# 3

# Pressing

The press section is the next part of the paper machine after the forming section. The most important functions of pressing are to increase sheet solid consistency in order to ensure adequate drying capacity, to consolidate the sheet, and enable web runnability in the early dryer sections. Increased sheet consistency increases wet strength and improves sheet consolidation and fiber-to-fiber bonding which increases sheet strength. This typically improves runnability and reduces press to dryer draw. Pressing can also have a significant impact on quality parameters such as smoothness, ink absorption, bulk, and moisture profile. 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 interchangeably in papermaking. 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 45% fiber and 55% water. At the end of the press section, the sheet is transferred to the dryer section.

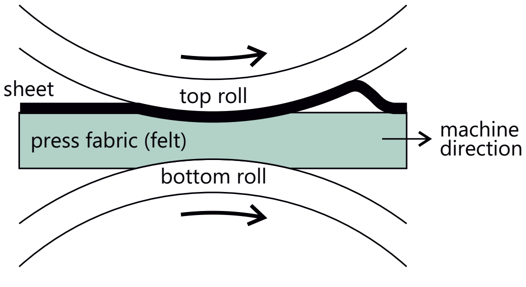


FIGURE 3.1. Schematic of simple press nip.

During pressing, the sheet is compressed between one or two fabrics and either two rolls, or a roll and a mated extended "shoe" 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 to support and convey the sheet through the press section, press water from the sheet, provide a medium to accept the water, maintain or impart sheet quality properties, and to drive undriven rolls. The fabric should provide proper protection for the sheet to resist crushing, shadow marking and groove marking. 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 the ability to maintain void volume under load are important during operation. Important press fabric properties include pressure uniformity, adequate void volume, required permeability, proper compressibility, batt/base ratio, compaction resistance, abrasion resistance, strength, contaminant resistance, heat and chemical resistance.

Many machine variables can significantly impact pressing. A high sheet basis weight increases the water that must be handled by the press. A higher sheet temperature lowers water viscosity and increases sheet solids. High press impulse (kPa.sec, psi.sec), the product of mean nip pressure (kPa, psi) and nip dwell time (usually measured in ms), increases total water removal and press solids. Press impulse is also the quotient of press nip linear load (kN/m) divided by press speed (m/sec), with the unit of $kN/m^2$ x sec = kPa.sec. The type of furnish and amount of refining affect the freeness and dewatering characteristics of the sheet. For example, higher freeness furnish and/or decreased refining yields higher solids out of the press. For each example, a change in the opposite direction would have the opposite effect.

## 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 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: Due to 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: Due to 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.

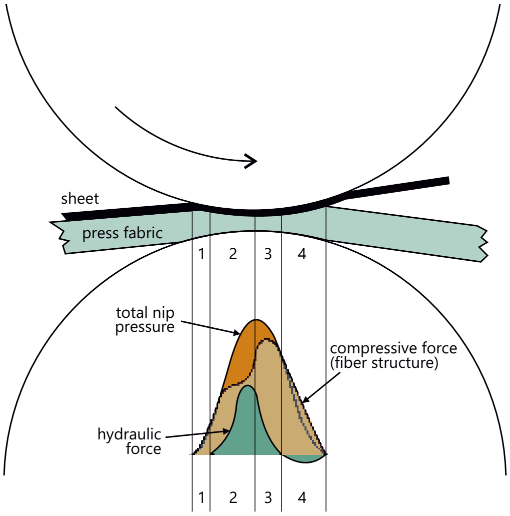


FIGURE 3.2. Transversal flow nip.

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 water to flow 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 into 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 Wahlstrom's model [4] can help identify the terms of compromise when pressing. The following equation represents a model for outgoing moisture ratio for a nip.

$$MR_{out} = k - f_1 - f_2 - f_3 - P - RW - R_1 - R_2$$

*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 non-uniform 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 rewetting 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.

*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 | ↑ | ↗ |

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.

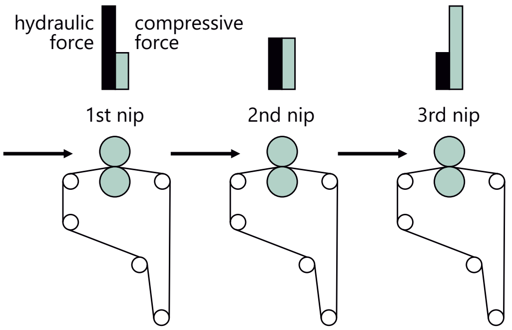


FIGURE 3.3. Distribution of hydraulic and compressive forces at different nips.

## Nip Dewatering

One concept that has gained attention in recent years is “nip dewatering”. Nip dewatering occurs anytime the water added to the nip by the conditioning system (the net effect of showers and vacuum) and water in the sheet exceeds the press fabric’s ability to handle it.

It has long been understood that the incoming fabric’s moisture ratio (MR) is a critical factor to effective water removal (Figure 3.4).

A fabric with a water content that is too low going into the nip will generate low hydraulic pressure. This is typical of fabrics which are too open or have too much void for the conditions. When this occurs for a brief period at the beginning of a fabric’s life, it is commonly referred to as the “break-in” period.

A fabric with a water content that is too high going into the nip can overwhelm roll void causing nip rejection (water being expressed at the nip entrance) or worse - sheet crushing.

It is a key objective of press fabric designers to design a fabric that will operate in the optimal hydraulic pressure zone.

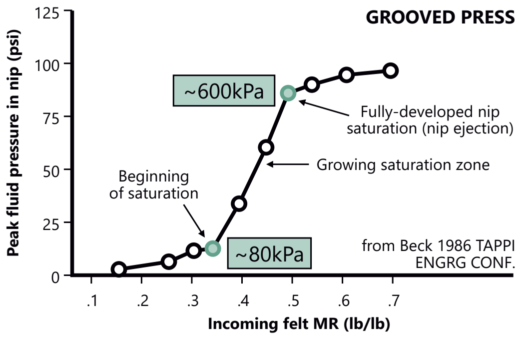


FIGURE 3.4. Sudden rise in fluid pressure with nip saturation (modified after [5]).

## 3.2 Press Fabrics

### 3.2.1 *Press Fabric Functions*

Once stock leaves 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, the cost of additional water removal is far less in the press section than the dryer section. Mechanically removing water in the press section by increasing nip pressures is far less costly than consuming energy in the dryer section. Therefore, the value of efficient press fabric performance cannot be overemphasized.

Water removal is not the only function of the press fabric. 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 sheet crushing (rupturing the sheet due to excessive hydraulic pressures).
    - Resist shadow mark (water flow mark in the sheet caused by the difference in hydraulic pressure between the land area and open area in a vented roll cover).
    - Resist groove mark (water flow mark in the sheet caused by the difference in hydraulic pressure between the land area and open area in a grooved roll cover).
    - Resist base fabric mark (imprint of base fabric).
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 being manufactured. This is particularly critical on paper or board that is to be printed.
4. Transport and carry the sheet. 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 from contaminants transferred from the sheet.
6. Drive non-driven rolls in the press section.

### 3.2.2 *Construction of Press Fabrics*

Press fabrics, in general, consist of two basic components as shown in Figure 3.5: the base fabric and the batt.

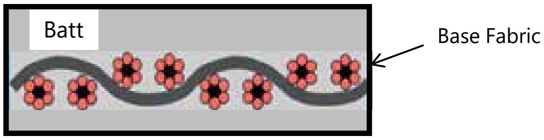


FIGURE 3.5. Typical press fabric structure.

**The Base Fabric**

Press fabrics are made of 100% synthetics, primarily polyamide (nylon) polymers. Base fabrics are constructed with cabled monofilament, single monofilaments (solid or hollow), or plied multifilament yarns (Figure 3.6).

With the increased use of recycled fibers in the paper stock, the use of plied multifilament yarns has greatly been reduced. Multifilament yarns tend to trap contaminants and are therefore more difficult to keep clean.

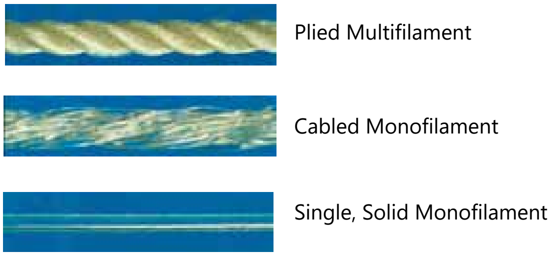


FIGURE 3.6. Yarn types.

Each yarn type 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, ease of cleaning and ease of installation.

Primary characteristics of the commonly used yarns are given in Table 3.2.

*TABLE 3.2. Characteristics of Multifilament and Monofilament Yarns Used in Press Fabrics.*

| Multifilament | Monofilament |
|---|---|
| Less durable | More durable |
| Supple | Stiffer than multifilament |
| Compressible | Resists compression |
| Higher elongation | Less stretch than multifilament |
| Low resistance to chemical attack | Better resistance to chemical attack |
| Poor cleanability | Easier to clean |

The base fabric may have a single-layer construction (one layer of MD yarns and one layer of CD yarns), a woven multilayer construction (multiple layers of MD yarns with only one layer of CD yarns), or a laminated, multiple base construction with multiple layers of both. The advantage of the multiple base construction design is that the base layers can be of different designs. They may vary in yarn count, yarn size, weave pattern, etc. For example, the top base layer can be very fine to impart the desired sheet properties and the bottom layers can be coarser in order to provide the necessary water handling properties. Laminated fabrics allow a wider range of base fabric pressure uniformity and low batt/base ratio, which is critical for open and clean operation. As paper machine speeds increase, the nip residence time decreases and better surface contact between the sheet and press fabric becomes a requirement.

The fabrics can be endless or joined with a seam. The yarn type selection and weave pattern of the base fabric are engineered to manipulate pressure uniformity, flow resistance, void volume, and compression properties. In practice, the basic classifications of press fabrics are: conventional (endless) designs, stratified (laminated) designs, and seamed fabrics. Figure 3.7 shows a few of the main types of base fabrics used in press fabrics.

Depending on construction, base fabric weight can range from 300 gsm (1.0 oz/ ft$^2$) for a single-layer base to 1099 gsm (3.6 oz/ft$^2$) for a triple-layer or four-layer base. Total finished fabric weight can range from 1068 gsm (3.5 oz/ft$^2$) to 2136 gsm (7.0 oz/ft$^2$).

It should be noted that single-layer base products are quickly becoming inadequate on most paper machine applications. They simply are not durable enough to withstand the forces generated on modern machines.

Seamed fabrics have shown a substantial increase in usage since their introduction in the late 1980s. In North America, approximately 75% of all press fabrics used are seamed, and that proportion continues to grow as seam technology has proven suitable for more applications. The use of seamed fabrics in Asia and Europe is less prevalent. The primary factors for the increase in use of seamed products are safety, reduced installation time and, in some cases, improved press fabric performance. There are basically two major types of seamed products (Figure 3.8): conventionally woven base, and laminated, multiaxial base (multiaxial in that the base layers are slightly angled to one another).

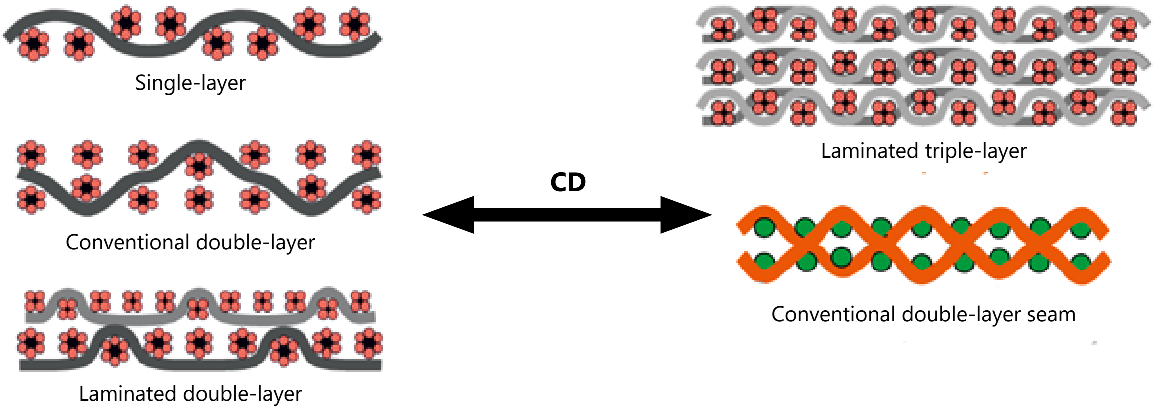


FIGURE 3.7. Major types of base structures.

FIGURE 3.8. Seamed press fabrics.

Conventionally woven seam bases are woven endless on traditional weaving looms with the seam loops formed on one edge during the weaving process (Figure 3.9). Conventionally woven seam bases have multiple layers of MD yarns with only one layer of CD yarns that are interwoven to lock the structure together.

FIGURE 3.9. Conventionally woven seam base.

Unlike conventionally woven bases, multiaxial bases are woven flat, similar to forming and dryer fabrics. Multiaxial bases are woven on high-speed, fully computerized weaving looms. The product quality and production rates are far superior to that of a conventional weaving loom.

Multiaxial weaving looms produce approximately 1.0-meter-wide panels of base material. The panels are then bonded together to a width suitable for any paper machine. The bonding of the base panels creates a slight spiral orientation of the base material (Figure 3.10). Multiaxial base angles vary between ~1-3° depending on fabric length and seamed or endless construction. Multiple base layers are laminated together with each layer angled in the opposite direction from the previous layer.

Forming the seam loops on a multiaxial base is also a different process compared to conventionally woven seamed felts. The seam loops on multiaxial products are not formed during the weaving process. After the base structure is completely bonded, the loops are formed by the removal of CD yarns on two opposite ends (180° apart) of the base. This leaves an opening in the weave pattern where the MD yarns can mesh together to form the loop. The number of CD yarns removed is dependent upon the desired length of the loops; longer loops if faster installation is the papermaker's top priority and smaller loops if mark resistance is more important (Figure 3.11).

## The Batt

The process by which the batt is locked to the base fabric is called needling. The batt is first carded into a uniform web and then is applied in a series of layers onto the base fabric. The web and base fabric are fed through zones on

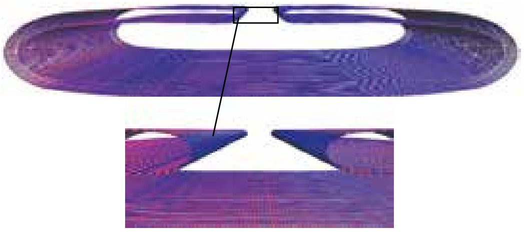


FIGURE 3.11. Seam loop formation on multiaxial base.

FIGURE 3.10. Multiaxial base production.

the needle loom where thousands of reversed barbed needles punch into the composite to lock the web to the base fabric. The batt is typically spliced at the start and stop of web application.

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. Another common unit is the decitex. Denier is actually a weight measure, but is globally accepted as an indicator of fiber fineness. As long as the specific gravity of the polymer is approximately the same, denier can be used to compare fiber diameters. Batt fibers range in size from 1.5 to 200 denier; the smaller the denier, the finer the batt fiber. The definition of denier is grams/9000 meters. A decitex is equivalent to grams/10,000 meters; therefore, the values are fairly similar between those units (denier/ 0.9 = decitex, decitex x 0.9 = denier).

The relative sizes of the most common fibers used in press fabrics are shown in Figure 3.12, and their relative impact on sheet properties are shown in Figure 3.13.

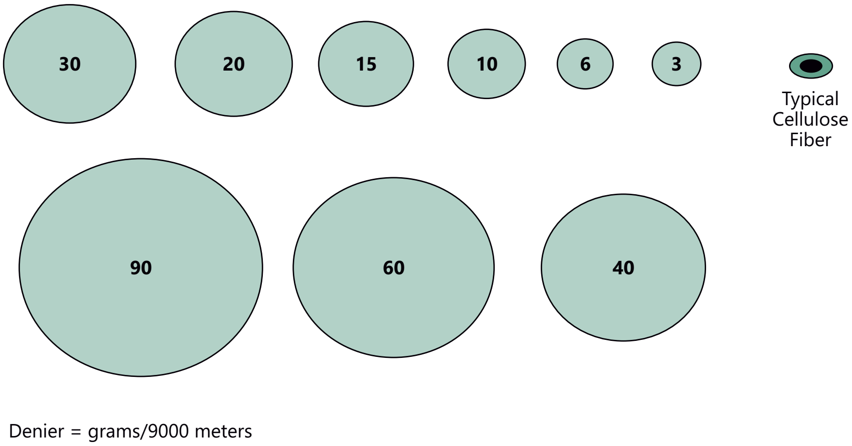


FIGURE 3.12. Relative sizes (in denier) of the most common batt fibers used in press fabrics.

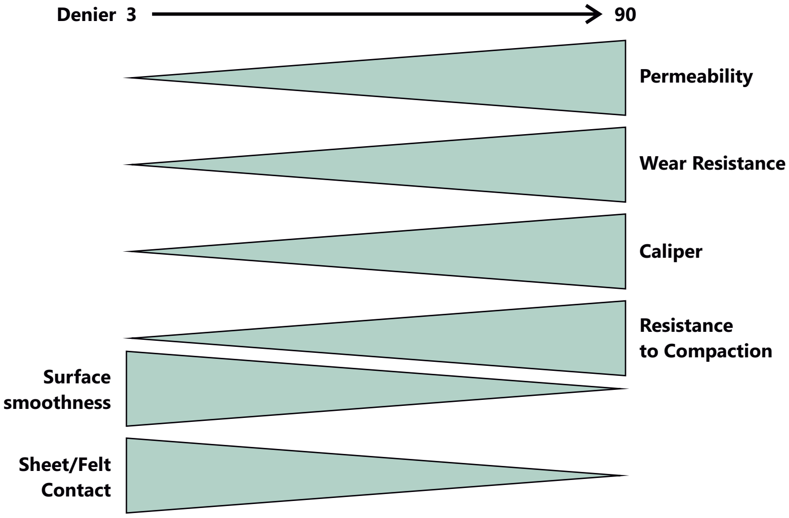
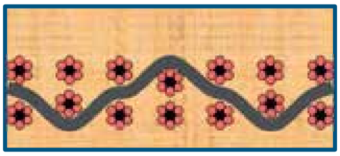


FIGURE 3.13. Effect of fiber denier on press felt properties.

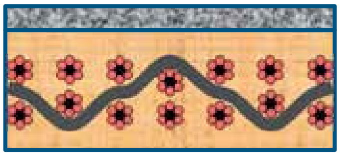
Many factors influence the selection process of the fiber denier (diameter). These include:

1. Pressure uniformity requirements
2. Water handling requirements
3. Break-in time (the time necessary for the paper machine to return to normal operating conditions)
4. Available Uhle box vacuum
5. Sheet control issues such as drop-offs, blowing, and sheet stealing
6. Fiber shedding propensity
7. Filling propensity
8. Bleed-through propensity

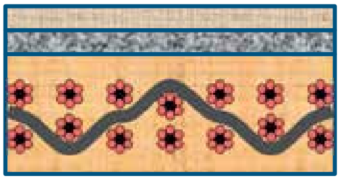
Fibers with different deniers can be blended or applied in stratified layers for desired performance attributes. Figure 3.14 shows the most common means of batt application. Figure 3.15 shows cross-sections of actual finished press fabrics.



Same denier batt throughout fabric

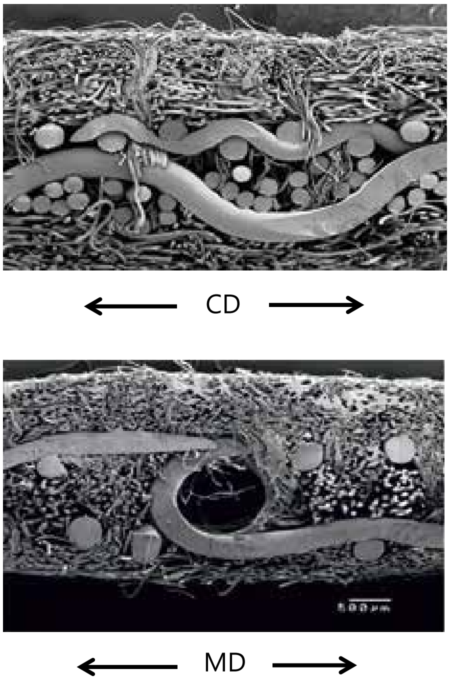


Fine denier cap over coarse fibers



Extra fine cap over medium denier intermediate layer with coarse fibers surrounding base fabric

FIGURE 3.14. Various batt applications.



Seamed felt with MD yarns forming the loops

FIGURE 3.15. Cross-sections of finished press fabrics.

### *3.2.3 Manufacturing of Press Fabrics*

Due to the needling process, the manufacture of press fabrics is different than forming or drying fabrics. Figure 3.16 shows the major manufacturing steps for press fabrics. The diagram shows all three methods of producing base fabrics: conventional weaving, multiaxial weaving, and nonwoven base formation.

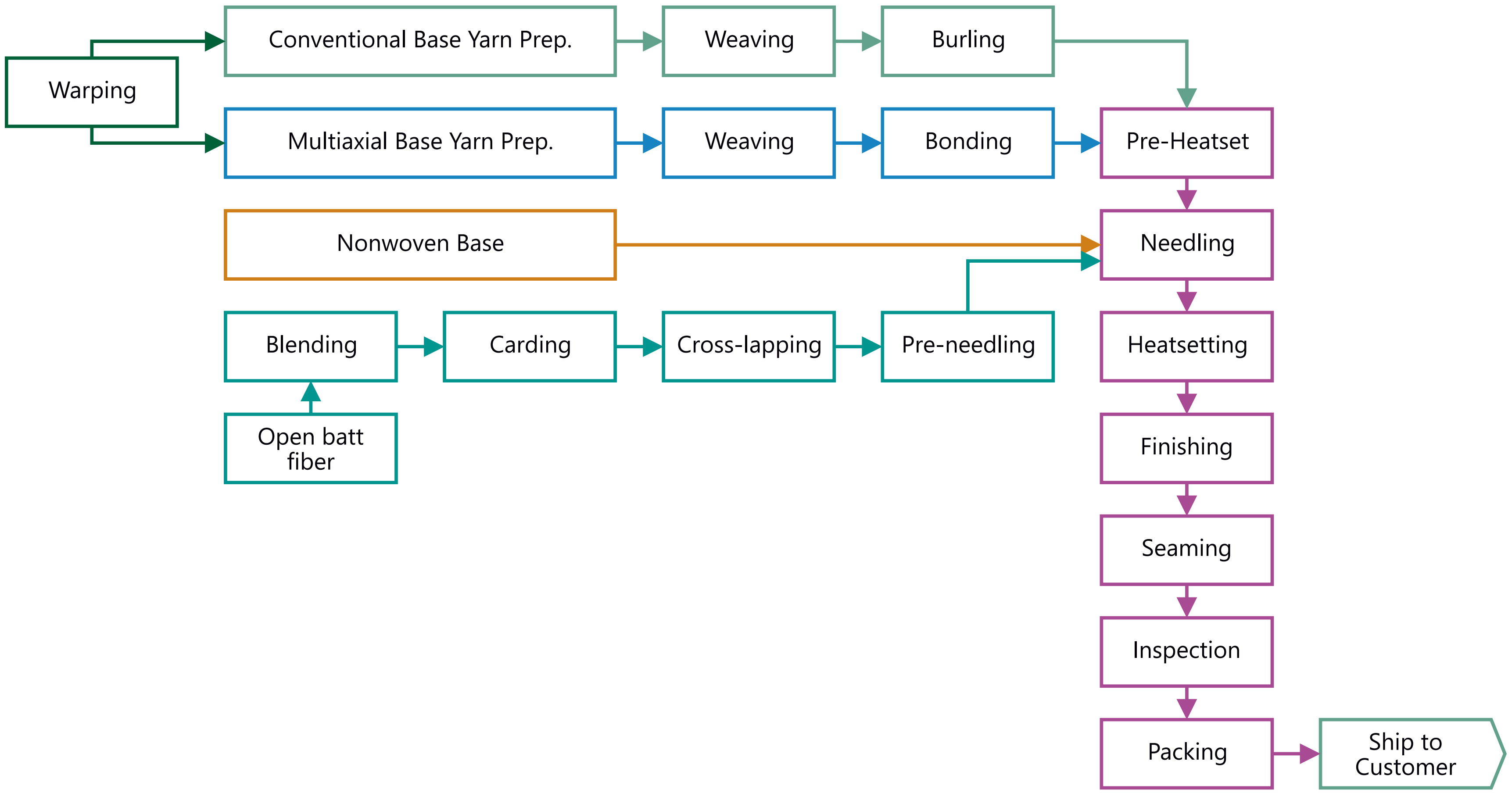


FIGURE 3.16. Process flow-chart for production of press fabrics.

### Yarn Winding and Warping

Yarns used to create base fabrics typically arrive at the manufacturing facility on large spools. They must then be transferred either onto bobbins that are inserted in shuttles for conventional weaving, or onto canisters (drums) to be put onto the back of conventional looms as warp beams (Figures 3.17 and 3.18).

FIGURE 3.17. Bobbin winding.

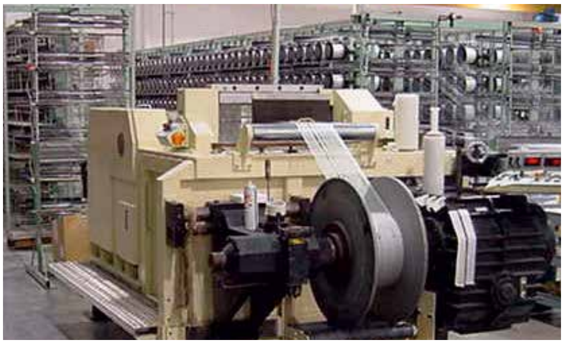


FIGURE 3.18. Warping.

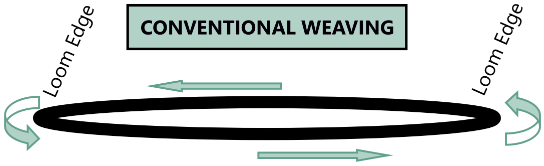


FIGURE 3.19. Conventionally woven base.

FIGURE 3.20. Endless weaving loom.

### Conventional Weaving

Endless fabrics are woven in a loop with the filling yarn forming the length of the fabric and the warp yarns forming the width. Fabric length will be twice the reed width (Figure 3.19 and see Figure 2.22 for view of reed in a loom). Woven loop seam fabrics are woven similar to an endless fabric; however, loops are formed at the ends of the fabric. Some looms for endless weaving are as wide as 31 m (102 ft) (Figure 3.20).

### Multiaxial Weaving

Much of multiaxial weaving technology is described in Section 3.2.2 explaining the production of multiaxial seamed felts. In addition to seamed bases, multiaxial bases can also be endless (the step of forming the loops is bypassed).

### Nonwoven Base Structure with Yarns Oriented in only One Direction (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. The yarns are encapsulated within a fibrous membrane. Figure 3.21 shows a nonwoven base material.

The top illustration in Figure 3.22 shows a triple-layer no-crimp felt structure and the bottom shows a double-layer base structure with one layer of nonwoven material laminated on top of one layer of woven material. Such nonwoven structures are excellent in providing pressure uniformity due to the absence of weaving knuckles. The generally low void volume of these fabrics has also been applied successfully where immediate nip dewatering is desired for the quickest break-in.

FIGURE 3.21. Nonwoven base material.

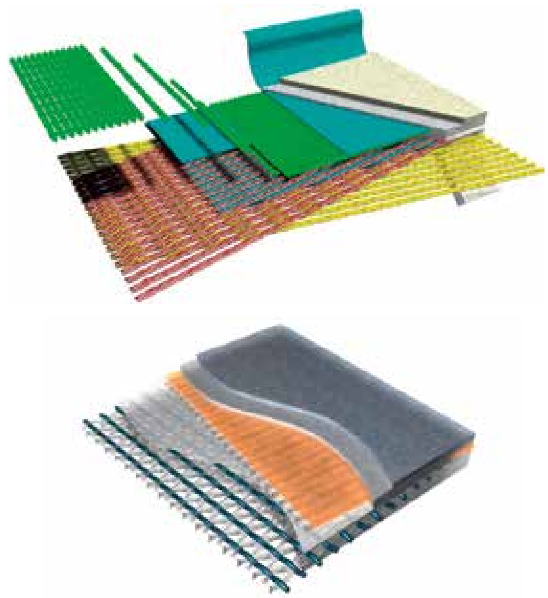


FIGURE 3.22. Nonwoven base products.

### Burling (Base Fabric Inspection)

Following the weaving operation, all base fabrics are thoroughly inspected to ensure there are no defects.

### Base Fabric Pre-Heatset

Base fabrics are then heatset (thermal stabilization), under tension, in order to eliminate any tension variations in the base materials and to transfer crimp from the MD yarns to the CD yarns. Too much crimp in the MD yarns can cause the felt to stretch excessively once tension is applied.

### Batt Preparation and Pre-Needling

Batt fibers are blended, carded (fiber combing and alignment), pre-needled (lightly needle punched), formed into a uniform layer of web and rolled onto an aluminum pole (Figures 3.23 and 3.24).

FIGURE 3.23. Carded web.

FIGURE 3.24. Pre-needled batt.

### Needling

The next step in the manufacturing process is needling. This is the operation where the carded and pre-needled batt is unrolled and needle punched into the base fabric.

Figure 3.25 shows the schematic of the needling process and a barbed needle used for this purpose. The needles move 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. 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 thermally fusible fibers, can be used to improve bonding.

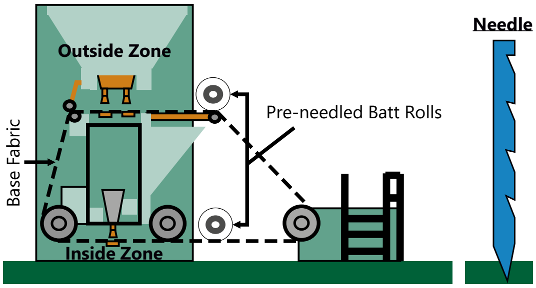


FIGURE 3.25. Schematic of needling.

### Heatsetting and Finishing

The final major step in the production of press felts is the finishing process (Figure 3.26).The needled felt is installed on a finishing frame; a full-width shower system wets it and it is put under a tension that closely simulates that of a paper machine, approximately 3.0 - 3.5 kN/m (17 - 20 pli). At that tension, the felt is heat stabilized. This establishes the projected running length on the paper machine. The desired running width is also marked on the felt while it is wet.

Full-width vacuum boxes remove excess water and ensure uniform moisture content across the width of the felt. Heated head rolls and heated air boxes uniformly dry the felt. Generally, a compaction roll is lowered onto the felt to reduce caliper and void volume. This is known as pre-compacting the felt and it helps the felt to break-in and start up faster on the paper machine.

FIGURE 3.26. Heatsetting and finishing.

### 3.2.4 Properties of Press Fabrics

The important properties of press fabrics vary, depending on application.

*Fabric Mass and Thickness*

Fabric "mass" is defined as the fabric weight per unit area (oz/ft$^2$ or g/m$^2$). Press fabrics should have a uniform mass distribution across the width. Uneven mass or thickness (caliper) may cause press bounce, press vibration and/or non-uniform water removal. 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 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.

*Batt/base ratio*

Batt/base ratio is defined as the mass of the batt fibers divided by mass of the base fabric. As this ratio increases, density of the felt also increases and the ability to properly clean/condition the felt decreases. However, a low batt/base ratio may cause marking on the sheet due to insufficient coverage of the base yarns.

*Air Permeability*

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

In Imperial units, the cfm value is usually measured at 0.5 in (12 mm) water column pressure. The metric measurement unit is m$^3$/(m$^2$.hr). Metric permeability may be tested at a different back pressure (100 Pascals versus 125 Pascals Imperial).

Typical values for the air permeability of a press felt can range between 15-250 cfm, (274-4572 m$^3$/(m$^2$.hr)) depending on the specific application of the product.

*Void Volume*

Void volume is the open 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.

A common misconception is that yarns and fibers hold and release water. In fact, the water exchange takes place in the fabric's voids.

*Flow Resistance*

Resistance to air and water flow can be important in press fabric design. Porosity is closely related to how much water a fabric will release over a suction/Uhle box. Reduced permeability due to compression can become a source of problems if it is too low and impedes water flow inside the nip itself.

*Compressibility and Resiliency*

Compressibility is a measure of compactness under load and resiliency is a measure of rebounding capability of the fabric after compaction. For optimum performance on the paper machine, the press fabric must be compressible enough under load that void volume in the felt is reduced and hydraulic pressures are increased. This is the mechanism that initiates water removal. However, the felt must also be resilient enough to rebound on the exiting side of the nip, to be ready to receive water from the sheet once again.

Figure 3.27 shows the impact of nine different press fabric designs on compressibility and resiliency. Choosing the right product for a particular application is extremely critical.

*Uniformity of Pressure Distribution*

Pressure distribution is a key driver for pressing efficiency. Uniformity is critical on all scales:

- Micro scale: The finer the surface, the more efficient initial pressing will be.
- Medium scale: The press fabric has to bridge patterns from vented rolls in order to minimize pressure loss over grooves and holes.
- Large scale: This includes formation flocs from batt manufacturing as well as patterns that are built into the fabric over time from non-uniform conditioning, wear, and pressing.

While it is intuitively obvious that pressing the web non-uniformly will yield different results where applied pressure is variable, it is one of the most misunderstood aspects of press performance.

*Additional Critical Properties*

Fabric dimensional stability, abrasion resistance, as well as contaminant and chemical degradation resistance are important requirements of modern press fabrics. The fabric must be dimensionally stable throughout its operation. Abrasive inorganics, as well as paper making chemical additives, have increased the importance of abrasion resistance in press fabrics. The increased use of secondary fibers has made contaminant resistance a necessity in today's press fabrics.

Certain oxidizing agents used for pulp bleaching or bacterial control can severely weaken polymers used in press fabrics. These conditions dictate the use of oxidation resistant fibers and yarns.

## 3.3 Application of Press Fabrics

To properly design a press fabric, the primary functions of the fabric itself must be considered (see also Section 3.2.1): 1) to convey and control the sheet through the press, 2) to press water from the sheet, 3) to provide a medium to accept water, 4) to maintain sheet properties, and 5) to drive undriven rolls. Each of these functions must be considered relative to many machine-related specifics including, but not limited to, press configuration, paper grade and basis weight, press load, and Uhle box vacuum capacity.

*Press Configuration*

There are many different press configurations (Section 3.5 Press Types). Each configuration has control points where the press fabric must either hold or release the sheet. Control points can include transfer from the forming fabric to the "pickup" fabric, from one press to another, or from the press to the dryer section. Attention must also be given to

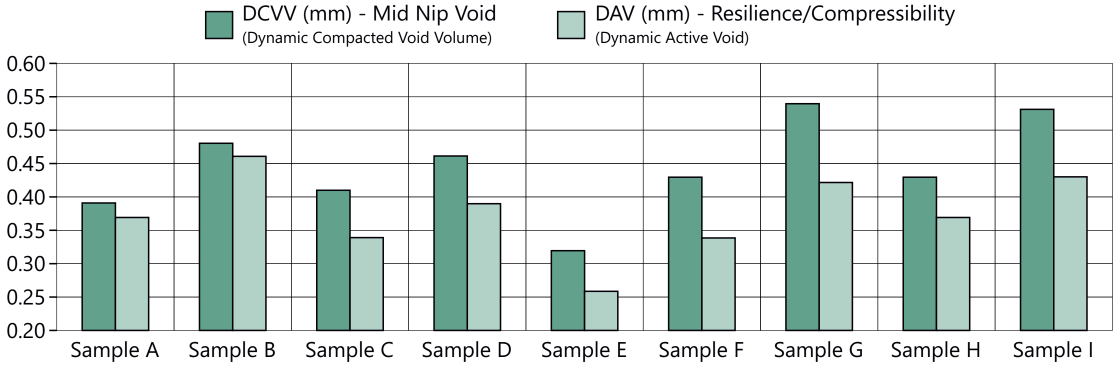


FIGURE 3.27. Press fabric compressibility and resilience.

the exit side of double felted presses where the sheet must stay with one fabric or the other in order to make the next transfer. Failure to fully control the sheet to the correct fabric can result in sheet wrinkles and creases, or worse, can cause significant downtime when the sheet sheds off and piles up in the wrong place. In the absence of dominant poor geometry, the web will follow the smoother surface. Generally, fabric designers can create a smoother surface by using finer surface deniers. Sometimes a designer will make one of the fabrics heavier, raising its water load, and increasing surface tension. Note that changing fabric design to affect sheet transfer is a compromise to overall press efficiency. It is preferable in many cases to optimize press geometry to control sheet transfer.

*Paper Grade and Basis Weight*

Paper grade determines the quality requirements such as smoothness or two-sidedness. The basis weight indicates the water volume to be removed through the press. The water load will dictate different bases with higher or lower void volume or water handling capacity. For example, for lower basis weight sheets with high smoothness requirements, thinner and lower void volume base fabrics with finer batt fibers would be used. For higher basis weight sheets with low or no smoothness requirements, higher void volume base fabrics with coarser batt fibers would be used.

*Press Load*

Press load is used to compare the load capabilities of one press to another. It is also used to characterize "in nip void volume" and caliper of different press fabric designs under load. The "in nip void volume" represents the "medium to accept water" (a primary function of a press fabric). For benchmarking purposes, press designs are compared using the specific pressure (kPa or psi), which is a function of press linear load (kN/m or pli), roll diameter, and roll hardness. Press load can vary significantly from press to press and from nip to nip. Typically, load is lower with softer rolls in the early more "flow controlled" presses and increases with harder rolls in the later more "pressure controlled" nips.

Uhle Box Vacuum Capacity and Dwell Time

Uhle box airflow (cfm/in$^2$) and dwell time (ms) are used to determine the capability of a vacuum system to dewater and maintain the operating performance of a press fabric. TAPPI [6] standards recommend 15-25 cfm/in$^2$ (660-1100 m$^3$/(m$^2$.min) of airflow (Figure 3.28) and 2-4 ms of dwell time (Figure 3.29). To properly dewater and condition the press fabric, the right volume of airflow and the right amount of dwell time are needed. Presses that are limited in airflow, dwell time, or both can require compromises in fabric design and/or will have limits on the effective life of the press fabric.

While Uhle box vacuum capacity is an important factor in controlling press fabric moisture ratio, it should be noted that more vacuum is not always better. The vacuum should be designed first to keep the fabric clean, and second, to return the fabric to the nip with the optimized moisture level for pressing efficiency. Drag over Uhle box covers is a common source of press fabric wear. This problem can be accentuated by excessive vacuum levels (20" Hg =~68kPa or above) and poor lubrication of the Uhle box cover.

Summary

These are the primary machine-related inputs that can be used to "design" a press fabric. There are many minor inputs that can also influence the final product. Machine operating goals and specific operating conditions can often conflict. These conflicts, combined with the functional requirement of the press fabric, ultimately lead to the best compromised design and to the best overall performing press fabric.

## 3.4 Service for Press Fabrics

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

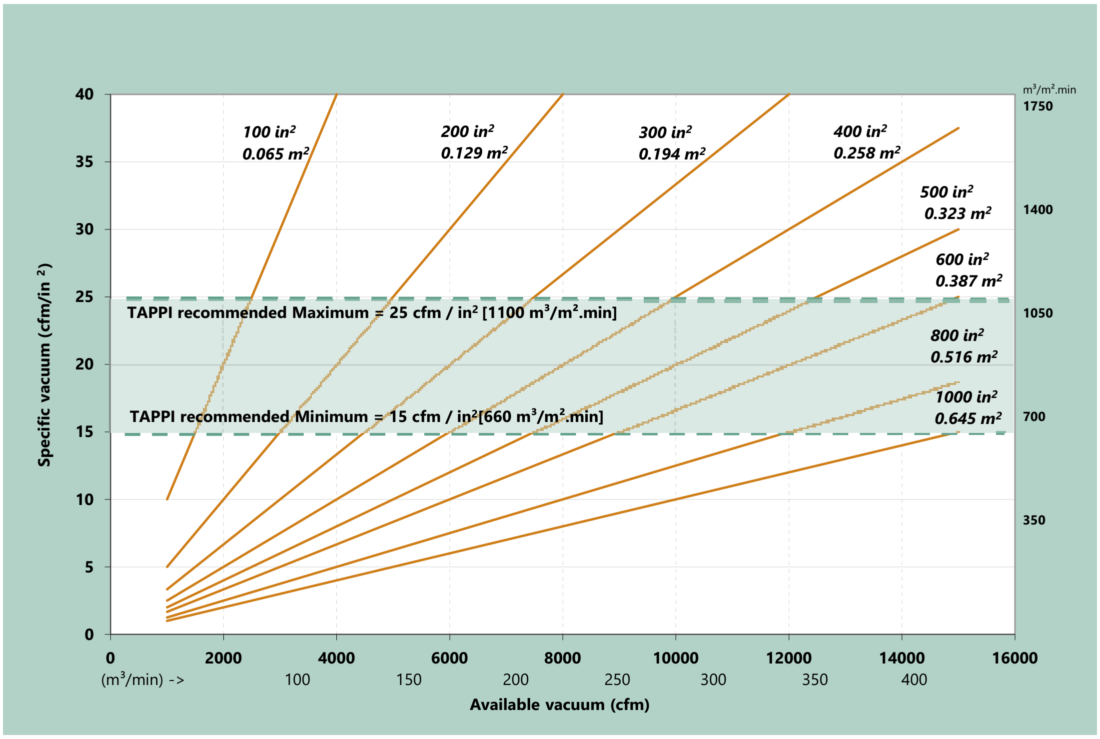


FIGURE 3.28. TAPPI guidelines for Uhle box vacuum density [6].

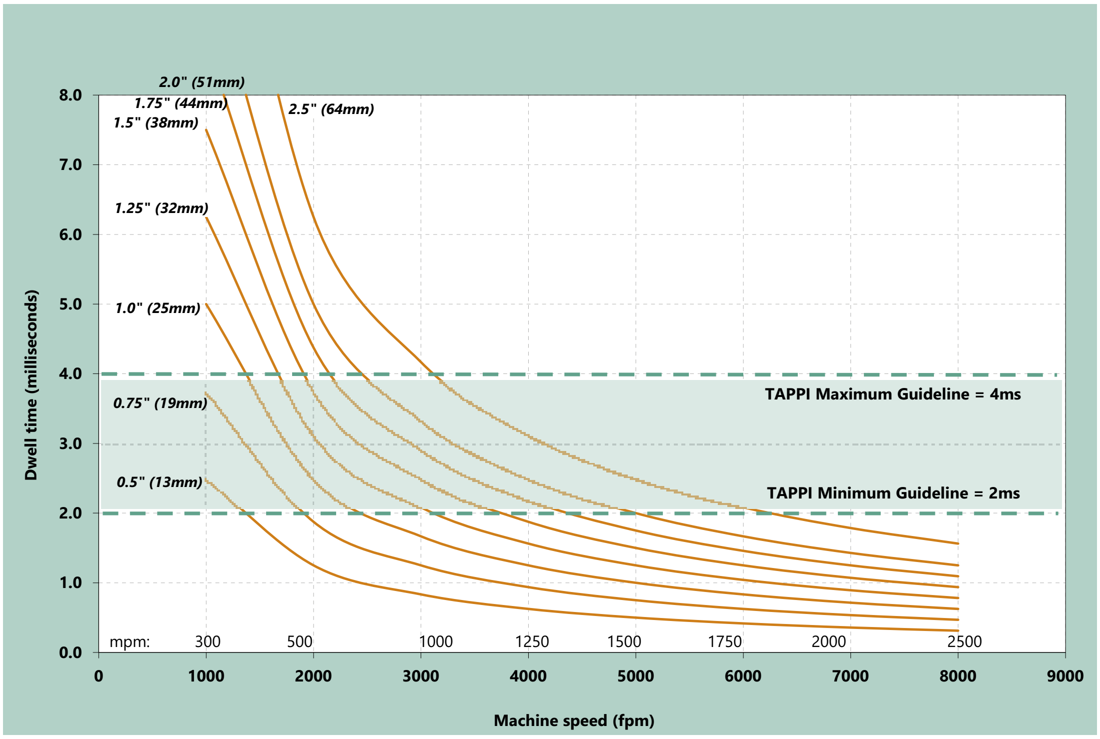


FIGURE 3.29. TAPPI standards for dwell time over Uhle box slots [6].

### 3.4.1 Installation and Operating Procedures

*Before Installation*

- Clean press and other machine components thoroughly.
- Check all machine components such as Uhle boxes and roll surfaces, for roughness.
- 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.
- Stage seamed fabrics in a dry location.

*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 the 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.
- Make sure seam is straight and in a good location for seaming.

*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. Typical values range between 15-25 pli (2.6 - 4.4 kN/m).
- Maintain tension during start-up and check frequently.
- Wet up by applying water evenly across the fabric using a full width shower (not a hose), making certain that no puddling occurs.
- When the fabric is uniformly wet, load press to normal weight and turn on vacuum equipment. Fabric may “run in” faster with press at “tail” load, intermediate speed, and felt fully saturated for a period of 20 - 30 min.

*Trimming*

Trimming should be delayed, if possible, in the event that the width narrows 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. Sticking a knife in Uhle box slot for stability is common.
- Jog the fabric a full revolution; then cut the trimmed loop and pull it free.
- If unraveling occurs after trimming, a heat-sealing iron is effective at stopping the unraveling.

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

### 3.4.2 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*

1. 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.
2. Reduce the machine speed to a crawl to increase the dwell time at the suction boxes and rolls.
3. 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.
4. Reduce the press load to the lowest practical level and leave the Uhle box vacuum on.
5. Rinse the fabric using flooding showers, lubricating showers, or high pressure showers (use low pressures so that the felt is not damaged).
6. Set showers at normal operating pres-

sures for 10-15 minutes to thoroughly rinse the fabric.

7. Shut off showers.
8. Use vacuum boxes to dewater the felts uniformly and to the lowest practical moisture levels.
9. 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.

*Unload/Lift the Press Roll*

Once the press section is stationary, the press roll must be unloaded/lifted such that there is no contact with the fabric; this will avoid localized felt compaction.

*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.

### 3.4.3 Repairing Damaged Areas of Fabric

Occasionally during the normal operation of a paper machine, fabrics may become damaged by an 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 for a short run period until an extended downtime is scheduled. Most mills maintain sewing kits containing braided nylon yarn with curved needles that can be used to sew the small damaged areas.

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

For damaged areas extending in the CD, 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 two inches (50 mm) 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 3.30 for CD direction.

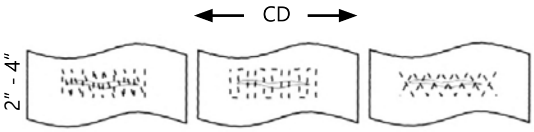


FIGURE 3.30. Damaged areas running in the CD and corresponding stitch types.

If the tear is in the MD, the stitch will be predominantly back and forth horizontally. Since there will not be tension on the MD yarns seen in the CD shear, the stitch needs to be only minimum of one inch (25 mm) on either side (Figure 3.31).

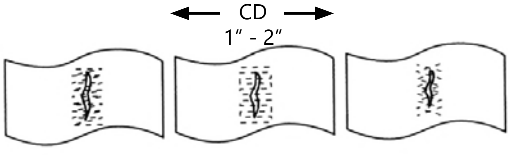


FIGURE 3.31. MD tear and stitch types.

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.

### 3.4.4 Potential Operational Problems

#### Guiding

In general, a press fabric will line up at right angles to the surface it touches first. As shown in Figure 3.32, 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.

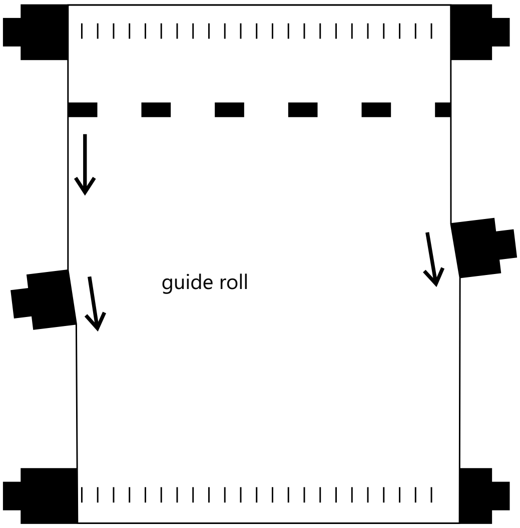


FIGURE 3.32. Press fabric guiding.

The above principle is valid for a normal guide roll wrap of 25°-35° (Figure 3.33). 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. The fabric position change takes place on the way towards the guide roll. The lead-in length must allow enough room for the fabric to steer across. The lead-out length needs to be short enough to lock in the CD position change; too long lead-out distance may cause the fabric to return to its original position, resulting in ineffective guiding.

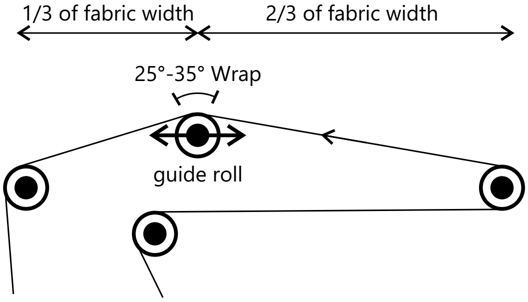


FIGURE 3.33. Lead-in and lead-out distances for guide roll.

*Other Factors Influencing Guiding*

Misalignment of a roll can cause guiding problems. The symptoms are typically characterized by a fabric that consistently tracks to 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 the 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. In this position, it provides the maximum widening or flattening effect on the fabric (Figure 3.34).

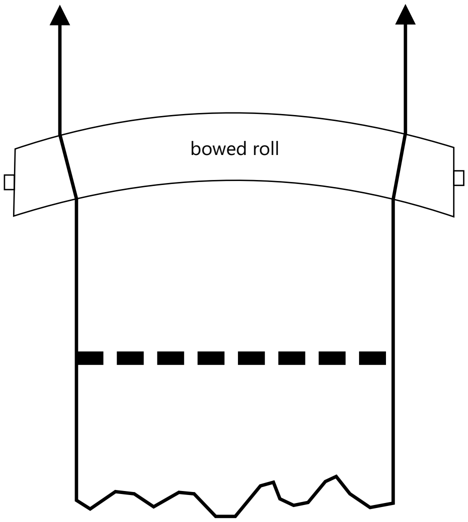


FIGURE 3.34. Widening effect of the bowed roll.

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 proportionally to the angle, causing the tradeline to lag in the center. The "neutral" bow position (even spreading across the whole width of the fabric) is set by putting the bow position in the run direction at 90° to the bisected fabric wrap angle over the bow roll.

### 3.4.5 *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. Distorting a fabric directly impacts its width.

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 3.35).

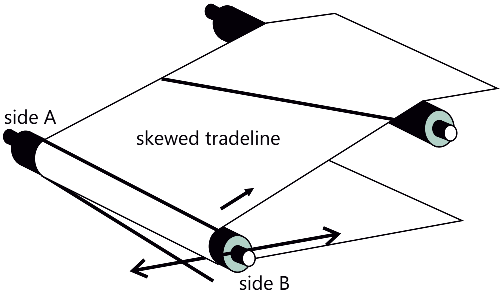


FIGURE 3.35. Schematic of a distance-producing device.

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 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 3.36). The center travels a shorter distance resulting in the fabric and guideline running ahead in the center.

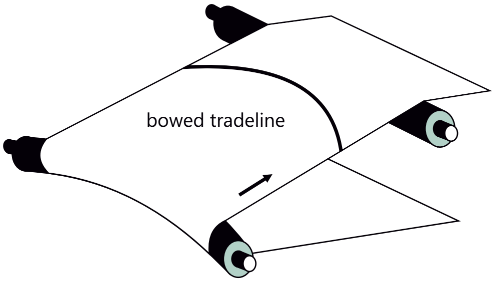


FIGURE 3.36. Roll deflection.

A bowed/spreader 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 3.37).

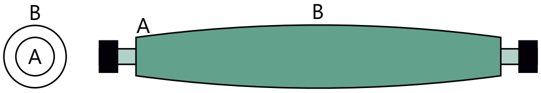


FIGURE 3.37. A crowned roll as a speed-producing device.

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 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 3.38)*

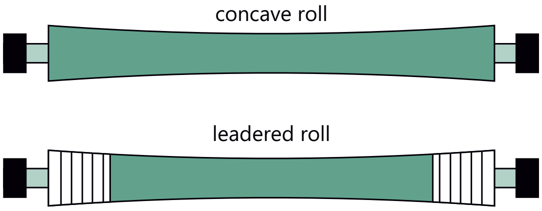


FIGURE 3.38. Concave (negative crown) and leadered rolls.

Concave rolls have the opposite effect of 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.

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

TAPPI TIP 0404-64 "Press Fabric Guiding" contains additional information [6].

### *3.4.6 Press Fabric Problems - Evaluation Guidelines*

Table 3.3 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.

1. 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).
2. Determine if fabric was trimmed and how much.
3. Measure tradeline distortion. Determine when it occurred. Is it bowed or skewed?
4. Measure maximum running width; usually equal to fabric roll width. Measure minimum running width. This will usually be at least two inches (50 mm) outside the maximum sheet width on either side or "wire" width for a pick-up fabric.
5. Determine whether previous fabrics and succeeding fabrics exhibited the same problem.
6. Determine operating temperature of press fabric or wet end.
7. Determine whether steam boxes were used on the 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 3.3 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. This can occur later in fabric life as well, when sheet-to-fabric contact is reduced due to fabric wear or if a felt becomes too closed, interfering with the operation of anti-blowing equipment. |
| **Drop-offs** | Occurs on pickup 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. This can also happen later in fabric life due to edge contamination or compaction. |
| **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. It may also occur early in life when the press fabric is still "open". |
| **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** | Defined as unacceptable rate of batt fiber loss. 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 are 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 yarns used in the CD and heavier designs make fabrics relatively stiffer. |
| **Seam wear** | Seam mark occurs when the seam area of a fabric causes an objectionable impression in the finished sheet. This can be a design issue or can be initiated by excessive seam area wear. Note that seam design is typically a compromise between marking and ease of installation. |
| **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:

1. 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?)
2. Was bounce present at start-up? When did it begin? Is it getting worse or better?
3. Was bounce present prior to last press fabric change?
4. Were any press rolls changed immediately prior to start of bouncing?
5. Did the next press fabric bounce? If so, answer the first two questions again.
6. 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 (kPa or inches Hg) compare to normal?
5. Were furnish and grades normal? Was the sheet wet on the fabric?
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 saveall 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.

Shoe press grooved sleeves can contribute to marking in either of two ways:

1. Groove widths too wide: The press fabric conforms to the groove shape, the lower nip load on the sheet over the groove area leads to a small-scale moisture variation, showing as marking.
2. Land widths too wide: Typical in low pitch designs, the lateral flow of water, fines, and fillers toward the grooves contribute to flow marking.

*Determination of the Causes of Sheet Marking*

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

1. 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 fabric side? Which press fabrics and rolls contact which side? It needs to be determined which press fabric or roll is causing the problem.
2. 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?
3. What are the grinding schedules of the rolls in the machine? What is the remaining roll cover thickness compared to new?
4. What are the loads? Are they normal?
5. What are the roll hardnesses? Are they normal?
6. How does the existing caliper of the press fabric compare with the initial or edge caliper?
7. Is the press fabric surface soft? Is the batt worn away?
8. Is the press fabric carrying more water than normal?
9. 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, hydraulic, and chemical.

- Mechanical causes
    - ▫ Improper roll crown/load
    - ▫ Improper roll dubbing
    - ▫ Bad press roll bearing
    - ▫ Scissored rolls (misaligned press rolls)
    - ▫ Worn or rough suction box covers
    - ▫ Excessive Uhle box vacuum
    - ▫ Poorly lubricated Uhle box
    - ▫ Improper high pressure shower oscillation
    - ▫ Excessive shower pressure
    - ▫ Abrasives in the system
    - ▫ Worn or rough press rolls
    - ▫ Drag on the saveall

- Hydraulic causes
    - ▫ Press fabric/press roll combination is unable to handle water properly.
    - ▫ Roll cover has been ground to the point that venting is reduced and hardness is increased, limiting void volume.

- Chemical causes
    - ▫ Acids left in contact with fabric as part of ineffective cleaning protocol.
    - ▫ Oxidation from bleaching agents carried over from pulp plant or from microbial control program.

**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

Sometimes, drop-off occurs towards the end of a pick-up felt's life cycle. Such cases are typically related to press fabric edges being worn or poorly conditioned.

#### 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 at start-up 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 cannot 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 of 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 the press section are given in Chapter 8.

### *3.4.7 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 have lost their uniformity or water handling capacity due to compaction or filling. 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 3.39, Table 3.4). 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 is generally the most effective. Continuous application is recommended as it is easier to keep a fabric clean than to clean a fabric 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 better able to remove or loosen the contaminants. High pressure roll side showers are usually not an

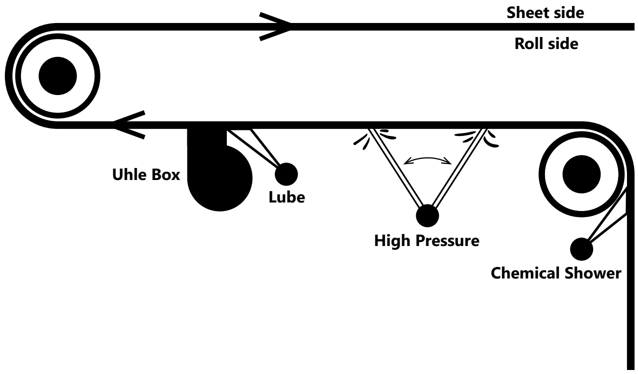


FIGURE 3.39. Press fabric conditioning system.

*TABLE 3.4. Press Fabric Conditioning System Requirements.*

| | Metric | Imperial |
|---|---|---|
| **Lube** | • 150 - 200 kPa<br>• Continuous<br>• Fan nozzle, 90° - 120°<br>• .05 - .09 lpm/cm of fabric width<br>• 75 - 100 mm spacing<br>• Stationary or optional oscillation<br>• Single coverage | • 20 - 30 psi<br>• Continuous<br>• Fan nozzle, 90° - 120°<br>• .03 - .06 gpm/in of fabric width<br>• 3″ - 4″ spacing<br>• Stationary or optional oscillation<br>• Single coverage |
| **Uhle Box** | • 12 - 20 mm slot width<br>• 660 - 1100 $m^3/(m^2.min)$ | • .5″ - .75″ slot width<br>• 15 - 25 $cfm/in^2$ |
| **High Pressure Shower** | • 12 - 21 bar<br>• Continuous<br>• Needle jet<br>• .11 - .15 lpm/cm of fabric width<br>• 150 mm spacing, double up at edges<br>• Nozzle distance to felt surface 75 - 100 mm<br>• Oscillation - 1 nozzle width per revolution<br>• Angle into run - surface cleaning & smooth surface (promotes sheet adhering to felt)<br>• Angle with run - internal cleaning & pill or roughen surface (promotes sheet release) | • 175 - 300 psi<br>• Continuous<br>• Needle jet<br>• .07 - .10 gpm/in of fabric width<br>• 6″ spacing, double up at edges<br>• Nozzle distance to felt surface 3″ - 4″<br>• Oscillation - 1 nozzle width per revolution<br>• Angle into run - surface cleaning & smooth surface (promotes sheet adhering to felt)<br>• Angle with run - internal cleaning & pill or roughen surface (promotes sheet release) |
| **Chemical Shower** | • 300 - 400 kPa<br>• Continuous or intermittent<br>• Fan nozzle<br>• 75 - 100 mm spacing<br>• Flow calculation according to dosage & concentration<br>• Stationary or optional oscillation<br>• Single coverage | • 40 - 60 psi<br>• Continuous or intermittent<br>• Fan nozzle<br>• 3″ - 4″ spacing<br>• Flow calculation according to dosage & concentration<br>• Stationary or optional oscillation<br>• Single coverage |

effective means to clean the fabric. The pressures required to penetrate the base fabric and affect the contaminants usually damage the press fabric. High volume roll side (a.k.a. "flooding") showers are effective when positioned at a nip point between a felt roll and fabric. These are most common on tissue machines.

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.

The 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 ±6° C 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 (kPa or inches of Hg) and vacuum capacity ($m^3/(m^2.min)$ or $cfm/in^2$ 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 ability to clean and dewater is related most closely to permeability. To optimize press fabric conditioning, a pump capacity of 660 - 1100 $m^3/(m^2.min)$ (15-25 $cfm/in^2$) is required. Each Uhle box should ideally be connected to a dedicated vacuum source, as shared vacuum can yield unpredictable results by favoring the most open application points. This means, for instance, that the most open fabric serviced by a shared vacuum source will pull more air to maintain pressure equilibrium between application points. As fabric permeability changes over time, this creates some variability.

Most Uhle box covers are made from ceramic or ceramic composites. Older machines may still use high density polyethylene (HDPE) covers; they must be monitored closely for wear. While ceramic covers are significantly more durable than polyethylene, they require greater care to prevent chipping and damage, and lubrication showers should be used to minimize felt wear. If ceramic is used, the radius of the trailing edge of the cover should be no less than 1.6 mm (1/16 in).

The most common cover pattern is single or double slotted. Other patterns used are the herringbone, serpentine, and trapezoid (Figure 3.40).

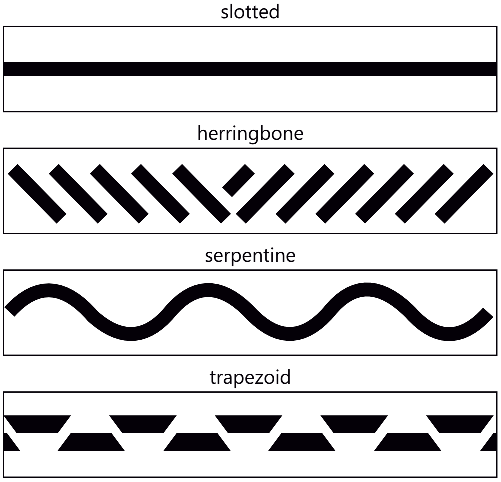


FIGURE 3.40. Common cover patterns.

The illustrated specialty patterns are used primarily on positions where seamed 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 2.5 cm (1 in) to minimize wear and shedding, and no smaller than 1.2 cm (0.5 in) to avoid plugging.

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 3.41).

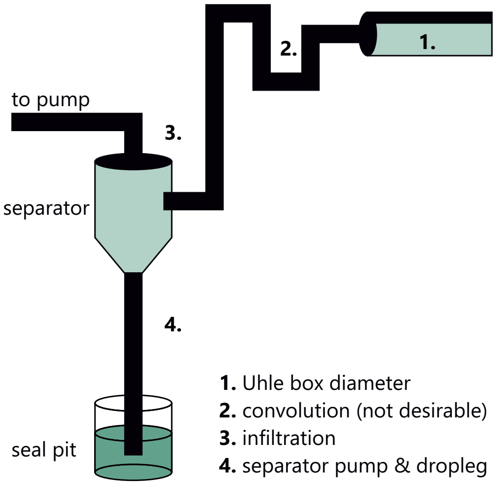


FIGURE 3.41. Typical vacuum system problem areas.

1. Uhle box and piping diameter: Uhle box tubes should be sized to keep the linear air velocities through the pipe below 18 m/s (3550 ft/min). 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 capacity.

4. Dropleg: An inch (2.54 cm) of Hg is equivalent to ~34.5 cm (~13.6 in) of water. If the dropleg to the seal pit lacks sufficient height, the vacuum induced water column can exceed the height of the dropleg. This can result in water from the seal pit being lifted into the separator and being carried over to the vacuum source. The Uhle box may flood and, pulsating vacuum levels may be seen. Worse still, the seal tank may be sucked dry and the vacuum capacity at the Uhle box seriously reduced due to the bypass flow from the open dropleg.

### *3.4.8 Returned Fabric Analysis*

Paper machine clothing manufacturers established customer service laboratories to enable the papermaker to learn more about the solution to press fabric problems. Working with returned, or 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 is 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 spectrophotometry 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.

### *3.4.9 Press Section Technical Services*

Press felts are generally the controlling factor for scheduling maintenance outages and therefore, close monitoring of the press felt condition is needed. Paper machine clothing manufacturers provide extensive technical support, which includes the following:

1. Crew training
2. Installation and seaming assistance
3. Start-up assistance
4. Showering surveys
5. Used fabric analysis
6. Moisture scan analysis
7. Permeability (perm) scan analysis
8. Weir flow analysis

The following TAPPI procedures can be used to analyze press and press clothing performance [5].

1. TIP 0404-19 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, and press roll crown.
2. TIP 0404-26 Paper Machine Clothing Performance Analysis. This method provides guidelines for good clothing performance analysis.

Machine surveys are commonly done in the paper industry to assess the performance and productivity of paper machines and the papermaking processes (Chapter 5). The collected data are analyzed and used to make recommendations to the papermaker to improve the process. Chapter 8 gives a guide for press section troubleshooting.

## 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 the common press types and the typical grades of paper run on each press type.

### *3.5.1 Straight-Through™ Press*

This press type covers an extremely wide grade and speed range as well as a range of nip conditions (Figure 3.42). 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)
- 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 can be difficult with endless fabrics

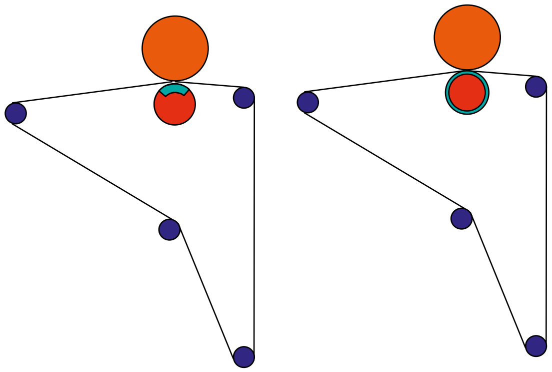


FIGURE 3.42. Straight-Through™ Press.

### 3.5.2 *Inver Press*

This type of press is generally used to make fine paper grades at low to medium speeds (Figure 3.43).

- Prone to drop-offs with some grades
- 2nd press prone to sheet blowing

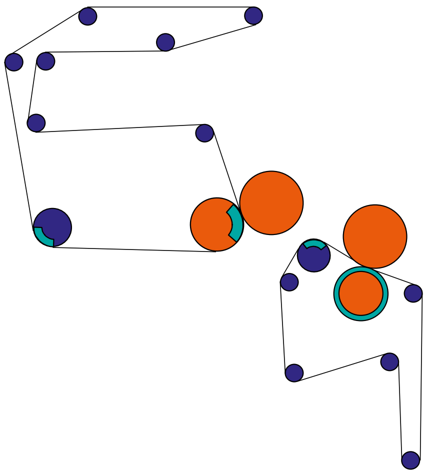


FIGURE 3.43. Inver press.

### 3.5.3 *Twinver™ Press*

This type of press configuration was a forerunner of the no-draw cluster press (Figure 3.44). Fine paper, newsprint, and LWC grades at medium to high speeds are generally made on the Twinver™. Some machines with Twinver™ have been converted to packaging paper grades.

- Common press arrangement for lightweight, high-speed grades (news and fine)
- 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

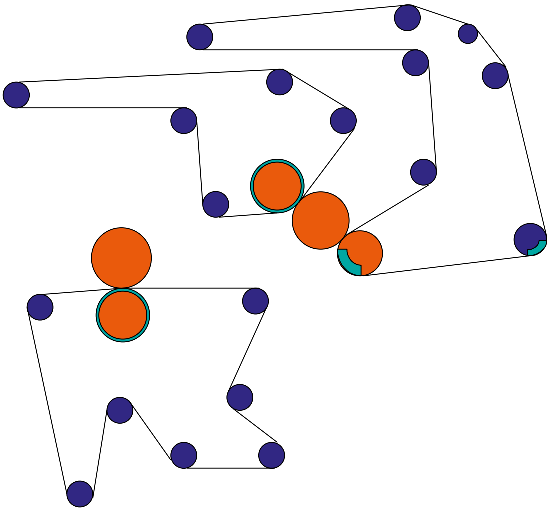


FIGURE 3.44. Twinver™ Press.

### 3.5.4 *Combi Press ("Uni Press")*

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 (Figure 3.45). It is a compact arrangement that can be applied in a limited space.

- Compact press arrangement
- No-draw effect through first two nips
- Less prone to drop-offs compared to a Twinver™ or Inver press
- Pick-up prone to shadow mark with large suction holes
- Loads limited by single-felting (crush) and load differential between 1st and 2nd nip on center roll

- Press fabric installations can be difficult with endless felts

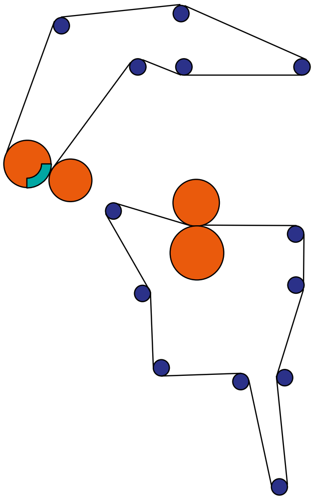


FIGURE 3.45. Combi Press (Uni Press).

### 3.5.5 *Four-Roll, No-Draw Presses*

TriNip™ is the most popular press arrangement for all high speed fine and newsprint grades. TriNip™ is also used to produce packaging grades (Figure 3.46). The double-felted first nip allows for higher press loads without crush. Some machines have a fourth press which reduces the differential of sheet smoothness from one side of the sheet to the other.

- Double-felted first press prevents crushing and allows higher loads
- Prone to sheet stealing by pick-up with some geometries
- 3rd press prone to vibration
- 4th press prone to blowing, vibration and sheet stealing

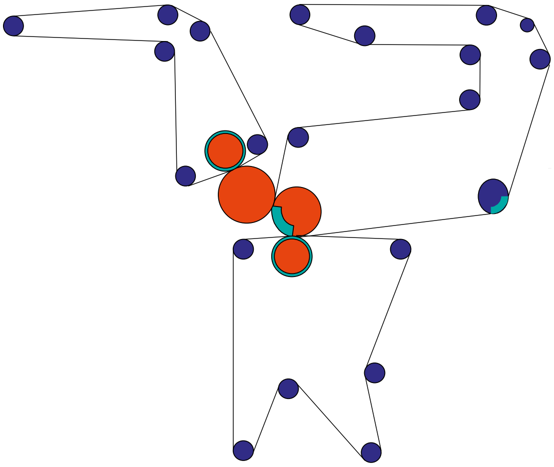


FIGURE 3.46. TriNip™ Press.

TriVent™ is evolved from TriNip™ press arrangement and is used primarily for high speed fine and newsprint grades with limited use for packaging grades (Figure 3.47). Separate 2nd press allows for higher loads in the 2nd and 3rd nips.

- Able to obtain higher press loads in the 2nd and 3rd press nips
- Other characteristics same as TriNip™

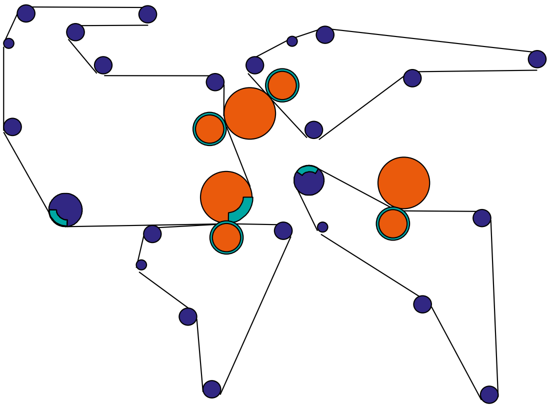


FIGURE 3.47. TriVent™ Press.

### 3.5.6 *Three-Roll, No-Draw Presses*

An alternative to the TriNip™ arrangement, the BiNip™ press is used to produce both fine paper and packaging grades (Figure 3.48). It improves bottom side sheet densification. Fine paper machines typically have a single-felted third press. Packaging machines typically have a double-felted third press (Figure 3.49).

- Less two-sidedness due to last felt on bottom side
- Double-felted first press prevents crushing and allows higher loads
- Prone to sheet stealing by pick-up with some geometries
- 3rd press prone to blowing and wad burns

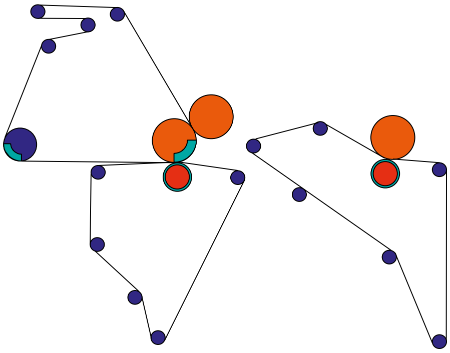


FIGURE 3.48. BiNip™ Press.

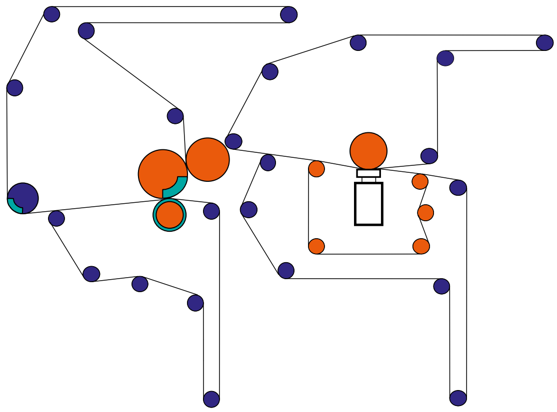


FIGURE 3.49. Double-felted third press.

BiVent™ is evolved from the BiNip™ press arrangement (Figure 3.50). A separate second press allows for higher loads in the second nip.

- Able to obtain higher press loads in the 2nd and 3rd press nips
- Other characteristics same as BiNip™

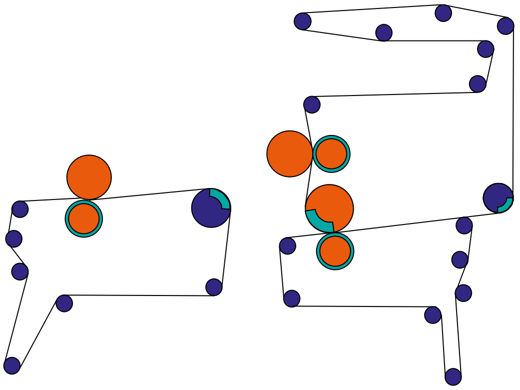


FIGURE 3.50. BiVent™.

### 3.5.7 *Two Double-Felted, No-Draw Presses*

Developed and used primarily to produce packaging grades of paper, these presses typically utilize large diameter press rolls or shoe presses. This press type comes in three common configurations. The tandem press (Figure 3.51) utilizes one bottom felt to support the sheet through both presses. The other two types of presses (Figures 3.52 and 3.53) utilize two double-felted presses. The difference between these two press types is the location of the sheet run and transfer between each press.

- High void volume felts are typically needed to avoid crushing
- Sheet following on the 2nd top felt can be a concern

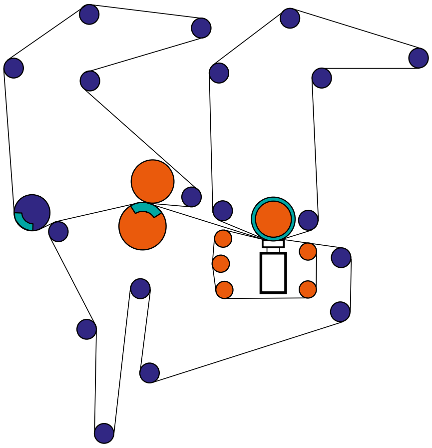


FIGURE 3.51. Tandem bottom - shoe in second press.

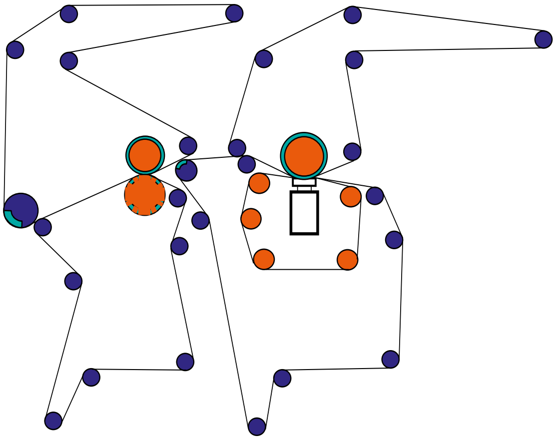


FIGURE 3.52. Two double-felted presses (roll + extended nip press - ENP).

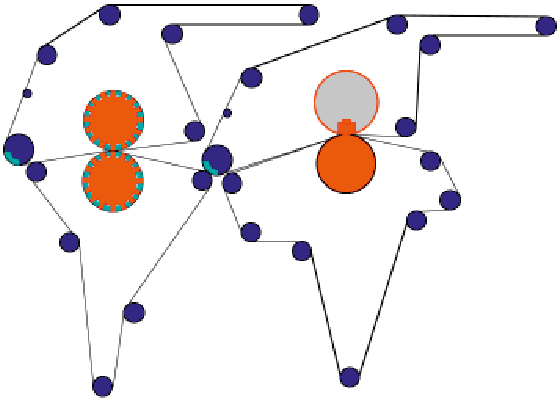


FIGURE 3.53. Two double-felted presses (long nip press - LNP + Shoe).

### 3.5.8 *Shoe Presses*

Shoe presses were developed to increase the nip dwell time for improved water removal and sheet densification. These presses operate up to 1500 kN/m (8500 pli) with nip widths up to 30 cm. Sheet consistencies in some instances have improved 4-7% out of the press section. Bulk can be increased while maintaining sheet moisture content, or bulk can be maintained while increasing dryness. However, for heavily loaded shoe presses with high exit peak pressures, sheet density is increased. Shoe presses are used on all paper grades including tissue.

The shoe press was developed by Beloit in 1980 and called the Extended Nip Press (ENP). It included an oil lubricated, 250 mm MD shoe loaded against an open-loop belt that ran around a series of rolls much like a press felt. Current designs from all suppliers have collapsed this belt into a cylinder and sealed the ends with rotating heads. Extending the nip and increasing nip load to the 1000 - 1400 kN/m range has increased the press dryness from 4% to 7% compared to roll pressing. This increased water removal has heightened the risk of felt marking and the need for venting in the roll covers and belts - challenges that have been met by the clothing suppliers. Figures 3.54 and 3.55 show shoe press examples, Beloit ENP and Andritz PrimePress X, respectively [7].

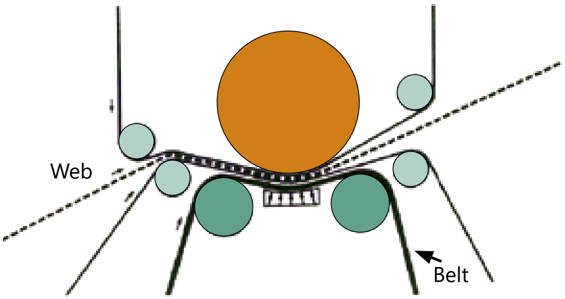


FIGURE 3.54. Beloit ENP.

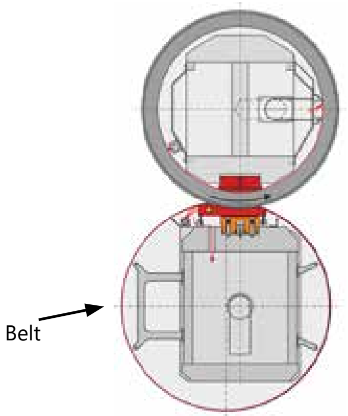


FIGURE 3.55. Andritz PrimePress X.

Shoe presses are common additions to press rebuilds due to their ability to increase press solids (Figures 3.56 - 3.59).

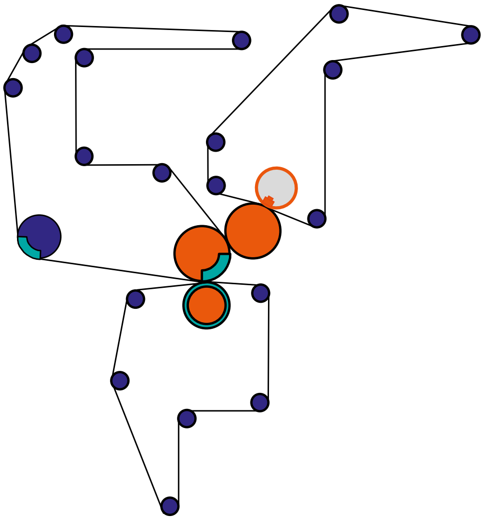


FIGURE 3.56. TriNip™ with a shoe in the third press.

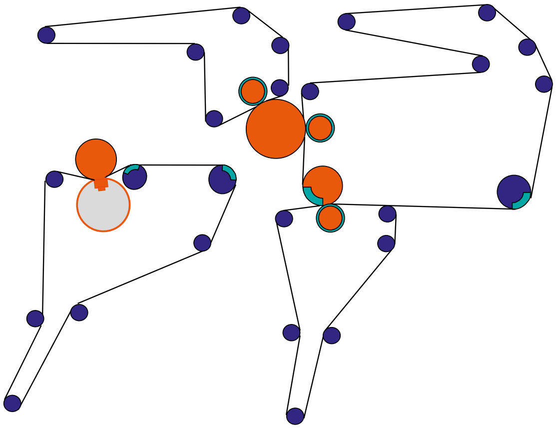


FIGURE 3.57. TriVent™ with a shoe in the fourth press.

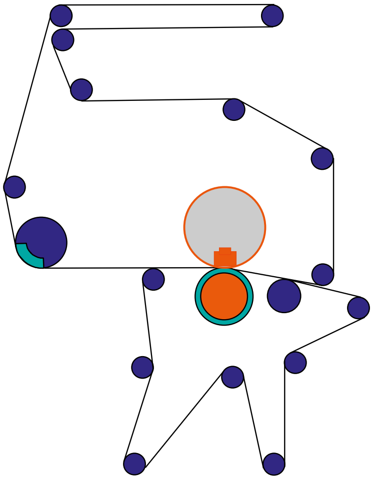


FIGURE 3.58. Single shoe.

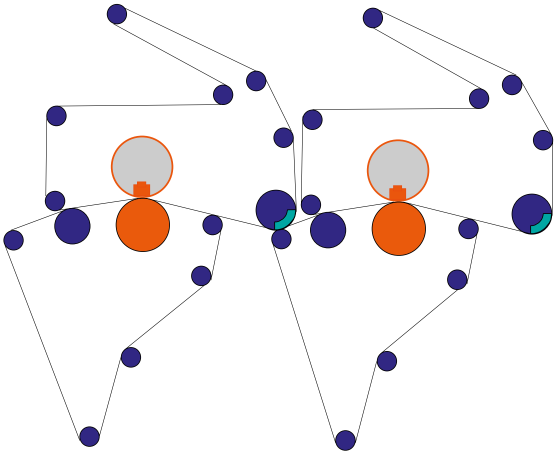


FIGURE 3.59. Tandem shoe.

### 3.5.9 Tissue Presses

Tissue presses come in three basic types with the oldest technology being double-felted (Figure 3.60).

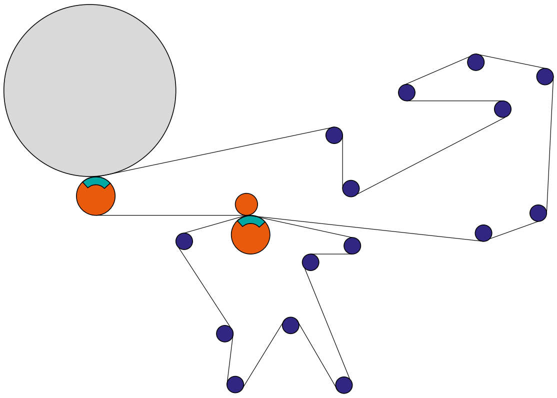


FIGURE 3.60. Tissue double-felted press.

Most double-felted presses have been rebuilt to single press configurations due to:

- Higher maintenance costs from more rolls, drives, felts, etc.
- Sheet following on the bottom felt
- Lower bulk sheet
- Higher energy costs due to vacuum required for two rolls

Single-felted tissue presses come in two types: single pressure roll (Figure 3.61) and double pressure roll (Figure 3.62). The single pressure roll has the option of using a shoe press in place of the roll press (Figure 3.63).

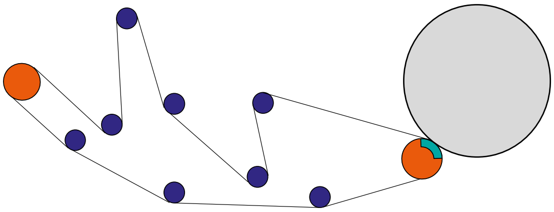


FIGURE 3.61. Tissue single pressure roll.

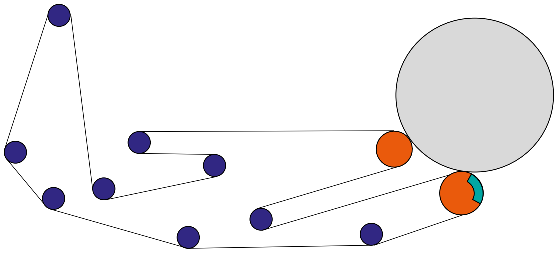


FIGURE 3.62. Tissue double pressure roll.

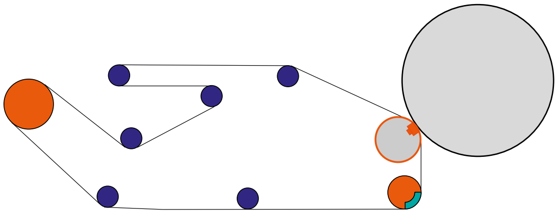


FIGURE 3.63. Tissue shoe press.

## 3.6 References

1. Reese, R. A., "Pressing Operations" in Pulp and Paper Manufacture, Volume 7: Paper Machine Operations, Eds. B. A. Thorp and M. J. Kocurek, TAPPI Press, 1991.
2. Wicks, L. D., "Press Section Water Removal Principles and Their Applications", Southern Pulp and Paper Manufacturer, January 1978.
3. Press Fabrics Training Manual, Asten, Inc., 1995.
4. Wahlstrom, P. B., Pulp and Paper Mag. Can., 70 (10), 1969.
5. Beck, D. A. "Fluid Pressures in a Press Nip" in TAPPI Engineering Conference, TAPPI Press, 1983.
6. Technical Association of the Pulp and Paper Industry (TAPPI), Peachtree Corners, GA, www.tappi.org, 2017.
7. Andritz Group, www.andritz.com, 2017.

*General References*

Helle, T., and Forseth, T., "Influence of Felt Structure on Water Removal in a Press Nip", TAPPI Journal, Vol. 77, No. 6, June 1994.

Laivins, G., and Scallan, A., "Removal of Water From Pulps by Pressing", TAPPI Journal, Vol. 77, No. 3, March 1994.

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