of fabric characteristics for pressure- and flow-controlled nips.

Figure 3.3 shows the distribution of hydraulic and compressive forces at the first, second and third nip in a press section. Hydraulic force is greater in early presses; compressive forces are higher in later presses. Table 3.2 lists typical sheet consistencies for various grades.

TABLE 3.1. Relative Importance of Fabric Characteristics for Pressure- and Flow-Controlled Nips.

Fabric Characteristics	Pressure-Controlled Nip	Flow-Controlled Nip
Caliper	↓	↑
Permeability	↔	↑
Void volume	↔	↑
Pressure uniformity	↑	↗

3.2 Press Fabrics (Felts)

3.2.1 *History*

Until the 1930s papermakers' felts had improved very little over the woven or pressed woolen fabrics observed in China by Marco Polo. In this pre-World War II era chemical treatments were developed to alter the woolen molecule. This improved the ability of wool to resist chemical, mechanical and bacterial degradation. In 1946 the introduction of staple man-made fibers contributed greatly to the strength and durability of wet felts. Early attempts to full or felt 100% synthetics resulted in fabrics that were too open or porous and unstable.

Since about 1944, the asbestos cement industry had been using fabrics made by a process known as needling. This was the process of laying a carded web of textile fibers on a woven base and needle-punching the web fibers into the base with barbed needles. It was considered that higher synthetic, unfulled fabrics might be made by this method to not only achieve desirable properties of woven, fulled felts, but also to make improvements in terms of life, finish and drainage. Needled fabrics were then produced in the synthetic ranges from 35% to 49%. In the late sixties, 75% to

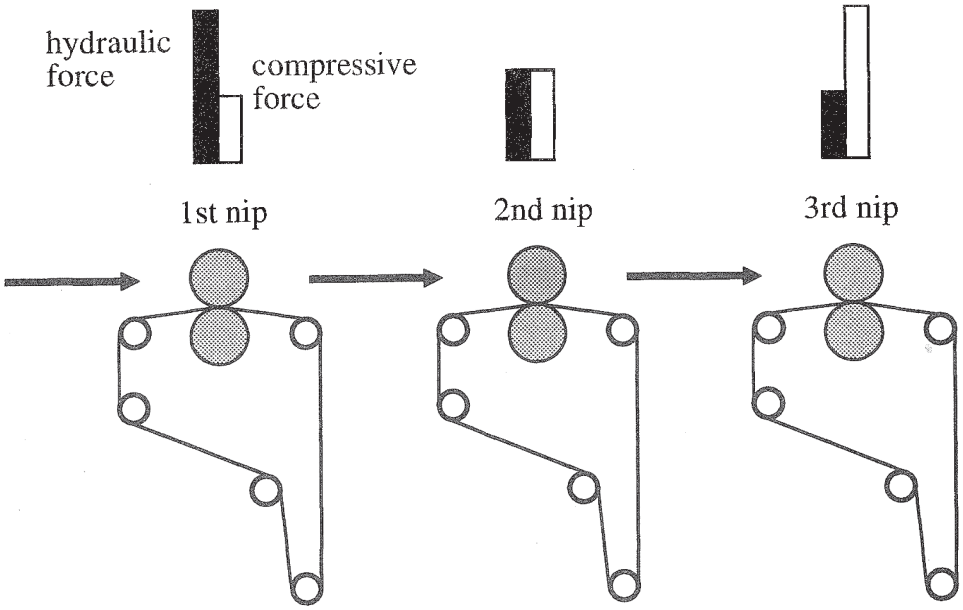


FIGURE 3.3. Distribution of hydraulic and compressive forces at different nips.

TABLE 3.2. Typical Press Dryness Number [5].

	Load		Exit Sheet Consistency, %
	kN/m	pli	
Newsprint			
First press	60	300	33
Second press	80	450	38
Third press	95	550	43
Bond			
First press	60	350	37
Second press	80	450	41
Third press	95	550	43
Corrugating medium			
First press	70	400	37
Second press	105	600	41
Third press	315	1800	46
Linerboard single felted			
First press	70	400	35
Second press	105	600	39
Third press	175	1000	42
Linerboard double felted			
First press	105	60	38
Second press	210	1200	43
Third press	350	2000	46

100% synthetic needled fabrics appeared and provided what some thought was the optimum in felt construction.

The introduction of the fabric press (inner fabric), whereby an incompressible fabric of monofilament or highly twisted multifilament synthetic is run between the felt and the press nip, resumed the evolution of the wet felt. The principle of the fabric press was built into the needled felt using a base fabric in mesh construction which provided significantly greater void volume within the total fabric structure. This improved the water handling capacity of the felt, allowing increased press loading. The fabric was easier to clean, and its tremendous strength and comparative rigidity provide remarkable improvements in felt life. The batt-on-mesh felt was, therefore, developed and felt-making took another step forward to the benefit of the papermaking industry.

3.2.2 *Press Fabric Functions*

Once the sheet has left the headbox, the general requirement of the paper machine is to increase the fiber consistency of the sheet from 0.2–1.5% to 92–96%. After the forming fabric, water removal costs far less in the press section than the dryer section. The value of efficient press fabric performance, therefore, can not be overemphasized.

Water removal, however, is not the only function of the press fabric. Its basic performance criteria includes other functions as well. In general, the press fabric must:

(1) Accept the water that is expressed from the sheet in the press nip.
(2) Provide the proper protection for the sheet to:
   - resist crush
   - resist shadow mark

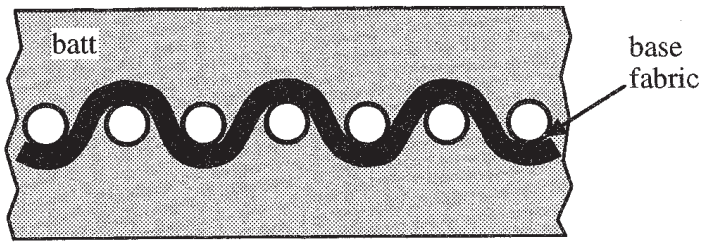


FIGURE 3.4. Schematic of a typical press fabric structure.

- resist groove mark
- resist base fabric mark

(3) Present the proper surface to the sheet so that the necessary degree of smoothness or finish requirement is imparted to the grade of paper to be manufactured.

(4) In case of closed draws, transfer the sheet from one position to another

(5) Provide desirable durability in terms of strength, resistance to mechanical abrasion, chemical degradation and fill-up.

3.2.3 *Construction of Press Fabrics*

Press fabrics, in general, consist of two components as shown in Figure 3.4: base fabric and batt.

The Base Fabric

Today, most press fabrics are made of 100% synthetics, primarily polyamide (nylon) polymers. Base fabrics are usually woven or constructed with cabled monofilament, plied multifilaments, spun yarns and/or single monofilaments (Figure 3.5).

Each yarn has properties that influence the operational characteristics of the press fabric. They are designed into the weave of the base fabric to affect sheet quality, water removal performance, runnability and ease of installation. Primary characteristics of the more commonly used yarns are given in Table 3.3.

The base fabric may be a single layer or multilayer mesh. The fabrics can be woven endless or woven flat and joined with a seam (Figure 2.3, Chapter 2). The weave of the base fabric is engineered to manipulate pressure uniformity, flow resistance, void volume, and compression properties. The basic classifications of press fabrics are conventional (endless) designs, stratified (laminated) designs and seam fabrics. Figure 3.6 shows the main types of base fabrics used in press fabrics.

Seam fabrics have shown a substantial increase in usage since their introduction in the late 1980s. The primary factors for the increase in use of seam products are safety, reduced installation time and, in some cases, improved press fabric performance. There are basically two types of seam products as shown in Figure 3.7.

Pin seam fabrics are woven flat with loops woven into the fabric in a separate process. These fabrics are characterized by crimp in the machine direction yarns. Woven loop seam fabrics are woven endless with loops formed during the weaving process. Like conventional endless fabrics, the woven loop design

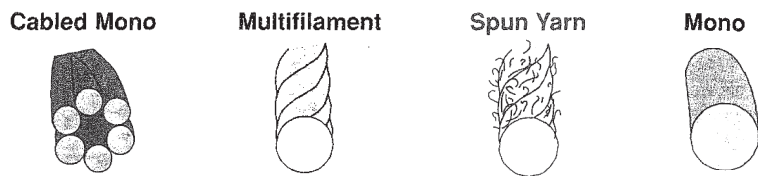


FIGURE 3.5. Yarn types used in manufacture of base fabrics.

TABLE 3.3. Characteristics of Multifilament and Monofilament Yarns Used in Press Fabrics.

Multifilament	Monofilament
Very durable	Durable
Supple	Stiffer than multifilament
Compressible	Resists compression
Higher elongation	Less stretch than multifilament
Low resistance to chemical attack	Better resistance to chemical attack

has crimp in the cross machine direction. Both products can also be made with laminated fabrics on the surface.

The Batt

The process in which the batt is locked to the base fabric is called needling. The batt is carded into a uniform web first and then is applied in a series of layers onto the base fabric. The web and base fabric are fed through a zone where several thousand reversed barbed needles are needle-punched into the composite to lock the web to the base fabric. The batt is typically spliced at the start and stop of web application. Some processes can apply the web in a spiral method that eliminates the cross machine direction oriented splice. These processes are generally applied on fabrics for critical press bounce and vibration prone positions.

The needling process can be engineered to affect the density, surface properties and permeability of the press fabric. The batt fibers that are used in the manufacture of press fabrics are purchased in standard sizes. The most commonly used unit to indicate the density of the fiber or yarn is the denier. Denier is actually a weight measure but it has become synonymous as an indicator of fiber fineness (Section 2.2.3). As long as the specific gravity of the polymer is approximately the same, denier can be used to compare fiber diameter. The relative sizes of the most common fibers used in press fabrics are shown in Figure 3.8. As can be seen from the figure, a 30 denier fiber is not twice as large as a 15 denier, and a 6 denier fiber is not twice as large as a 3

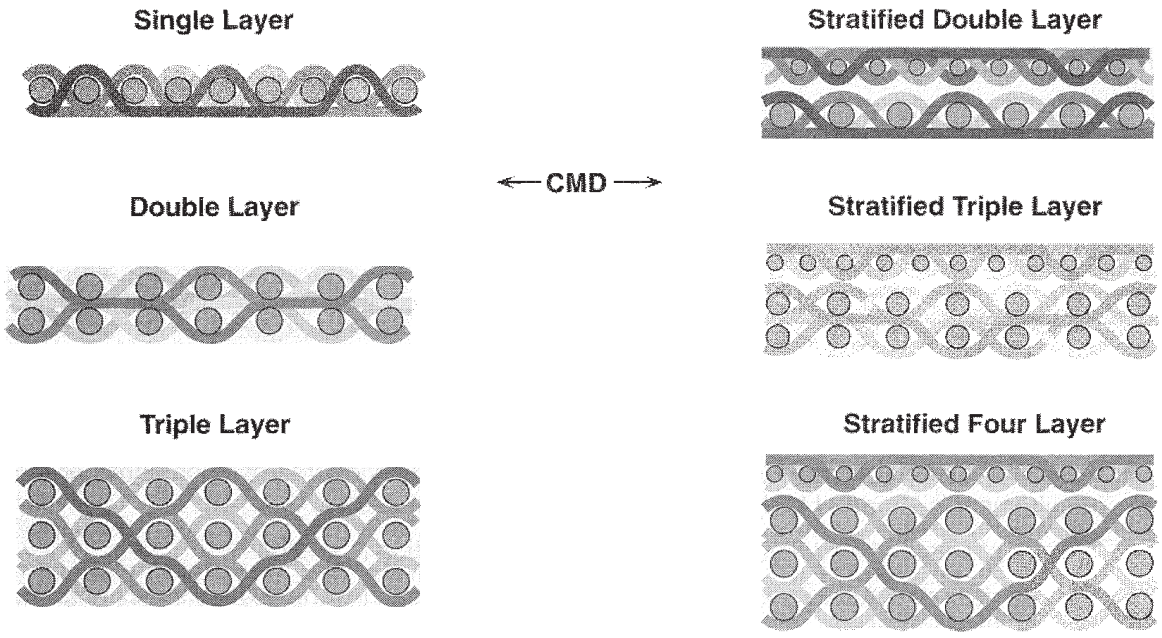


FIGURE 3.6. Major types of base structures used in press fabrics.

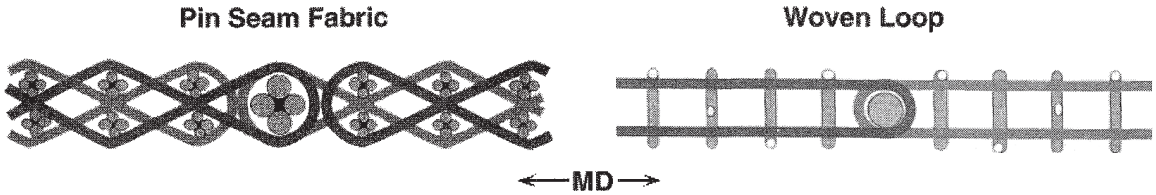


FIGURE 3.7. Seam fabrics.

denier fiber. The relation between denier and diameter is explained in Section 2.2.3 for some common paper machine clothing materials.

Many factors influence the selection process of the fiber denier. These include:

- water handling requirements of the fabric
- break-in time
- available uhle box vacuum
- sheet control issues such as drop offs, blowing and sheet stealing
- fiber shedding propensity
- filling propensity
- bleed through propensity

Fibers with different deniers can be blended or applied in stratified layers for desired performance attributes. Figure 3.9 shows the most common means of batt application.

3.2.4 *Press Fabric Designs*

Conventional woven felts, which were woven with spun yarns became obsolete. Other major press fabric designs that have been used are explained below. Of these, the first two designs also have become obsolete.

Batt-on-Base Felt

A woven fabric, usually of spun yarns, is used as the base fabric on which fiber batt is needle-punched. Batt-on-base felts were made of either a combination of wool and synthetic fibers or 100% synthetic fibers (mostly nylon), which became the standard. The base fabric, which can have synthetic content between 50–100%, can be woven as endless belt or can be woven flat and joined later. The batt web has synthetic content between 20 and 100%. After washing and chemical treatment, the felt is stretched on the dryer to the operating dimensions. Singeing is usually done to prepare the surface and remove the loose fibers. Finally, the felt is dried at an overstretch length for easy installation. Figure 3.10 shows the random nature and structure of the top surface of a needled felt.

Batt-on-base felt designs have become obsolete and are not used anymore.

Baseless Felt

In this type of structure, no base fabric is used; felt is made by needle-punching only. The absence of base yarns reduces marking

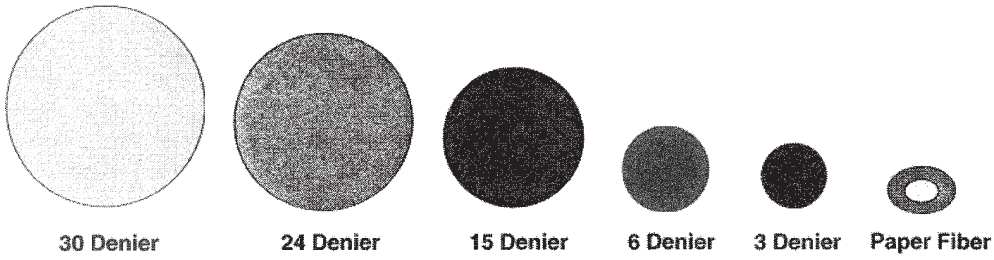


FIGURE 3.8. Relative sizes of the most common fibers used in press fabrics.

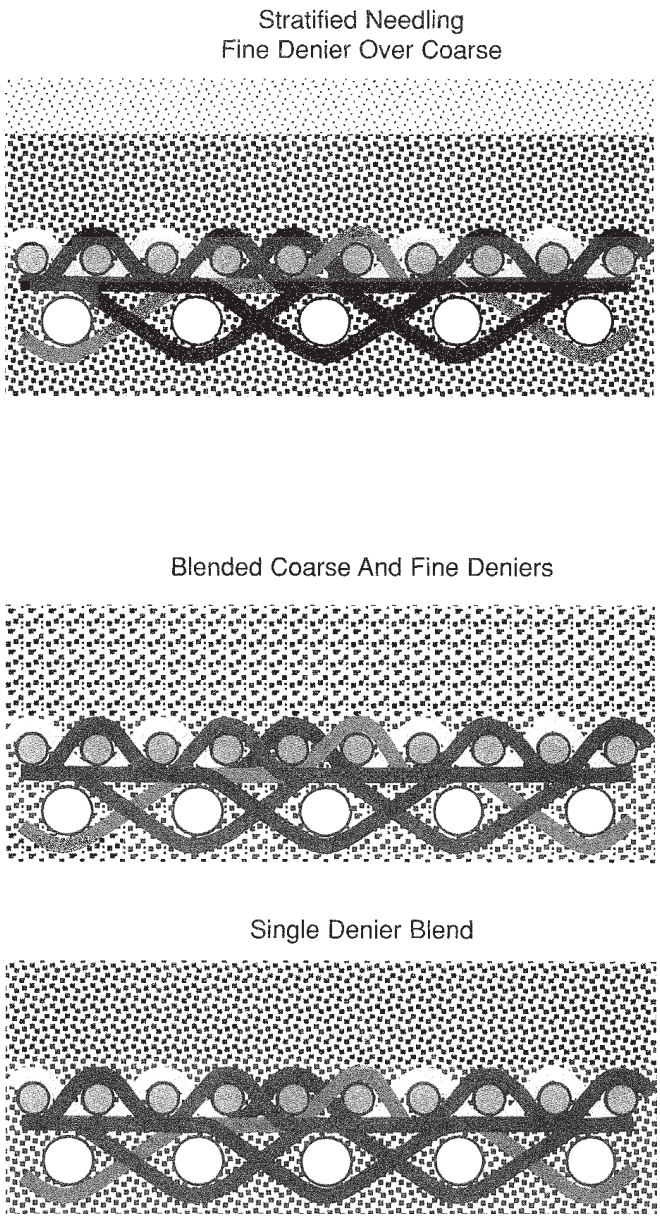


FIGURE 3.9. Most common ways of batt application.

and provides a uniform pressure distribution in the press nip. Nonwoven felts are suitable for suction, grooved and shrink sleeve presses, to provide a smooth sheet finish for fine paper and board machines. This type of design is outdated and not used anymore.

Batt-on-Mesh Felt

Needle-punched batt-on-mesh felt structure is similar to batt-on-base felt structure. Batt-on-mesh fabrics are generally made of 100% synthetic materials. The base structure may be a single or multilayer fabric woven with 100% monofilament, a combination of mono- and multifilament, all high twisted multifilament, all high twisted multifilament treated with resin for rigidity, or any combination of these yarns. Since these yarns are stiffer than spun yarns, batt-on-mesh fabrics have higher resistance to compression and compaction than batt-on-base felts. The base mesh is woven endless and the batt is applied on needle-punching machines. Figure 3.11

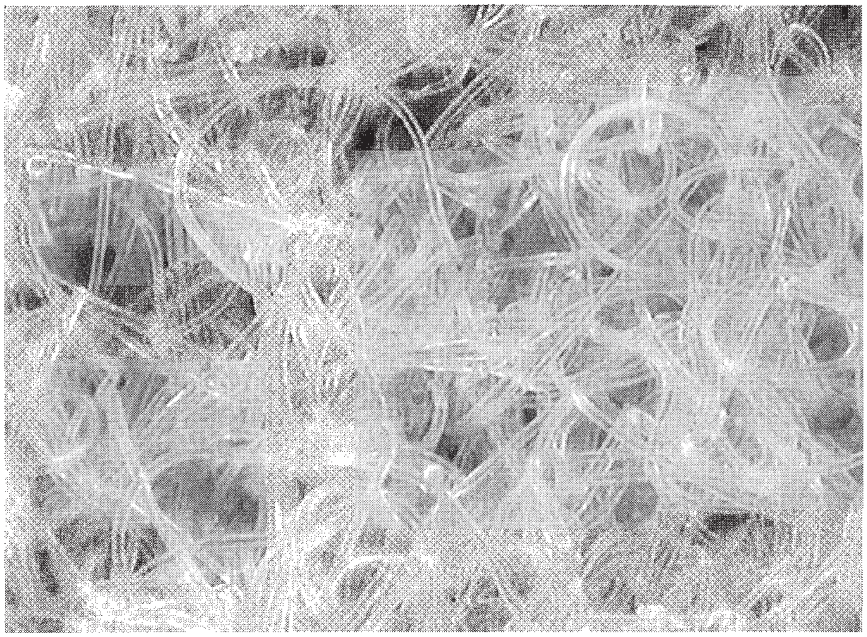


FIGURE 3.10. Random nature of the top surface of a needled press fabric.

shows a batt-on-mesh felt with single layer monofilament base fabric. Installation of batt-on-mesh fabrics may be more difficult than batt-on-base fabrics due to stiffer base structure.

Multifilament batt-on-mesh fabrics are suitable for suction, grooved and shrink sleeve presses. Resin treated multifilament fabrics are applicable on first and second suction presses for coarse paper grades such as kraft. Monofilament or mono- and multifilament combination base structural felts have excellent stability, resistance to wrinkles, and provide good finish for fine paper applications on suction pick-up positions, straight suction presses, and grooved or shrink sleeve presses.

Felts with No-Crimp Base-Fabric (Knuckle-Free)

In this type of design, the base fabric is not a woven fabric but is formed by two or more, completely separate uncrimped yarn layers. Figure 3.12 shows a two layer no-crimp felt structure. It is reported that the no-crimp base fabric structure provides improved sheet dewatering, good resistance to compaction and dimensional changes, resistance to filling and improved microuniformity of pressing. Eliminating knuckles in the base structure reduces the possibility of paper fines and dirt being trapped at the yarn crossover points. Moreover, it reduces sheet marking. Other advantages of knuckle-free felts include improved abrasion resistance, easy cleaning and smoother surface. However, due to lack of interlacing of yarns, void volume is drastically reduced and fabric stability may suffer.

Laminated (Stratified) Press Felts

In this relatively new press fabric structure, two or more base fabric structures are included in the fabric. The top base fabric is usually a single layer. The bottom base fabric can be a one, two or three layer integrally woven fabric (Figure 3.13). Laminated fabrics allow a wider range of base fabric pressure uniformity and low batt-to-base ratio which is critical for open and clean operation. As the machine speeds increase, the nip resistance time decreases and better surface contact between the sheet and press fabric becomes a requirement.

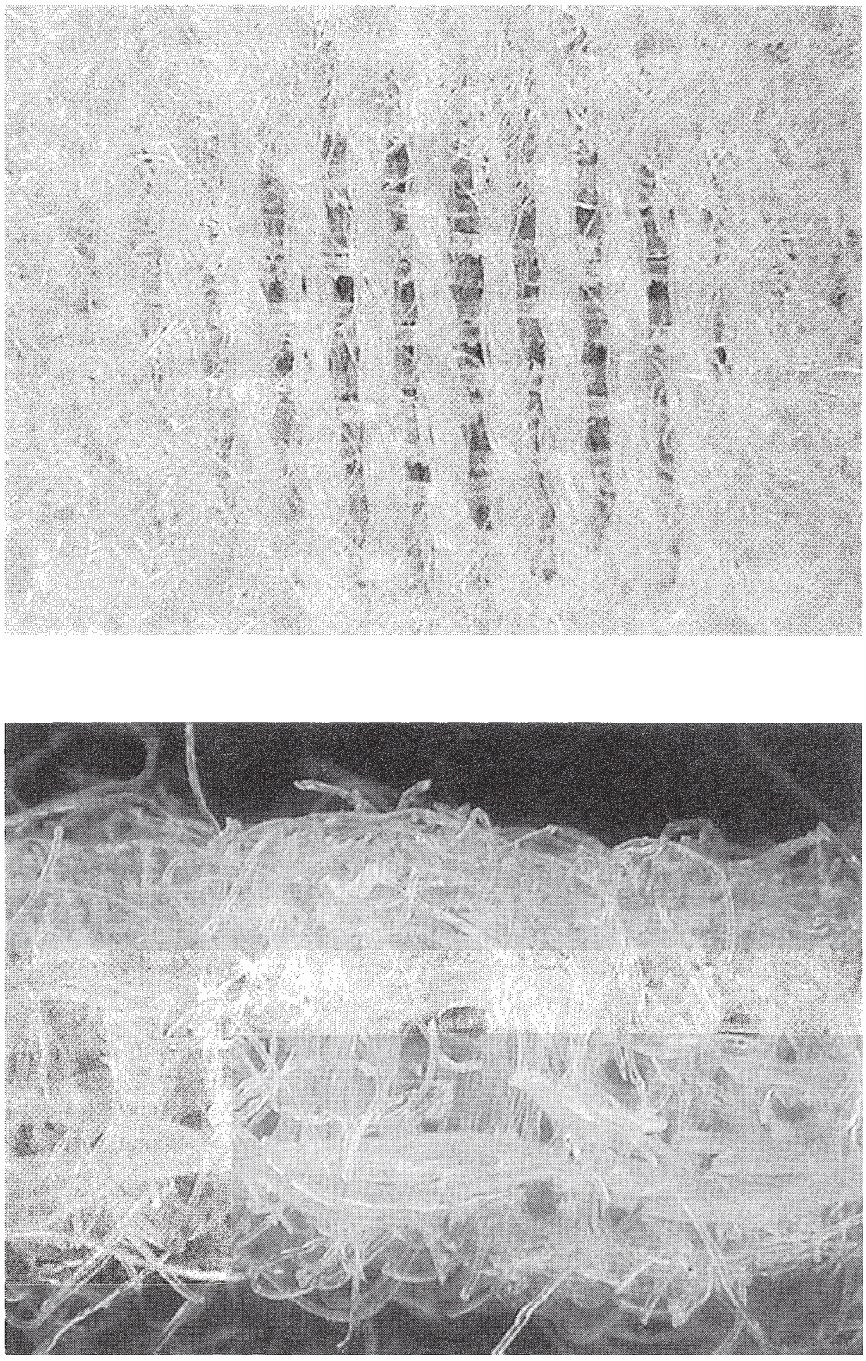


FIGURE 3.11. Batt-on-mesh press fabric structure: paper surface with exposed base fabric and cross-sectional view along the MD.

Continuous research is being done to develop new and improved press fabric designs. The latest developments include utilization of round, hollow yarns in cross machine direction. Hollow yarns flatten under pressure and immediately rebound after exiting the nip as shown in Figure 3.14. Flexing of yarns provides better sheet contact which in turn improves water removal and smoothness. Machine runnability and printability on the sheet are also improved. Another development is 100% monofilament (no batt) press fabrics.

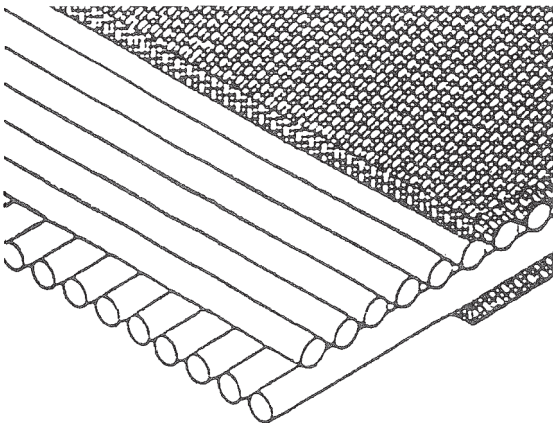


FIGURE 3.12. Two-layer no-crimp base press fabric [6].

Table 3.4 shows the base fabric weight, total fabric weight and air permeability ranges of typical single and multilayer fabrics.

3.2.5 *Manufacturing of Press Fabrics*

Due to batting, manufacture of press fabrics is different than forming or drying fabrics. Figure 3.15 shows the major manufacturing steps for press fabrics.

Batt fibers are blended, carded and usually preneedled first. Base fabrics are woven (except no-crimp base fabrics) similar to forming fabrics. They can be woven as a flat or endless belt as shown in Figure 2.3 (Chapter 2). The warp (MD) direction of an endless woven belt becomes the CD direction on the paper machine.

Flat woven fabrics have to be joined or pin-seamed to make an endless construction.

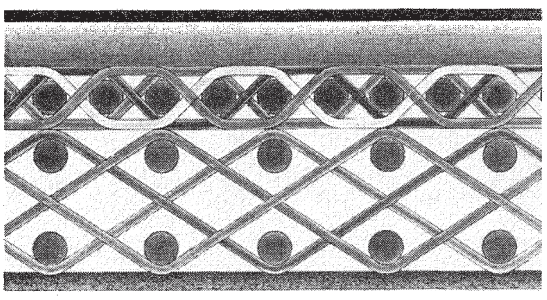


FIGURE 3.13. Cross section of a laminated press fabric.

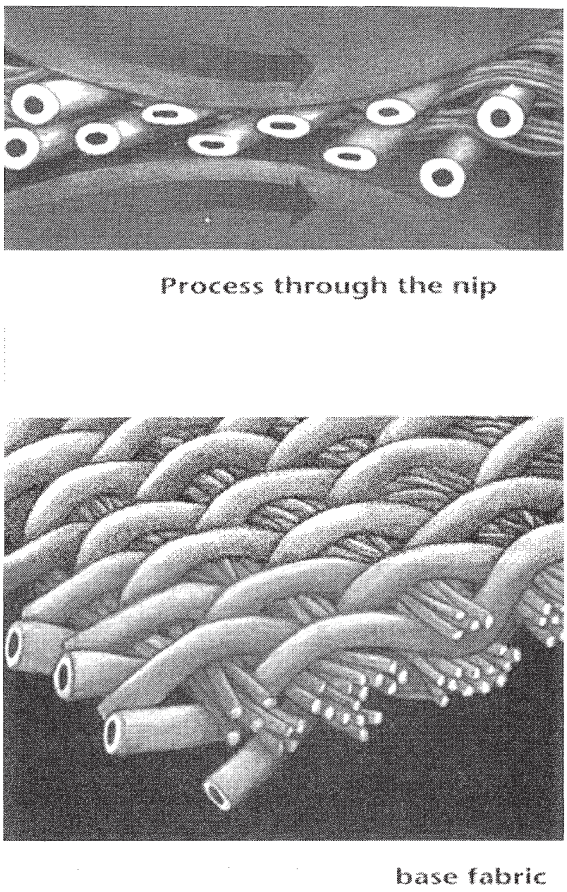


FIGURE 3.14. Fabric with hollow yarns in CD.

Today, approximately 25–30% of the press fabrics are seamed. Usually pin seaming is used which makes installation of the fabric on paper machine a lot easier. Figure 3.16 shows a press fabric seam. Monofilament warp yarn ends are looped and woven back into the fabric at the two ends of the fabric. A monofilament pin passes through the loops connecting the two ends together after the installation of the fabric on the paper machine.

Endless fabrics are woven in a spiral with the filling yarn forming the length of the fabric. Fabric length will be twice the reed width. Woven loop seam fabrics are woven similar to an endless fabric; however, loops are formed at the ends of the fabric (Figure 3.17). Some looms for endless weaving are as wide as 31 meters (Figure 3.18).

After base fabric manufacturing, carded fiber web is needle-punched into the base struc-

TABLE 3.4. Typical Property Ranges of Single and Multilayer Press Fabrics.

Structure	Base Fabric Weight (oz/sq ft)	Total Fabric Weight (oz/sq ft)	Air Permeability (cfm)
Single layer	0.9–1.8	2.3–4.9	8–160
Two layer	1.9–2.7	3.7–5.8	12–140
Three layer	2.2–2.7	4.0–6.0	15–120
Laminated two layer	2.5–2.7	4.6–5.2	12–90
Laminated three layer	2.2–2.7	4.9–7.0	15–130
Laminated four layer	3.4–3.8	5.2–7.0+	15–130+

ture to form the batt. Batt laying can be applied from preneedled web (Figure 3.19) or as part of a direct lay batting system (Figure 3.20). Figure 3.21 shows the schematic of needling process and a barbed needle used for this purpose. The needle plate moves up and down into the batt and base fabric several hundred times a minute. In the process, the barbs on the needle grab and penetrate the batt fibers into the base structure. In modern press fabrics, different length and diameter fibers can be used to obtain stratified batt layers, the coarsest fibers typically being next to the base fabric and the finest fibers being on the surface. Special purpose fibers such as fusible fibers can be used to improve bonding.

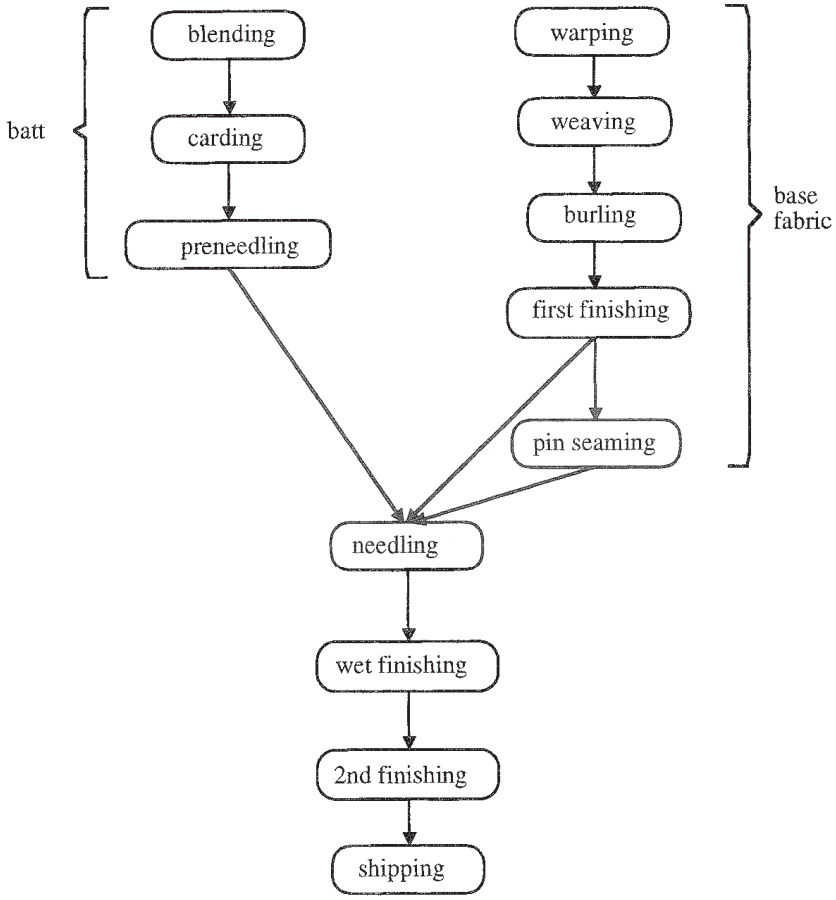


FIGURE 3.15. Manufacturing steps of press fabrics.

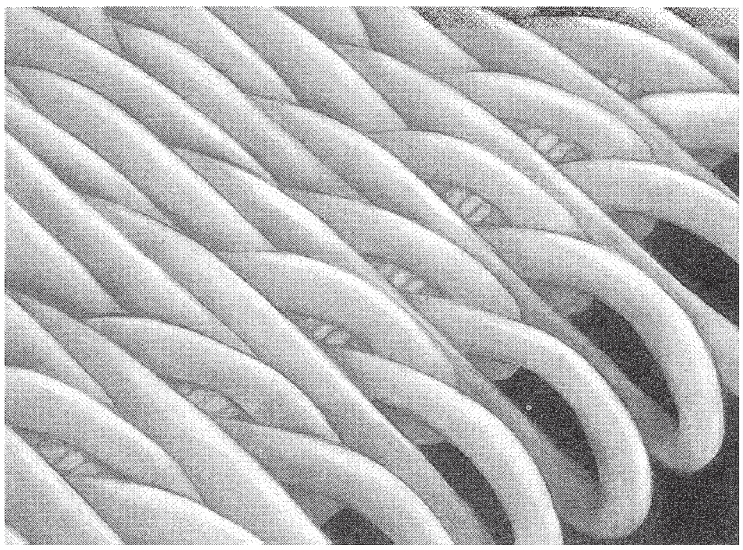


FIGURE 3.16. Pin seam press fabric.

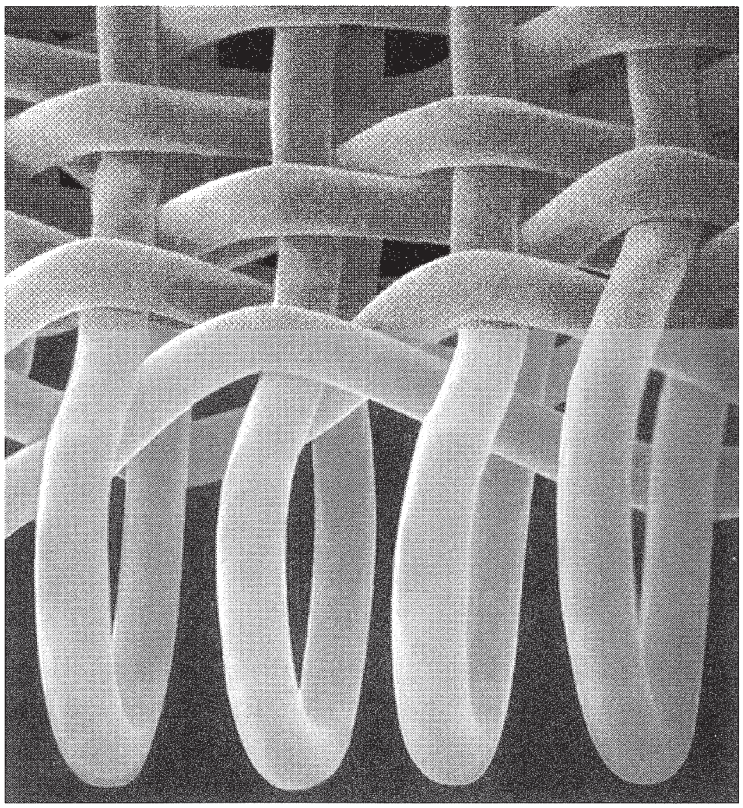


FIGURE 3.17. Woven loop seam fabric.

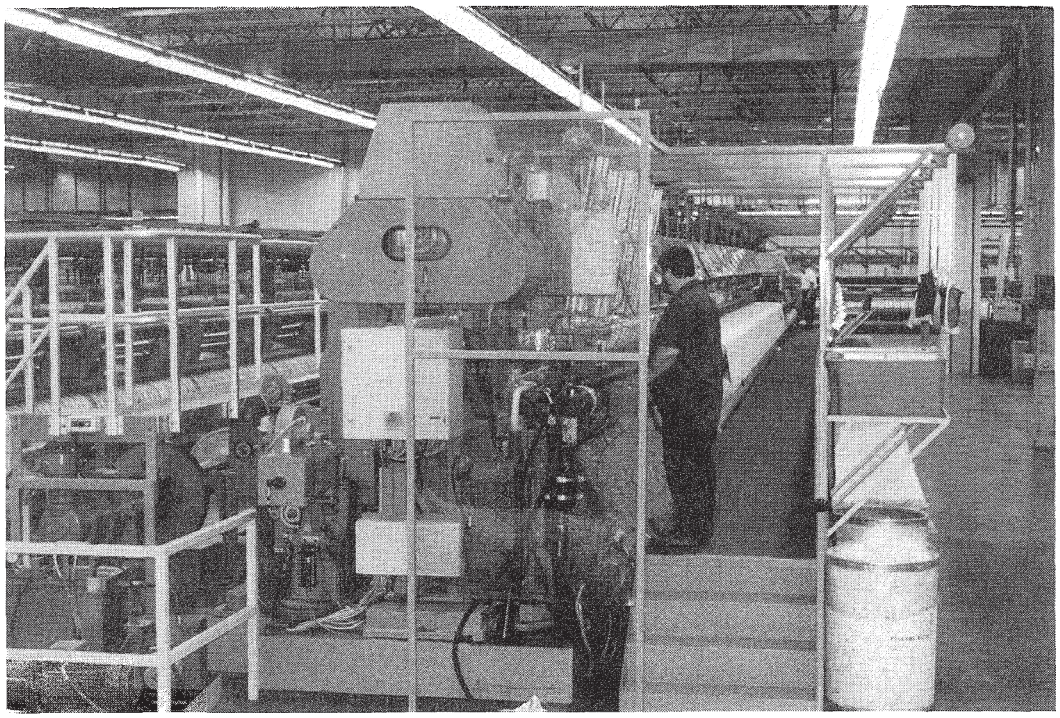


FIGURE 3.18. Weaving machine for endless base fabric manufacturing (machine width = 31 meters).

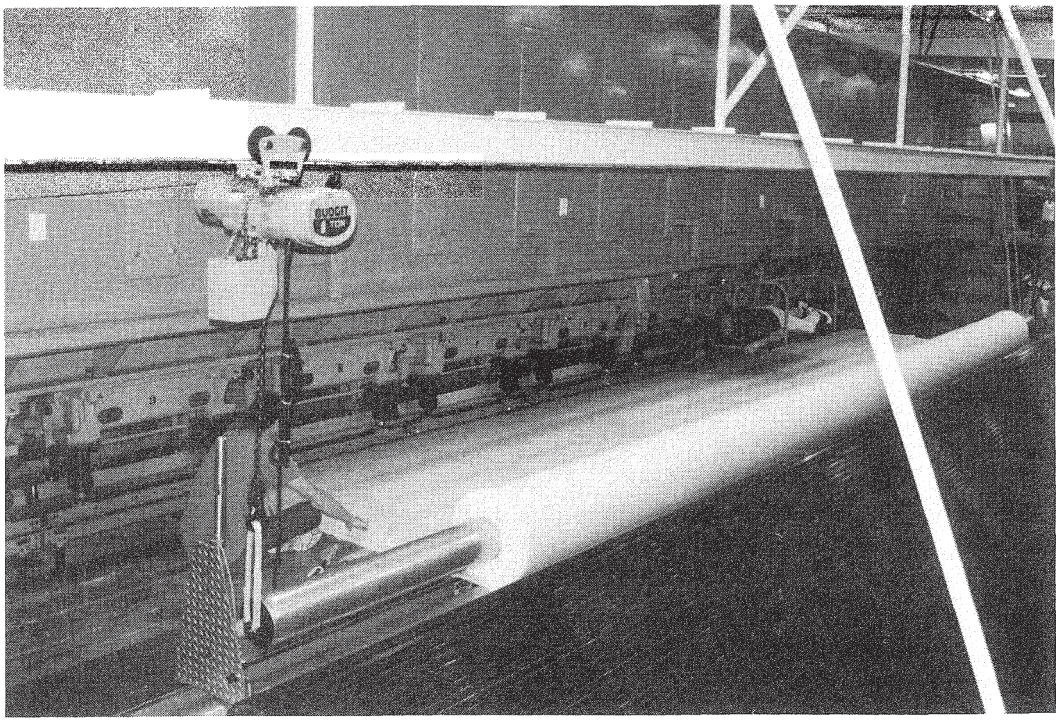


FIGURE 3.19. Preneedling.

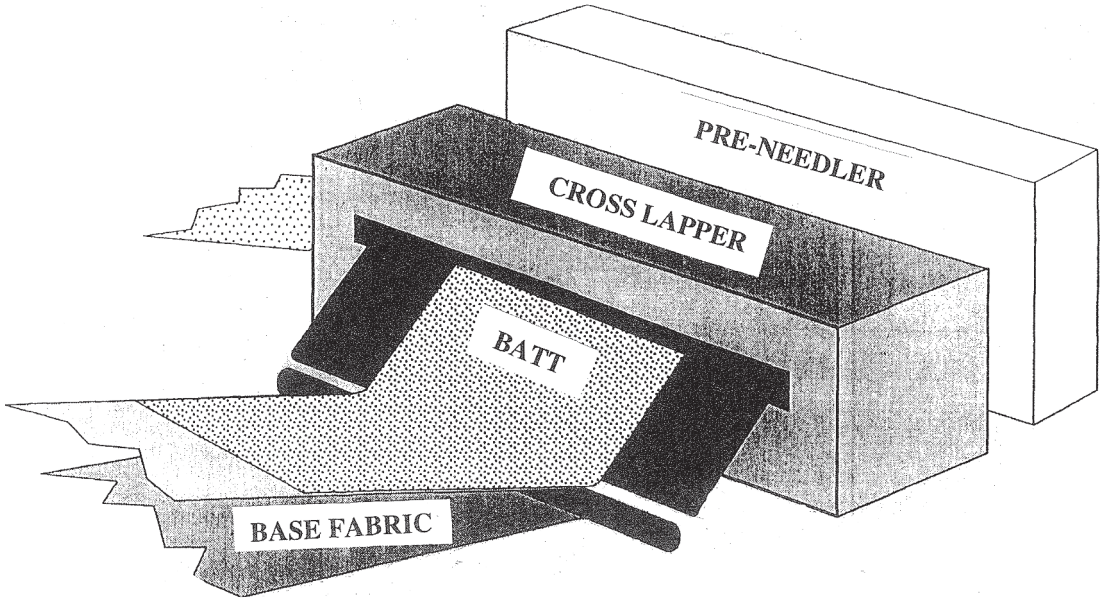


FIGURE 3.20. Direct-lay batting.

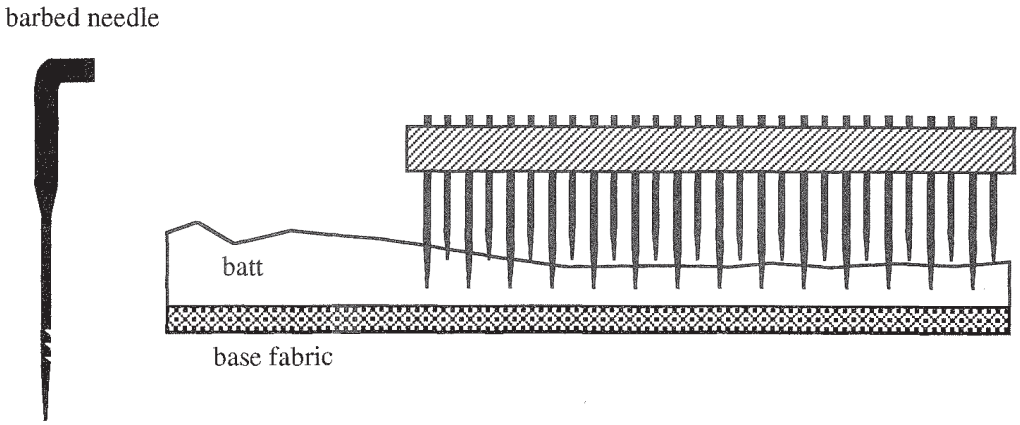


FIGURE 3.21. Schematic of needling.

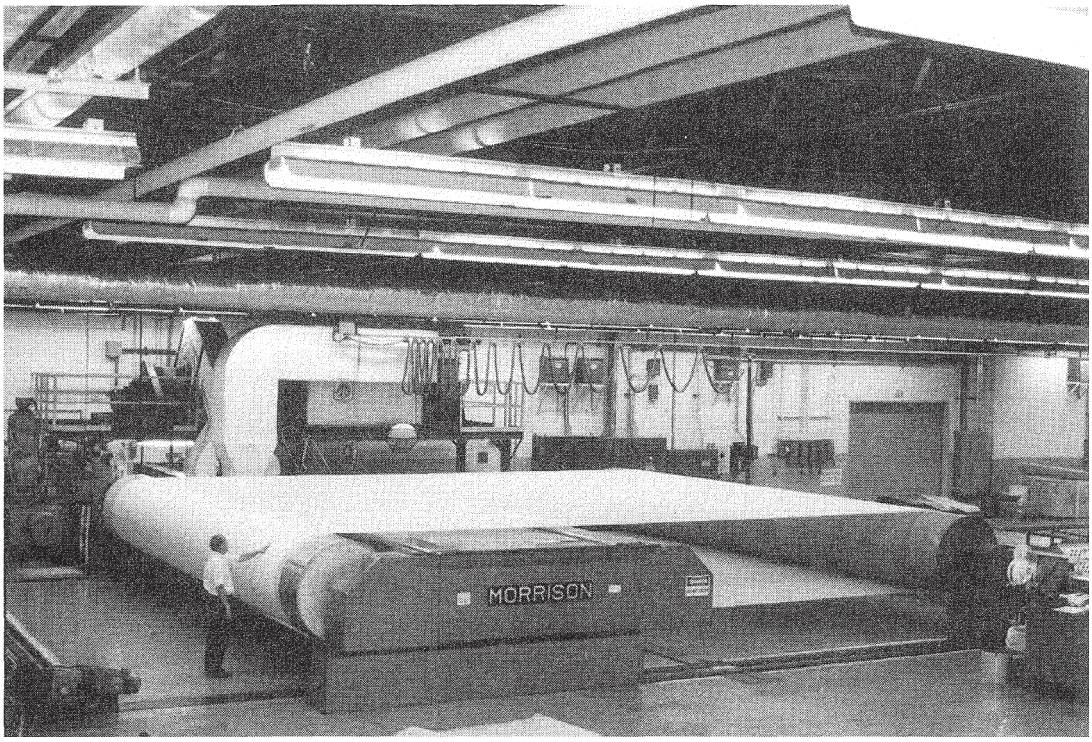


FIGURE 3.22. Press fabric heatsetting.

The remaining major manufacturing steps are heatsetting for stabilization (Figure 3.22), washing (Figure 3.23), treatment and singeing. Treatments can refer to a chemical additive, a special process, or a specialty fiber that is designed to improve the properties of the press fabric. Most treatments are either colorless or reddish-brown in appearance. The most common uses for treatments are:

- improved flexibility
- improved batt adhesion
- shed resistance
- resistance to chemical degradation
- resistance to mechanical wear
- improved compaction resistance
- inhibit contamination
- inhibit wad burns

Singeing is done to remove loose fibers and properly prepare the surface. Press fabrics are sealed in packages prior to boxing in order to protect the fabric against moisture and dirt. The fabric remains in this package until ready for installation. Certain types of press fabrics are rolled and put into a paper tube to prevent possible creasing of the fabric.

3.2.6 *Properties of Press Fabrics*

Based on their structures (number and dimensions of base yarns, size of batt fibers, the smoothness of the surface finish), press fabrics are classified as superfine, fine, medium and coarse. The important properties of press fabrics are as follows.

Fabric Mass and Thickness

Fabric "mass" is defined as the fabric weight per unit area (oz/sq ft or g/m^2). Press fabric should have a uniform mass distribution across the width. Uneven mass or thickness (caliper) may cause press bounce or vibration. Thickness is important for felt wear and compaction characteristics which influence void volume and drainage of the fabric. The rate of thickness change during the operation depends on the fabric design. The thickness decreases quite rapidly during the early days of the operation. After a certain thickness loss, the fabric has to be removed from the machine. Thicker fabrics are also used to increase nip width and residence time.

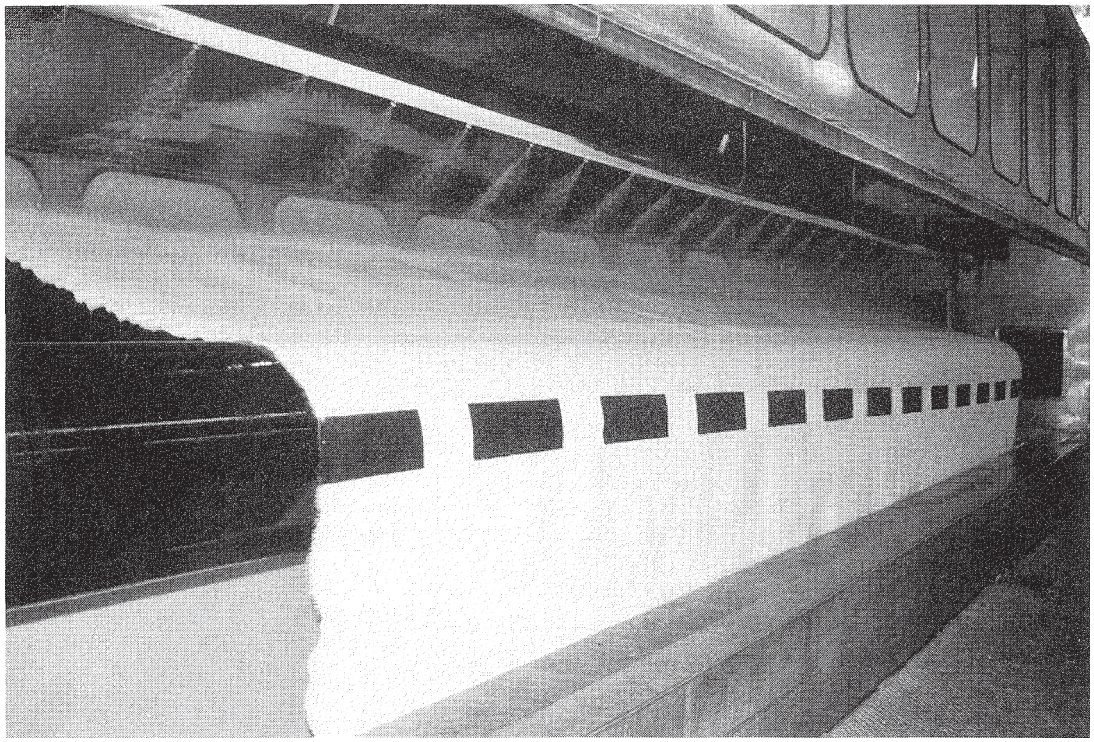


FIGURE 3.23. Press fabric washing.

Batt-to-Base Ratio

Batt-to-base ratio is defined as the mass of the batt fibers divided by mass of the base fabric. As this ratio increases, compactness of the felt also increases, which is not very desirable for dewatering capability. However, a small batt to base ratio may cause marking on the sheet due to base yarns.

Air Permeability

Similar to forming fabrics, it is measured as the air volume (cubic feet) passing through of per unit area (square feet) of fabric per minute (cfm) at 0.5 inch water column.

Void Volume

Void volume is the volume that is not occupied by the yarns and fibers in the fabric. It is an indication of the amount of water that the felt can absorb. Void volumes are measured at various loads to predict the fabric's performance on different types of presses.

Flow Resistance

Properly designed fabrics should provide adequate drainage and filtration of water and therefore should have minimum resistance to flow. Resistance to water flow in the fabric is measured in three directions using water permeability testers: machine direction, cross machine direction and vertical direction. Low flow resistance indicates higher water acceptance capacity of the fabric.

Compressibility and Resiliency

Compressibility is a measure of compactness under load and resiliency is a measure of rebounding capability of the fabric after compaction. Compaction resistance is a desired property in press fabrics. A compaction resistant fabric can be either incompressible or compressible but resilient.

Uniformity of Pressure Distribution

Pressure from the rolls should be transferred to the sheet uniformly by the felt in

order to prevent uneven sheet moisture profiles. Press fabrics with fine base structure and fine batt fibers provide more uniform pressure distribution. Too coarse base yarns, improper weave design or insufficient batt may also cause sheet marking.

Fabric dimensional stability, abrasion resistance, contaminant and chemical degradation resistance are important requirements of modern press fabrics. The fabric should be dimensionally stable throughout its operation. Some fabrics may get narrower after running some time due to heat from furnish and steam boxes. Smooth sheet transfer also requires dimensional stability. Abrasive inorganics in alkaline paper making and paper making chemical additives for mechanical conditioning have increased the importance of abrasion resistance in press fabrics. Increased use of secondary fibers has made contaminant resistance a necessity in today's press fabrics. Paper making chemical additives such as bleaching, oxidizing and cleaning agents require chemical degradation resistance.

3.3 Applications of Press Fabrics

3.3.1 *Installation and Operating Procedures*

Before Installation

- Clean press and other machine components thoroughly.
- Check all machine components such as uhle boxes and roll faces for rough surfaces.
- Ensure that stretch roll and hand guide are perpendicular to the machine.
- Check automatic guide for free movement and guide palm for cuts or grooves.

Installation

- Install fabric to run with the arrow and fabric number (if applicable) on sheet side.
- Keep fabric as dry as possible during installation.
- Spread fabric out evenly across width of the machine and make certain that the guideline is straight and parallel to the CD.
- Ensure that the fabric is flat and free of wrinkles and machine debris.
- Adjust stretch roll until fabric is snug.

Start-Up

- Load press to dead weight and jog slowly while checking that the fabric is flat and free of creases and wrinkles.
- Increase fabric tension to normal running level (14–22 pli) making certain that tension does not exceed 30 pli (5.4 kilogram per cm).
- Maintain tension during start-up and check frequently.
- Wet up by applying water evenly across the fabric using a full width shower, making certain that no puddling occurs.
- When the fabric is uniformly wet, load press to normal weight and turn on vacuum equipment.

Trimming

Trimming should be delayed, if possible, in the event that the width comes in during break-in. If trimming is necessary, the following procedure is recommended:

- The fabric should be trimmed on the non-guide paddle side.
- A guide mark should be made with a pen or marker on the edge to be trimmed.
- A razor or sharp knife should be held firmly on the guide-mark where the fabric is supported
- Jog the fabric a full revolution; then cut the trimmed loop and pull it free.
- If raveling occurs after trimming, a heat-sealing iron is effective at stopping the raveling.

If a seam fabric is trimmed, special caution should be taken to ensure that the pintle is not cut so that it can be stitched back into the fabric. This will keep the seam from opening on the edges.

3.3.2 *Fabric Shutdown Procedures*

When a machine is scheduled for a shutdown exceeding two hours and the clothing is to remain on the machine, the following procedures will help to extend fabric life as well as prevent start-up problems.

Wash Fabric and Follow with a Thorough Rinsing

It is important to remove contaminants from the fabric. If allowed to remain in the fabric, they would harden and be difficult to remove and may affect start-up.

- Reduce the machine speed to a crawl to increase the dwell time at the suction boxes and rolls.
- Shower on the felt cleaner and allow it to act on the fabric for 15–20 minutes. Ensure that the whole fabric has been treated.
- Reduce the press load to the lowest practical level and leave the uhle box vacuum on.
- Rinse the fabric using flooding showers, lubricating showers, or high pressure showers (use low pressures so the felt is not damaged)
- Set showers at normal operating pressures for 10–15 minutes to thoroughly rinse the fabric
- Shut off the showers.
- Use vacuum boxes to dewater the felts uniformly and to the lowest practical moisture levels.
- A fabric softener or wetting agent can be applied to improve wet-up of the fabric at start-up.

Relax Fabric Tension

Once the fabric has been cleaned, rinsed, and conditioned, the showers and vacuum should be turned off and the machine stopped. Release the fabric tension by backing off the stretch roll. This will prevent excessive tension from developing and roll deflection from occurring as the fabric dries.

Inspect Rolls, Showers and Uhle Boxes

- Inspect all roll surfaces for wear or damage which could cause abnormal wear to the fabric.
- Inspect and clean shower nozzles and uhle box covers.

3.3.3 *Repairing Damaged Areas of Fabric*

Occasionally during the normal operation of a paper machine, fabrics may become damaged by some object producing a hole or tear in the fabric. Due to the rising cost of downtime, it may be feasible to try and repair the damaged area temporarily until an extended downtime is scheduled. Sewing kits utilizing nylon thread or similar type yarn with curved needles may be supplied by the various paper machine clothing suppliers usually free of charge.

While there is no one method for repairing these areas, some suggestions are given below:

- The mended area should not be appreciably thicker than the fabric itself.
- In stitching, caution should be used not to pull the thread too tight causing the area to pucker, allowing for normal widening and stretching during machine operation.
- Two steps may be necessary for complete repair: closing the damaged area with stitching and then covering the closure with additional stitching.
- After stitching is completed, the ends should be left untied. A resin used for sealing edges of seam fabrics may be applied thinly to the roll side to prevent the yarns from coming loose.

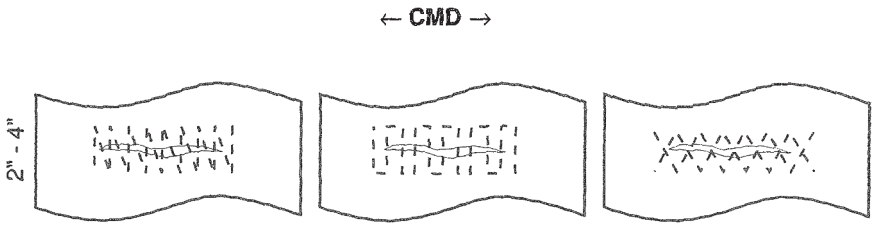


FIGURE 3.24. Damaged areas running in the cross machine direction and corresponding stitch types.

- Inspection of the damaged area as often as possible is recommended for safety purposes in case the fabric starts coming apart causing injury to personnel.

For damaged areas extending in the cross machine direction (Figure 3.24), the repair must be strong enough to prevent the fabric from ripping off the machine when run under tension. The stitch should extend vertically at least 2 inch on either side of the tear. The length will depend on the fineness of the fabric and the paper grade. Various stitching methods are shown in Figure 3.24.

If the tear is in the machine direction, the stitch will be predominantly back and forth horizontally. Since there will not be tension on the MD yarns seen in the cross machine direction shear, the stitch need to be only minimum of 1 inch on either side (Figure 3.25).

Depending on the size and direction of the tear, both vertical and horizontal stitching as a backup may be required on both types of tears. In addition, a "needle punch board" and batt can be provided for by punching the batt back and forth in the damaged area for grades such as fine paper.

3.3.4 *Guiding*

In general, a press fabric will line up at right angles to the surface it touches first. As shown in Figure 3.26, a guide roll angled or pivoted with the run of the press fabric will cause it to guide in the direction of the roll side that it contacts first. If the guide roll is angled in the opposite direction or pivoted away from the run of the fabric, it will cause it to track to the other side.

The above principle is valid for a normal guide roll wrap of 25° to 35° (Figure 3.27). Angles greater than recommended could cause a distance effect and skew the fabric. Angles less than recommended could result in poor fabric response to the guideline roll effect. The distance from the lead in roll to the guide roll should be approximately twice that from the guide roll to the lead-out roll. This ensures that the fabric response to the guide roll is effective.

Other Factors Influencing Guiding

Misalignment of a roll can cause guiding problems. The symptoms are typically characterized by a fabric that consistently tracks to

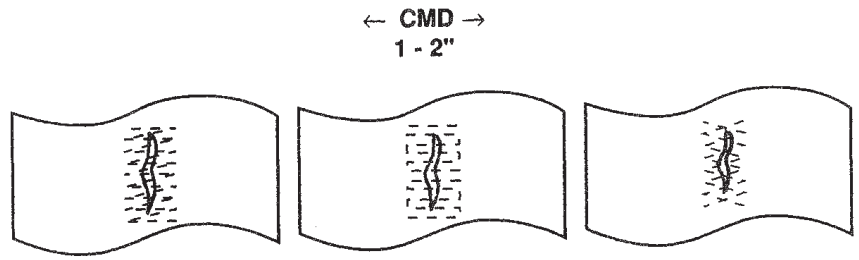


FIGURE 3.25. Machine direction tear and stitch types.

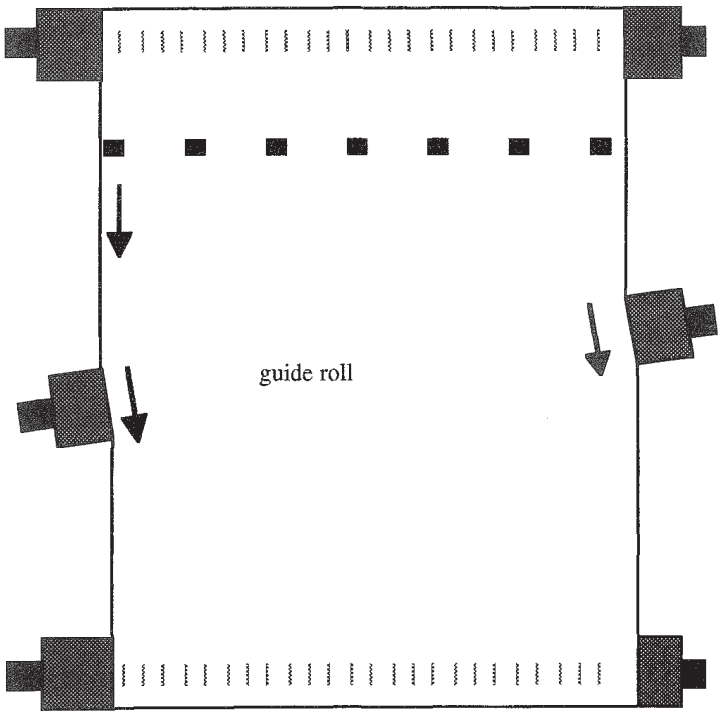


FIGURE 3.26. Press fabric guiding.

one side. It can occur with any roll but usually it is the stretch roll that is the culprit. With independent movement on each side of the stretch roll, it is inherently more likely to be skewed. The influence on the fabric is the same as by the guide roll. However, because of the large degree of wrap by the press fabric, the guideline will skew due to distance effect that is created. The stretch roll should be checked periodically for misalignment.

Bowed Rolls

A bowed roll positioned in the same plane as the fabric run operates on the guiding principle, guiding the edges away from the center.

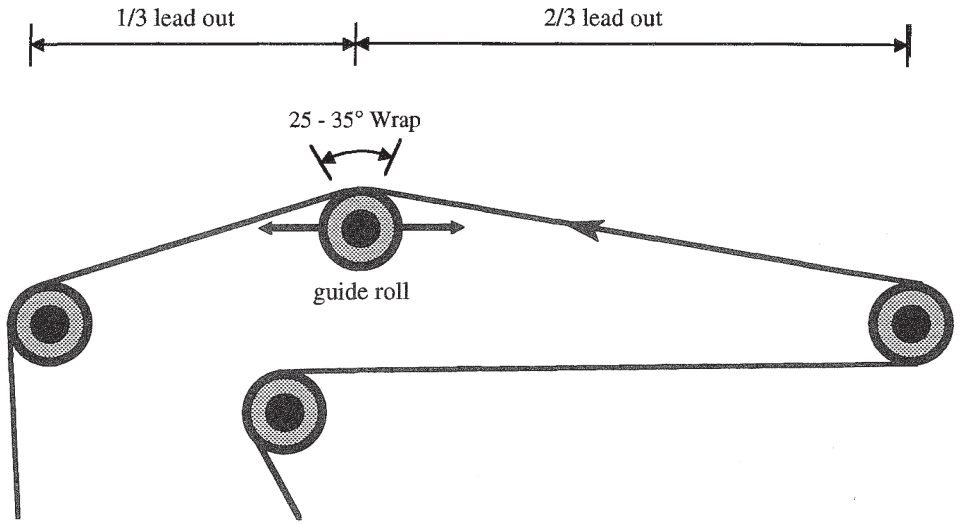


FIGURE 3.27. Lead-in and lead-out distances for guide roll.

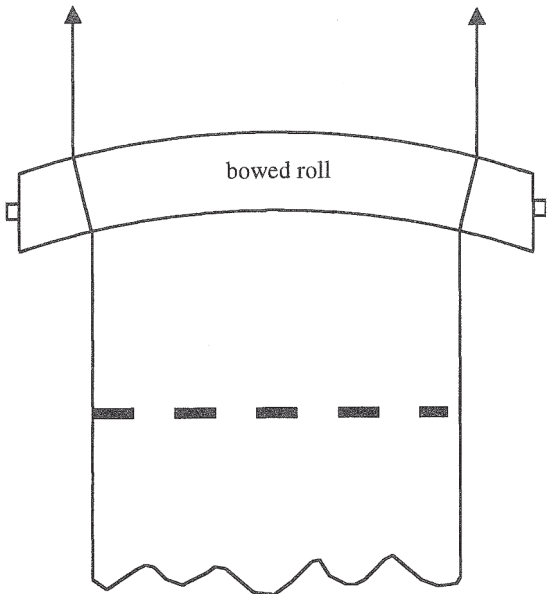


FIGURE 3.28. Widening effect of the bowed roll.

In this position, it provides the maximum widening or flattening effect on the fabric (Figure 3.28).

If the bow is turned into the plane of the fabric run, the widening and flattening effect will be lessened, proportional to the angle. A distance effect will be created, increasing proportional to the angle, causing the tradeline to lag in the center.

3.3.5 *Fabric or Guideline Distortion*

Press fabrics are designed to run with a straight guideline. A line that is bowed or skewed will distort the weave changing the permeability and other properties of the fabric. This could negatively impact water handling capability and result in a poorer response to conditioning and cleaning. The distortion could also cause the fabric to become unstable and possibly wrinkle.

Press fabric distortion is caused by two effects: distance-producing devices and speed-producing devices.

Distance Producing Devices

A distance-producing device is anything that causes a point on the fabric to travel a greater distance than any other point on the fabric during a revolution of the fabric. A cocked or skewed stretch roll, for instance, is such a device. However, any roll that is misaligned can cause the distance effect and fabric skew (Figure 3.29).

Side "B" would travel a shorter distance than side "A," and all points between "A" and "B" will travel progressively shorter distances per revolution than side "A." This will result in the "B" side skewing ahead. Adjustment to

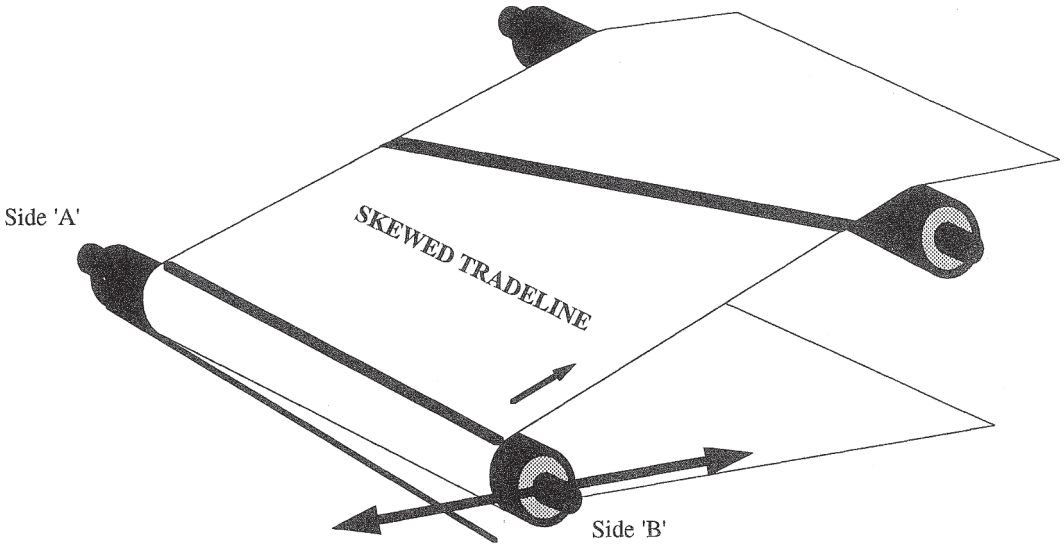


FIGURE 3.29. Schematic of a distance-producing device.

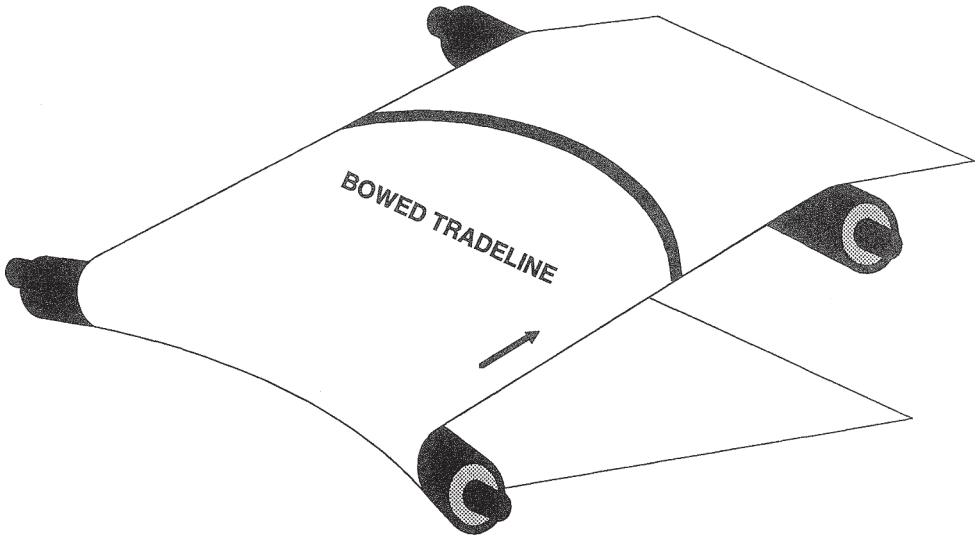


FIGURE 3.30. Roll deflection.

equal the horizontal positioning of both "A" and "B" side of the stretch roll will usually correct the skew.

Limber press fabric rolls or too high fabric tension causing roll deflection can cause the edges of the fabric to travel a greater distance than the center (Figure 3.30). The center travels a shorter distance resulting in the fabric and guideline running ahead in the center.

A bowed roll, such as Mt. Hope roll, that is turned into the press fabric run will also cause a distance effect in the center of the fabric. As the effect is greater length in the center, causing the tradeline to bow behind, the bowed roll is frequently used to correct a guide line that chronically runs ahead in the center.

Speed-Producing Devices

A speed-producing device is anything that causes a point on the fabric to travel at a different speed per revolution than any other point on the fabric. A crowned roll is such a device (Figure 3.31). If point "B" is the center of the crowned roll and point "A" is the edge of the roll, it can be seen that point "B" must travel at a greater speed to make one revolution in the same time that it takes point "A" to make one revolution. As a result, the center and all points of greater in diameter than point "A" are pushed ahead. The result on the press fabric is a guideline that is bowed ahead. The degree of bow is proportional to the difference in circumference.

Other Speed-Producing Devices (Figure 3.32)

Concave rolls have the opposite effect as a crowned roll. The edges are greater in circumference resulting in higher surface roll speed at the edges. The effect on the fabric would be to correct a chronic problem with guideline bowing ahead.

Leadered roll is a roll that has had the surface altered to create a greater diameter. This usually involves wrapping the roll with fabric

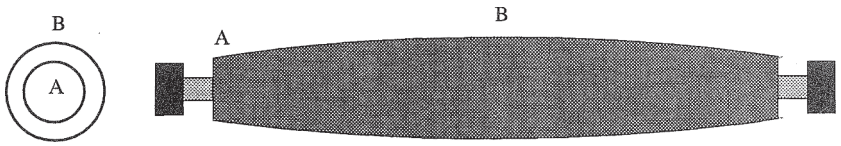


FIGURE 3.31. A crowned roll as a speed-producing device.

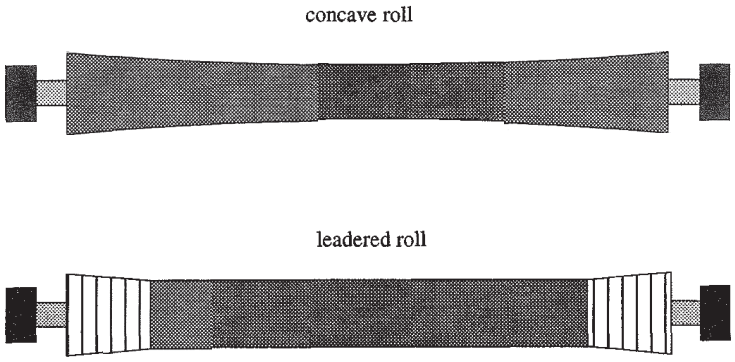


FIGURE 3.32. Concave (negative crown) and leadered rolls.

and/or tape, resembling a screw thread. Thread direction changes at the roll center line and must be set to widen, not narrow, the sheet or fabric running across it.

There may be other speed or distance producing devices that cause guideline distortion, but the point to remember is that distortion is caused by one of these devices. It follows then that one of these devices can also be used to correct distortion. Occasionally, it will be seen that fabrics from two different suppliers will show a different guideline distortion on the same position. Usually several devices on a position are affecting the fabric guideline, whose position is the net result of these several devices. The internal resistance to distortion of fabrics from different manufacturers may result in a different net effect.

3.3.6 *Press Fabric Problems—Evaluation Guidelines*

Table 3.5 gives a summary of common press fabric problems.

Dimensional Stability

Too Narrow

The question is whether the fabric started too narrow or became too narrow after running.

- Measure length and width (preferably at start-up and after running at least one day). If accurate measurement is not possible, determine sizes relative to fabric rolls and to amount of jack. Also note the tension (tight/slack).
- Determine if fabric was trimmed and how much.
- Measure tradeline distortion. Determine when it occurred. Is it bowed or skewed?
- Measure maximum running width; usually equal to fabric roll width.
- Measure minimum running width. This will usually be at least two inches outside maximum sheet width on either side or "wire" width for a pick-up fabric.
- Determine whether previous fabrics and succeeding fabrics exhibited the same problem.
- Determine operating temperature of press fabric or wet end.
- Determine whether steam boxes were used on press.

Too Wide

The same procedures apply for the items above, additionally:

- Check to see whether variable bowed rolls are used.
- Check to see if press fabric is worn excessively.

TABLE 3.5. Common Press Fabric Problems.

Blowing	Common on last press on machines that make lightweight fine paper and news at high speeds. The sheet rides on the fabric entering the nip. Usually during initial start-up the sheet will bubble or lift off the felt prior to entering the nip. This can cause a wrinkle in the sheet as it passes through the nip.
Drop-offs	Occurs on PU positions usually during initial start-up as the sheet rides on the bottom of the fabric from the pick-up roll to the first nip.
Bleed-through	Occurs primarily on machines that make highly refined (slow draining stock) and highly filled grades. Paper stock and/or filler material will collect on inside felt rolls causing guiding problems and vented rolls to plug.
Bounce/vibration	Typically occurs on highly loaded, hard roll presses (last press positions). The intensity of the nip makes the press sensitive to mass variations in the fabric which usually causes once or twice per revolution bounce. Most high frequency vibrations are caused by machine problems.
Shedding	Most critical on coated grades which can cause coater streaks or printing problems with the sheet of paper. It usually occurs later in life as the fabric is starting to wear and the batt fibers weakened by mechanical or chemical action.
Poor drying	A common problem on all grades in which the felt causes poor water removal in the nip, either from rewet or misapplication of design. It is usually indicated by high sheet draws and/or increased steam usage in the dryer section.
Difficult installation	Common problem on older machines in which the stiffness of the fabric makes it very difficult to bend around rolls and pack into tight spaces. Single monofilament CD structures and heavier designs make fabrics relatively stiffer.
Seam wear (mark)	Occurs with all seam products in which the batt over the seam wears prematurely, exposing the seam and base. This causes an impression mark in the sheet.
Shadow mark	Usually occurs in the first nip suction presses, where water loads are high. If flow resistance in a nip is too high, fines and filler material in the sheet will migrate to areas of low pressure causing a density variation in the sheet. It can also be caused by the suction couch roll.

Press Bounce or Vibration

Press bounce may be caused by either the press rolls or the press fabric. Improperly balanced rolls, worn rolls, corrugated rolls, or flat areas caused by leaving rolls nipped when the machine is down may cause bounce.

Answers to the following questions may reveal the cause of bounce:

- What is the machine speed? What is the frequency of bounce? (Once or twice per revolution of the press fabric? Where relative to tradeline? Once per roll revolution? Which roll? Is it more of a high frequency chatter?)
- Was bounce present at start-up? When did it begin? Is it getting worse or better?
- Was bounce present prior to last press fabric change?
- Were any press rolls changed immediately prior to start of bouncing?
- Did the next press fabric bounce? If so, answer the first two questions again.
- Is the fabric length a multiple of a press roll circumference? (What are the roll hardnesses? What is press loading? What was the effect of cocking the tradelines?)

Water-Handling Problems

Running Wet or Speeds Down

Press water removal may be less than standard resulting in slow speeds, increased dryer steam, increased draws, crushing, or increased paper breaks. Profiles may also be poor. Causes of running wet or slow speeds can be stock-related, machine-related or clothing related. Analysis of the problem can be very complicated:

(1) When did poor water-handling occur?
- Were start-up speeds down? How long?
- Were speeds slow late in life? When?

(2) How much were speeds down?
- What is normal speed?
- What is normal break-in time?

(3) Were press loads normal? If not, why?

(4) Was water removal equipment operating normally? How much uhle box capacity was available? Measure air flows if possible. How did uhle box vacuum (inches Hg) compare to normal?

(5) Were furnish and grades normal? Was the sheet wet on the wire?

(6) Did problem occur after any change such as press fabric or forming fabric change?

(7) How did the steam use compare to normal?

(8) Did any crushing occur? In what press? Was it localized?

(9) How was press fabric tradeline? Distorted tradelines can close up fabrics.

(10) Is the problem localized? If so, where?

(11) What is the effect of cutting back lube or cleaning showers?

(12) Is nip condition flooded or dry? Is there a save-all pan? What is the condition of roll doctors or purge showers?

(13) How did the previous and succeeding fabrics perform?

Marking

Sheet marking is typically caused by either the press rolls, press fabrics or the forming fabric. The marks can be either a physical impression or a flow pattern.

Physical impression marks are almost always a result of nonuniform pressing by the press fabric. It can be caused by yarns in the base fabric that are too large, too widely spaced, or too rigid. If insufficient batt is used or if the fabric is worn, base fabric yarns may become exposed and mark the sheet. Physical impression marks will typically occur in the latter presses where nip intensities are usually high.

Flow pattern marks are usually a result of flow resistance in the nip that causes lateral water movement in the sheet. This causes a concentration of fines and/or filler material in the sheet that shows the vented pattern of the press roll. The area over the suction holes or the roll grooves represents zones of low pressure under load that can cause a density variation in the sheet that may be visually apparent. Flow marks usually occur in nips where water loads are high. Worn press rolls are usually the cause; however, filled fabrics or fabrics that run too wet can contribute to the problem.

Determination of the Causes of Sheet Marking

(1) Examine sheet samples in low angle light (best at about 20°).

(2) What is the pattern of the marks?
- Can it be associated with the pattern of the press roll in the machine? Trace pattern from spare roll if possible or, if a grooved roll, count the number of grooves per unit length.
- Are there large number of marks per unit length? This will distinguish a press fabric mark from a groove mark.
- Is the direction of the mark diagonal? This will confirm or eliminate a forming fabric related mark.

- Is the mark on the top side or wire side? Which press fabrics and rolls contact which side? It needs to be determined which press fabric or roll is causing the problem.

(3) When did the marking begin?
- Does the date coincide with a roll change?
- Does the date coincide with a press fabric change?
- Have any press fabric or roll changes occurred since the beginning of the sheet mark problem?
- Did a roll change, press fabric change, or a forming fabric change eliminate the problem?

(4) What are the grinding schedules of the rolls in the machine? What is the remaining roll cover thickness compared to new?

(5) What are the loads? Are they normal?

(6) What are the roll hardnesses? Are they normal?

(7) How does the existing caliper of the press fabric compare with the initial or edge caliper?

(8) Is the press fabric surface soft; is the batt worn away?

(9) Is the press fabric carrying more water than normal?

(10) In all instances obtain a sample of both the objectionable mark and the sheet that is considered satisfactory.

Fabric Wear

Excessive press fabric wear has many causes which can be divided into three categories: mechanical, chemical, and hydraulic.

(1) Mechanical causes
- improper roll crown/load
- improper roll dubbing
- bad press roll bearing
- scissored rolls (misaligned press rolls)
- worn or rough suction box covers
- improper high pressure shower oscillation
- excessive shower pressure
- abrasives in the system
- worn or rough press rolls
- drag on the save-all

(2) Hydraulic causes: In some cases the press fabric is unable to handle water properly under load in which case hydraulic damage may occur to yarns and batt material.

(3) Chemical causes
- reductive agents in the system
- oxidative damage

Wrinkling

Uniform fabric tension across the entire width of the fabric is the best way to avoid press fabric wrinkling. The most common cause of uneven tension is uneven moisture distribution during press section start-ups. Proper wet up procedures will avoid slack areas or pockets that may develop wrinkles. Tradeline alignment can be an indicator of potential wrinkling. On exceptionally long draws, a supporting press fabric roll or bowed roll may be necessary.

In the event that wrinkling occurs, the press should be relieved and the fabric spread evenly across the width of the machine. Hot water or a steam hose may help flatten the wrinkle. The press should then be loaded lightly and started up slowly.

Drop-offs

Proper pick-up usually depends upon the presence of a uniform water film on the surface of the fabric to adhere the sheet to the fabric. Drop-offs can occur during the initial start-up or later in life. Many factors can influence the propensity for drop-offs:

- freeness of the stock
- press geometry
- sheet weight
- pick-up roll vacuum

Most drop-off problems occur during initial start-up of a new press fabric. In this situation the press fabric is usually designed too open or the batt component applied too coarse. Sometimes adding filler to the fabric or cutting back on uhle box vacuum will alleviate the problem. While the problem may be related to the design of the fabric, other factors could contribute to the problem:

- poor deckle trim
- improperly set pick-up roll vacuum deckle
- plugged suction pick-up roll
- improperly positioned pick-up roll
- worn forming fabric (poor sheet release)
- improperly set draws

Blowing

Blowing, like drop-offs, is influenced by the same factors and can either occur during the start-up of a new fabric or later in life. The majority of problems are usually initial and occur in the last press. Blowing is usually seen as a bubble or layer of air between the fabric and the sheet. The propensity for blowing is contributed by the press geometry. The sheet and fabric are in contact with each other entering into the nip. Air that is either entrained in the fabric or expressed backwards in the nip causes the sheet to lift off the fabric ahead of the nip. This can cause sheet wrinkles or breaks.

If the sheet blows when the fabric is new but stops after break-in, the fabric design may need to be modified to decrease the potential air volume in the fabric by increasing its density. Modifying the surface characteristics of the fabric may provide better contact between press fabric and the sheet. If the sheet does not blow when the fabric is new but blows as the fabric gets older, conditioning and cleaning efficiency may need improving or the fabric may need to be manufactured more open.

Sometimes, increasing sheet draws between the presses or running the fabric tighter can reduce or eliminate the blowing.

Crushing

Crushing may be caused by press loading too high for the flow resistance of the sheet. It also occurs when the press fabric can not accept the water at the rate it is squeezed into the fabric at the press. The result is a deformation of the sheet. On a new press fabric the problem may be too low a permeability or insufficient void volume within the press fabric. On an older fabric anything that reduces the void volume such as wear, filling or compaction contributes to crushing. Possible temporary solutions to minimize crush are to increase sheet temperature and to reduce press loads.

Troubleshooting guidelines for press section are given in Appendix C.

3.3.7 *Press Fabric Conditioning*

Press fabrics must be kept clean of filler materials that accumulate in their structure. Very seldom are press fabrics removed because they are worn out. They are generally removed because they are filled or compacted to the point where they no longer handle water uniformly or lack the drainage capabilities to maintain pressing efficiency. All fabrics should be continuously and mechanically conditioned from start-up to removal.

Good cleaning systems use hydraulic forces from high and low pressure showers to loosen and flush contaminants from the press fabric structure through a uhle box. A typical system includes a high pressure needle shower, a lubricating shower, and a uhle box and vacuum system (Figure 3.33). Chemical showers are sometimes used to facilitate the cleaning process.

Showers

High pressure showers provide hydraulic forces to loosen contaminants and minimize felt compaction. Continuous operation on the sheet side generally is most effective. Continuous application is recommended as it is easier to keep a fabric clean than to clean a fabric

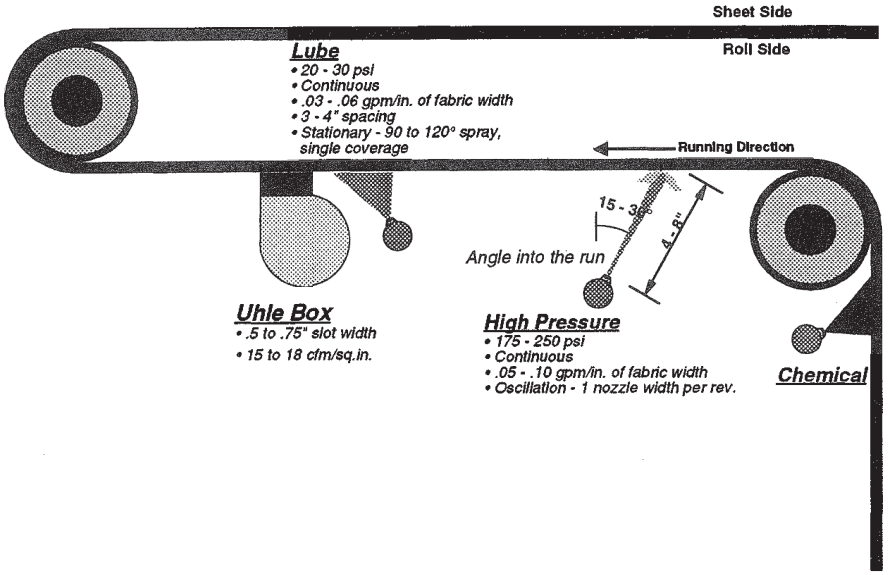


FIGURE 3.33. Press fabric conditioning system.

once it has become contaminated. Sheet side showers are more effective as the contaminants are usually filtered or trapped by the surface batt fibers and sheet side showers are more able to remove or loosen the contaminants. Roll side high pressure showers are usually not an effective means to clean the fabric. The pressures required to penetrate the base fabric and affect surface contaminants usually damage the press fabric.

Oscillator speed should be coordinated with machine speed so that the shower jet moves one nozzle width per fabric revolution. This provides complete coverage and cleaning of the fabric.

High pressure shower pumps must be interlocked with press drives so the shower will not operate when the fabric is not running, or if the oscillator fails.

Lube showers should be located immediately ahead of each uhle box on the same side of the fabric as the uhle box. These showers provide lubrication to reduce wear between the fabric and the uhle box cover.

Chemical showers provide a solvent or detergent that facilitates the cleaning process. The showers may be located either on the roll or sheet side and chemicals are applied at the point where the felt and felt roll converge. This provides a flushing action that allows the chemical to penetrate the fabric thoroughly. Chemicals that are used continuously should be applied to the fabric as far ahead of the uhle box as practical to allow sufficient time for the cleaning solution to work.

pH of the shower water and cleaning solutions is critical in that there should not be a large differential between the stock and the showers. The pH of the sheet and showers should not vary more than ± 1. This is to prevent pH shock that could cause precipitation of filler material. This guideline does not apply to batch cleaning as stronger solutions can be used to clean the fabric as long as it is thoroughly rinsed afterwards to neutralize pH.

Temperature of the shower water should be within $\pm 10°F$ of the stock temperature. As with pH, this is to prevent upset of the sheet in the press section.

Dewatering

The typical dewatering system consists of one or more uhle boxes connected to a vacuum pump. The variables that can usually be controlled in vacuum dewatering are dwell time (slot width), pressure difference (inches

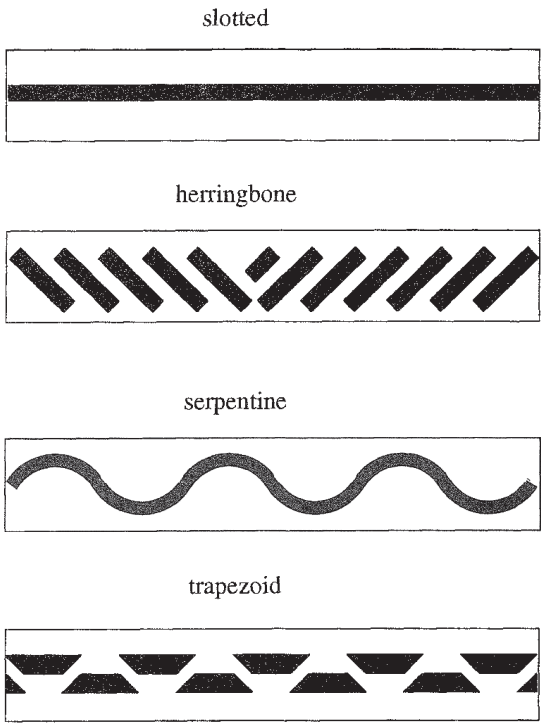


FIGURE 3.34. Common cover patterns.

of Hg) and pump capacity (cfm/sq in. of open area). Pump capacity is an important measure of dewatering energy and it should not be sacrificed to maximize one or more of the other variables. Uhle boxes do more than dewater fabrics. Showers loosen surface contaminants. The uhle box, not the showers, is the primary mechanism of fabric cleaning.

The ability to clean and dewater is related most closely to permeability. To optimize press fabric conditioning, a pump capacity of 15–18 cfm/sq in. is required. Uhle boxes on a single press fabric should be connected to a dedicated vacuum source. In nonisolated vacuum systems, air flow is proportionate to the fabric permeability.

Most uhle box covers are made from high density polyethylene. Other cover materials used are ceramic or ceramic composites. While ceramic covers are significantly more durable than polyethylene, they require greater care to prevent chipping and damage, and felt wear is usually increased. If ceramic is used, the radius of the trailing edge of the cover should be no less than 1/16 inch.

The most common cover pattern is single or double slotted. Other patterns used are the herringbone, serpentine, and trapezoid (Figure 3.34).

The illustrated specialty patterns are used primarily on positions where seam fabrics are used. They are designed to minimize wear at the seam by providing support over the slots and reducing the degree in which the fabric is pulled into the slots. It is recommended that slot widths be no wider than 1 inch to minimize wear and shedding.

In order for a press fabric conditioning system to operate efficiently and effectively, special attention should be given to the design of the vacuum system. There are four common sources of problems with the vacuum system (Figure 3.35).

(1) Uhle box and piping diameter: Uhle box tubes should be sized to keep the linear air velocities through the pipe below 5000 fpm. Air velocities significantly in excess of this speed induce a pressure gradient from the blanked end of the uhle box tube to the outlet side. This creates a skewed moisture profile in the fabric.
(2) Convolution: Excessive turns and angles in the piping results in a loss of vacuum efficiency. This is important with systems that are marginal for vacuum.
(3) Infiltration: Atmospheric air that enters the system through improperly sealed joints or holes in the piping robs the fabrics of vacuum.
(4) Drop leg: An inch of Hg is roughly equivalent to a foot of water. If the drop leg to the seal pit lacks sufficient height, the inches of Hg at the uhle box can exceed the footage height of the drop leg. This can result in water being sucked from the seal pit back into the uhle box.

3.4 Service for Press Fabrics

3.4.1 *Service Laboratories*

Paper machine clothing manufacturers established customer service laboratories to enable the papermaker to learn more about the

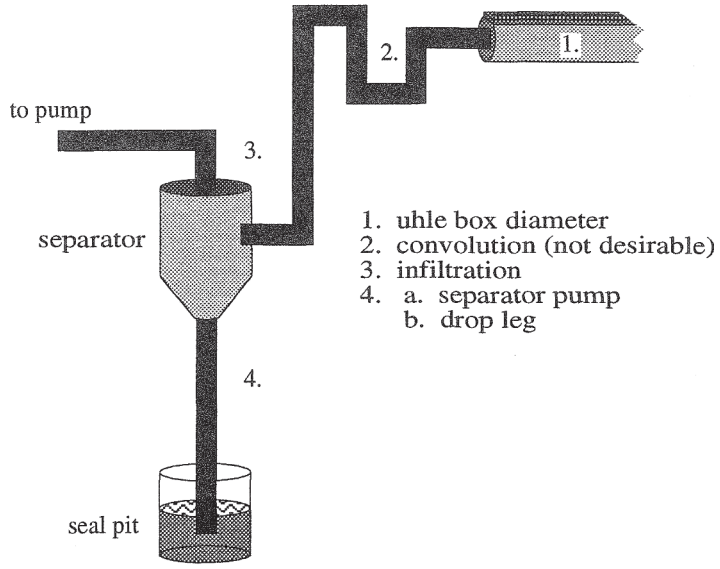


FIGURE 3.35. Typical vacuum system problem areas.

solution to press fabric problems. Working with returned, used fabrics, the laboratory often identifies the conditions that help determine the cause of the less-than-satisfactory fabric performance.

A comparison of the initial and residual measurements are made to determine the condition of the fabric. As a general rule, a laboratory analysis on a used fabric is a good tool for trend analysis and data comparison as well as to identify press section and machine-related problems.

Laboratory analysis, in general, does not provide enough information to understand application related problems. Application problems, such as initial blowing and drop-offs, that result from the design specification of the press fabric are usually diagnosed with data gathered from on machine performance compared to normal operation (Chapter 5). In some cases, the physical analysis of the fabric helps resolve application problems.

Chemical Analysis

Standard fill-up analysis determines the general type of plugging materials. These are divided into four categories:

- alkaline extractables—pitch/oil, starch, dyes, salts, dirt and detergents
- alcohol extractables—grease, oil, tar, wax, ink, pitch, and stickies (resins and latex)
- ash—alum, titanium, clay, iron, sand, talc and all inorganics
- cellulosic materials—paper stock and fines

Qualitative analysis is done for positive identification of any material in the four categories above. Infrared spectrophotography is used for specialized identification of foreign materials in the used fabric that are difficult to identify. Chemical degradation tests are done for acid, alkaline, reductive and oxidative damage.

Physical Analysis

Strength tests and profiles are done to determine the residual strength of used fabrics compared to original strength. This often reveals if the fabric could have performed longer. Profiles indicate possible problem areas such as undercrown, overcrown, misaligned rolls, worn suction boxes or any source of unusual machine wear across the width of the fabric. Weight profiles can confirm these problems as well. Caliper profiles reveal problems of uneven compaction and/or uneven physical wear. Air permeability profiles can reveal any

filled or compacted streaks across fabric width.

3.4.2 *Technical Service*

In today's practice in the papermaking industry, technical service is the primary contact a clothing supplier has with its customer and product. Outside of direct communication with the paper machine superintendent usually performed by the sales engineer, the technical service engineer is the main source of running performance information.

In general, technical service is made up of the following:

- general visual observations of the press clothing and sheet
- physical measurements of the press clothing and sheet using specialized instrumentation
- a thorough analysis of the data to translate how well the clothing is performing
- a usable report documenting findings and making pertinent recommendations

The technical service engineer reviews the press section performance and records baseline information for future comparisons. Engineers use a variety of instruments to collect baseline information. These instruments are useful to the papermaker as troubleshooting tools and as capable aids in setting and maintaining machine variables. The most widely used instruments and measurements are listed below:

- tensiometer: This instrument measures fabric tension in pli.
- running caliper gauge: The running caliper gauge is used to measure the thickness of running fabrics, which is useful when predicting fabric removal and determining loading conditions.
- gamma gauge: The gamma gauge measures the mass of the fabric. The reading obtained with the gamma gauge can be used to help determine the water balance in the press.
- water content in the fabric: Microwave measuring instruments are used to measure the amount of water in the fabric. These measurements are used to evaluate the profiles of the press fabrics.
- draw measurement gauge: Tachometer devices are used to measure clothing and sheet draw in real time to determine draw schedule throughout the machine.
- vibration analysis: Synchronous time averaging with Fast Fourier Transform (FFT) analyzer can isolate vibration sources and determine how much influence each source is having on the overall vibration in a press section.

The following TAPPI procedures can be used to analyze press and press clothing performance [7].

(1) TIS 014-46 Press Section Monitoring: This method discusses the following parameters: fabric thickness, fabric total mass, fabric water content, sheet water to fiber ratio, degree of fabric filling/openness (permeability), running fabric length, fabric tension, fabric tradeline distortion, fabric and roll speeds, press vibration, press roll alignment, press roll crown.
(2) TIS 014-54 Paper Machine Clothing Performance Analysis: This method provides guidelines for good clothing performance analysis

3.5 Press Types

Press types have evolved over the years to achieve faster speeds, improve water removal, and influence sheet properties. The following illustrations and discussion will comment on these press types and how they relate to the degree of two-sidedness in the sheet and how they can influence press fabric performance.

Two sidedness is defined as the percent drop in brightness from top side of the sheet to the bottom side based on the K&N ink test [8]. K&N ink test measures the percent drop

in brightness between the uninked and inked sample.

$$\% \text{ Drop} = \frac{\left(\begin{matrix}\text{Initial} \\ \text{Brightness}\end{matrix} - \begin{matrix}\text{Final} \\ \text{Brightness}\end{matrix}\right) \times 100}{\text{Initial Brightness}} \tag{3.2}$$

$$\text{Two Sidedness} = \% \text{ Drop Bottom} - \% \text{ Drop Top} \tag{3.3}$$

The sheet from a fourdrinier is more dense on the top side due to the wash out of fines and fillers on the bottom side of the sheet. The surface density of the sheet is increased on the fabric side of each nip. The effect on sheet density is greater with each proceeding nip. Surface smoothness is used to indicate two sidedness. Sheet smoothness is measured with the Sheffield and Parker Print methods.

3.5.1 *Straight-Through™ Press (Figure 3.36)*

This press type covers an extremely wide grade and speed range as well as a range of nip conditions. Specific fabric requirements depend on water load, speed, sheet properties, sheet weights and nip conditions.

- used on virtually all grades
- variations in this type of press include inverted and reversed 2nd press (fabrics on the top side of the sheet)

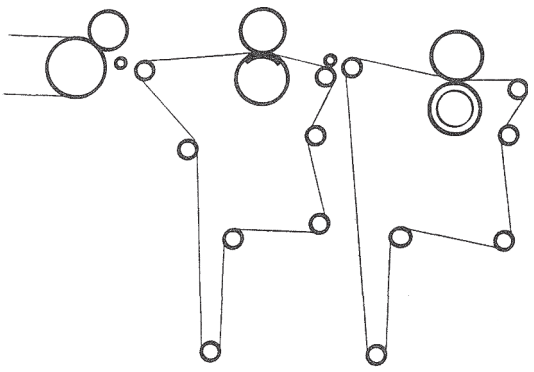


FIGURE 3.36. Straight-Through™ press.

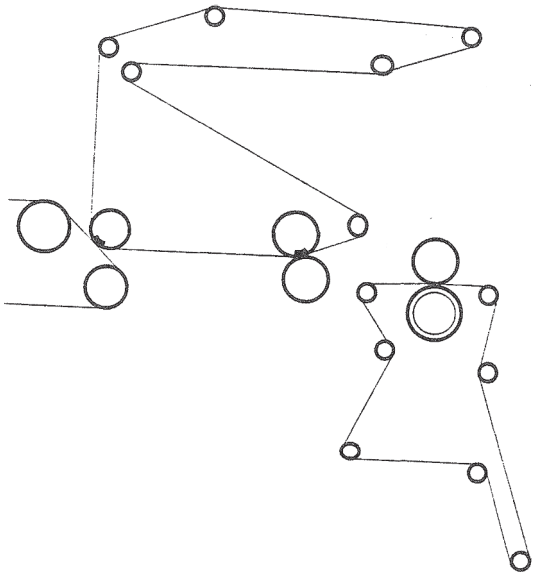


FIGURE 3.37. Inver press.

- open draws prone to sheet breaks
- prone to blowing and wad burns, if top roll not doctored
- speeds limited due to sheet breaks at open draws.
- installation a problem with multilayered fabrics

3.5.2 *Inver Press (Figures 3.37)*

This type of press is generally used to make light to medium weight fine paper grades at low to medium speeds.

- common press arrangement for fine paper grades
- prone to drop-offs with some grades
- 2nd press prone to sheet blowing
- KN: +2 to +4

3.5.3 *Twinver™ Press (Figure 3.38)*

This type press configuration was a forerunner of the no-draw cluster press. Newsprint and LWC grades at medium to high speeds are generally made on the Twinver™.

- common press arrangement for light weight, high-speed grades (news and fine)

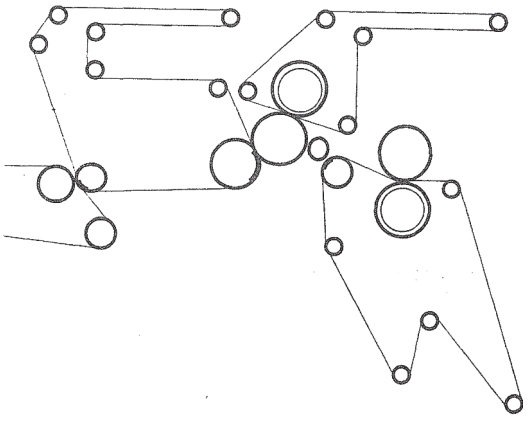


FIGURE 3.38. Twinver™ press.

- prone to sheet stealing or edge flipping by pick-up at the center roll
- 3rd press prone to vibration
- prone to drop-offs with some grades
- prone to sheet blowing in the 3rd press
- KN: +5 to +7

3.5.4 *Combi Press (Figure 3.39)*

This press has many of the characteristics of the Twinver™ press but without the disadvantage of a long inverted run which is prone to drop-offs. It is a compact arrangement that can be applied in a limited space.

- compact press arrangement
- no-draw effect through first two nips

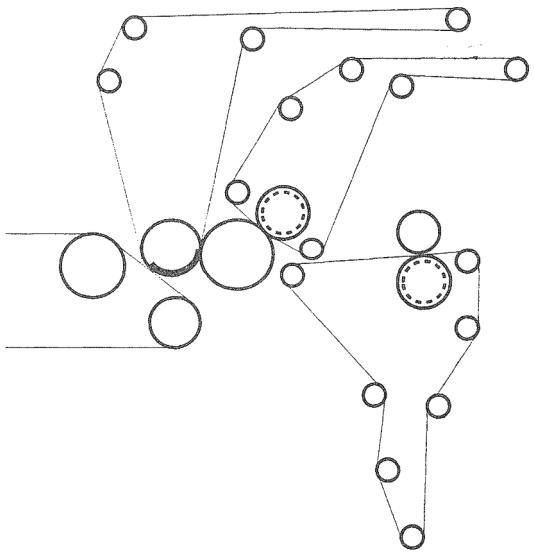


FIGURE 3.39. Combi press.

- less prone to drop-offs compared to a Twinver™ or Inver press
- pick-up prone to shadow mark with suction holes greater than 9/16 inch
- loads limited by single-felting (crush) and load differential between 1st and 2nd nip on center roll
- without 3rd press, KN: +10 to +13 (very two sided); with 3rd press KN: about +7
- difficult press fabric installations

3.5.5 *Four-Roll, No-Draw Presses*

TriNip™ is the most popular press arrangement for all high speed fine and newsprint grades (Figure 3.40). Double felted first nip allows for higher press loads without crush. A 4th press adds symmetry to sheet quality.

- popular no-draw, high-speed press
- double-felted first press prevents crushing and allows higher loads
- prone to shadow mark due to two nips on suction roll
- prone to sheet stealing by pick-up with some geometries
- 3rd press prone to vibration
- KN: +9 to +12 (very two-sided); the last two presses have fabrics on the top side.

TriVent™ is evolved from TriNip™ press arrangement (Figure 3.41). Separate 2nd press

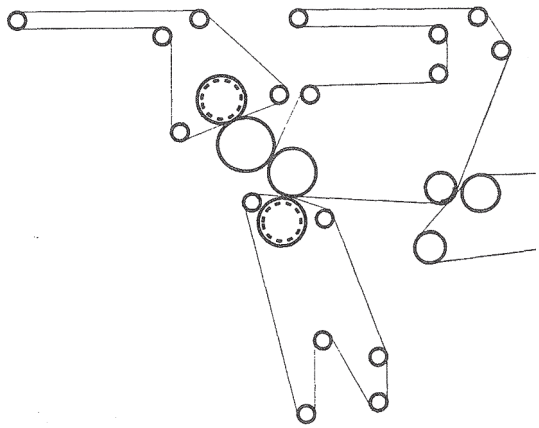


FIGURE 3.40. TriNip™.

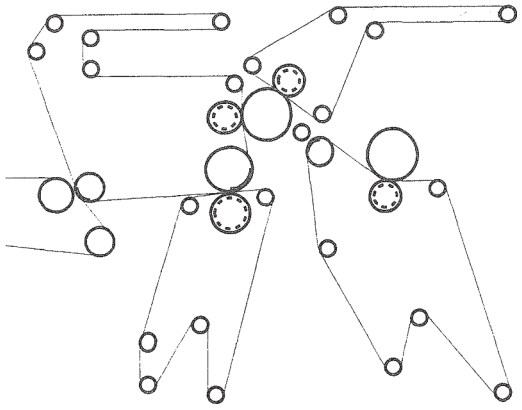


FIGURE 3.41. TriVent™.

reduces propensity for shadow mark and allows for higher loads in the 2nd and 3rd nips.

- able to obtain higher press loads in the 2nd and 3rd press nips
- prone to water rejection in the 2nd nip
- other characteristics same as TriNip™

3.5.6 *Three-Roll, No Draw Presses*

Alternative to TriNip™ arrangement, the BiNip™ press is popular on medium to heavyweight grades (Figure 3.42). It improves bottom side sheet densification.

- less two-sided due to last felt on bottom side; KN: +5 to +7
- double-felted first press prevents crushing and allows higher loads
- prone to shadow mark due to two nips on suction roll

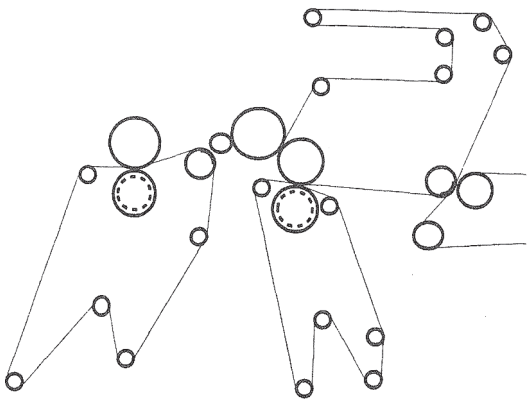


FIGURE 3.42. BiNip™.

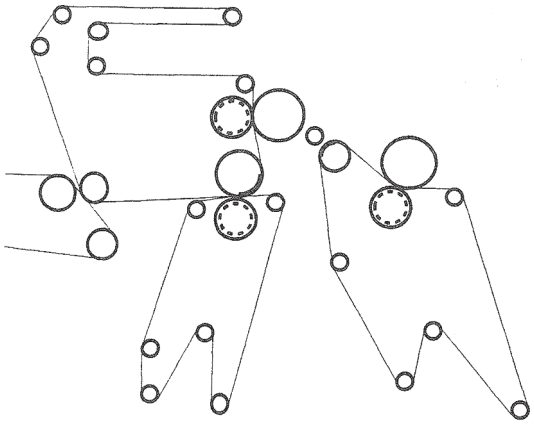


FIGURE 3.43. BiVent™.

- prone to sheet stealing by pick-up with some geometries
- 3rd press prone to blowing and wad burns

BiVent™ is evolved from the BiNip™ press arrangement (Figure 3.43). Separate 2nd press reduces propensity for shadow mark and allows for higher loads in the 2nd nip.

- prone to water rejection in the 2nd nip
- able to obtain higher press loads in the 2nd and 3rd press nips
- other characteristics same as BiNip™

3.5.7 *Shoe Presses*

Shoe presses were developed to increase the nip residence time for improved water removal and sheet densification. These presses operate up to 8500 pli with nip widths up to 10 inches. Sheet consistencies in some instances have improved 3 to 4% out of the press section. In all cases, sheet density is increased. The predominant grades made with shoe presses are linerboard and corrugating medium with some bleached board machines equipped with shoe presses. Recent innovations have seen application of shoe presses for fine paper and newsprint grades.

The original shoe press developed by Beloit consists of a special blanket or belt that runs inside the felt run and is pressed by a hydraulic shoe that forms the nip. Recent developments have eliminated the blanket run and contain

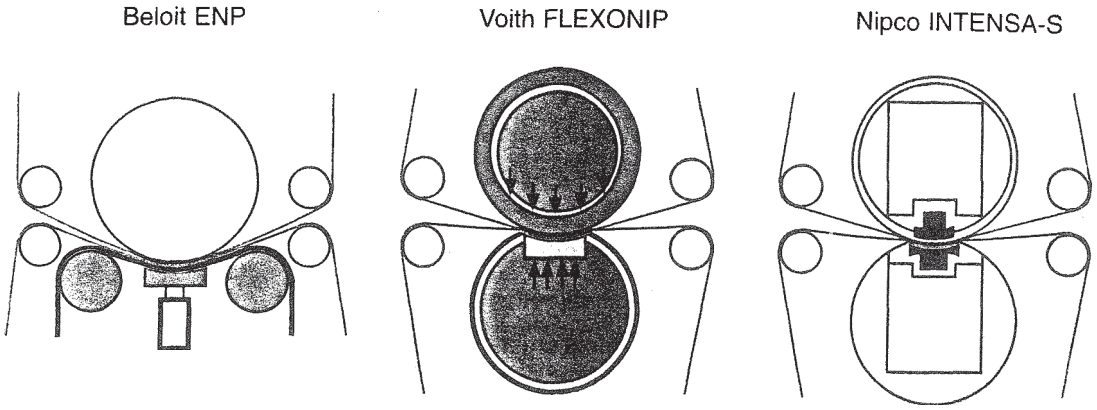


FIGURE 3.44. Shoe presses.

the shoe press inside a large diameter roll (Figure 3.44). Felt compaction and mark are potential problems with shoe presses. High water loads necessitate high void volume press fabrics.

3.6 References

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3.7 Review Questions

1 Explain how water is removed from the sheet in the press section.

2 What are the differences between flow controlled nips and pressure-controlled nips?

3 Compare the requirements of press fabrics to those of forming fabrics. Which type requires more stringent properties?

4 Explain the differences in manufacturing of press fabrics from forming fabrics.

5 What are the reasons for press fabric treatments? Explain.

6 Define press vibration. What are the causes of it? What are the remedies?

7 What are the effects of distance- and speed-producing devices?

8 Find out how the K&N ink test is done. What is the significance of this test?