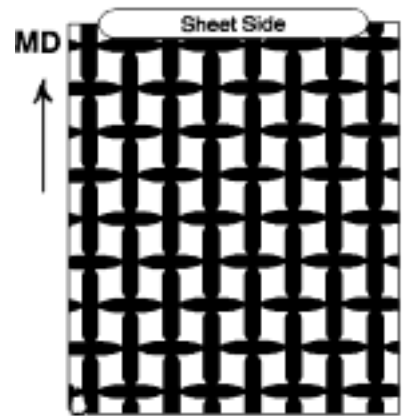

FORMING FABRIC TERMINOLOGY

This forming fabric terminology document has been prepared to assist the understanding of those people dealing with the selection and/or purchase of forming fabrics. It is not a catalogue of the only designs available but includes the major designs that have been used during the evolution of the synthetic monofilament forming fabric.

MESH

Mesh is a description of the number of yarns that are contained within one unit area of a forming fabric (square inch or 10 cm x 10 cm). Mesh describes the same thing for single-, double- or triple-layer constructions.

It is common practice to present the number of machine direction yarns first followed by the number of cross machine direction yarns – e.g., 76 x 50 mesh/inch describes a typical single-layer fabric having 76 machine direction yarns (measured over one inch across the fabric) and 50 cross machine direction yarns (measured over one inch in the machine direction). The mesh of 76 x 50 could also be described as 300 x 197/10 cm square in metric terms.



- 150 x 100 mesh/inch would describe a typical standard double-layer structure
- 150 x 135 mesh/inch would describe a typical X-pick double-layer structure
- 76 x 70 mesh/inch has been used to describe a standard triple-layer structure

(However, this number only indicates the top papermaking surface mesh/inch, not the total mesh of the fabric. The total mesh depends on the type of construction in the base fabric and the stitching yarn frequency per inch.)

YARN DIAMETER

The diameters of all the yarns used in the construction of a fabric should be specified as they can directly affect drainage rate and wear volume.

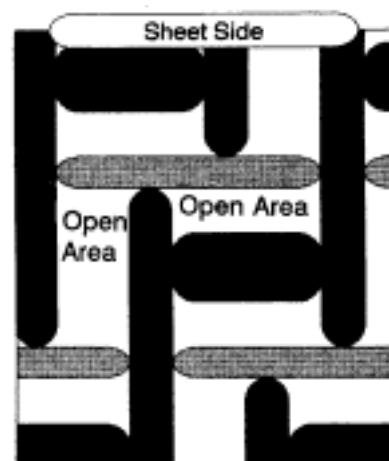
Yarn diameter can be specified in thousandth of an inch or millimeters – e.g.,

- 0.007" that converts to 0.1778 mm
- 0.008", which converts to 0.203 mm
- 0.009", which converts to 0.228 mm

PERCENTAGE TOP SURFACE OPEN AREA

The percent (%) top surface open area indicates the total open area of the combined drainage holes (orifice) in the top surface of a fabric. The percent open area is calculated using a plan view of the top surface of the fabric and subtracting the area taken up by the yarns from the total area, leaving the area of openness that is usually expressed as a percentage of the total area.

Experience has shown that in multi-layer constructions, this figure gives a much better indication of the drainage potential of a fabric than CFM that can be dramatically affected by the center and bottom plains in a multi-layer construction.



CFM (CUBIC FEET/MIN.)

CFM is a term that was heavily used when single-layer fabrics were the main filtering media. For the simple single-layer construction, it gave the papermaker a good indication of the drainage potential of the fabric. It was also a good quality control tool for the fabric manufacturer. However, double- and triple-layer fabric constructions have a center and bottom layer, which can have a considerable influence on CFM but not necessarily on drainage rate.

CFM is still used by the manufacturer as a quality control tool for all fabric designs but papermakers are starting to realize that it is not always a good indicator of the drainage potential of a fabric.

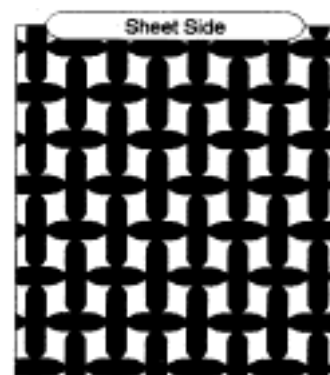
CFM is measured using the Standard Frazier Air Permeability tester. It is a measure of the volume of air (cubic feet) that will pass through a standard unit area of a fabric when under a pressure differential of 1/2" water gauge.

When CFM is specified, it should always be qualified at what differential pressure the measurement was taken as this will directly affect the final number.

HOLES/UNIT AREA

The number of drainage holes per unit and the dimensions of each group of holes give the papermaker an indication of the fineness of the top papermaking surface and the uniformity of that surface.

The number of holes per unit area can be expressed as holes/square inch or holes/square centimeter. The dimensions of the holes are, again, arrived at by using a plan view of the top surface of the fabric. Dimensions are expressed length and width in inches or millimeters.



FIBER SUPPORT INDEX

Fiber Support Index, as adopted by the paper industry, was originally developed by Beran for use when running single-layer fabrics. It is a number that takes into account the support length of the surface of the yarns on which the sheet of paper is formed. Beran also recognized that the cross machine direction support lengths were preferable to machine direction support lengths and, therefore, gave them a double weighting.

Experience has shown that this same Beran Fiber Support Index can be used to compare the support characteristics of single-layer, double-layer, X-pick double-layer and triple-layer fabric structures with good results.

Fiber Support Index is affected by the weave pattern and mesh of the surface of the fabric on which the sheet is formed but not the yarn diameters. It does not, however, give any indication of the uniformity of support lengths in either direction.

Some examples of fiber support index are:

		Fiber Support Index
Single-layer 4-harness satin weave NORMAL	Mesh 76 x 50 =	84
Single-layer 4-harness satin weave INVERTED	Mesh 76 x 50 =	92
Standard double-layer 7-harness E-weave	Mesh 150 x 110 =	85
Standard double-layer 8-harness G-weave	Mesh 150 x 110 =	95
Standard double-layer 8-harness H-weave	Mesh 150 x 110 =	83
X-pick double-layer 7-harness E-weave	Mesh 150 x 123 =	114
X-pick double-layer 7-harness G-weave	Mesh 150 x 123 =	122
X-pick double layer 8-harness H-weave	Mesh 150 x 123 =	114
Triple-layer plain weave top	Top Mesh 72 x 70 =	141

DRAINAGE INDEX

Drainage Index was also conceived by Beran and it worked quite well with single layers but because it also uses CFM as part of the equation, however, it fails to be a good indicator of drainage on multi-layer fabrics due to the influence of the center and bottom planes on these structures as discussed under CFM.

It is for this reason that papermakers are steering away from it use in the selection of multi-layer forming fabrics.

WARP

Warp is a textile term used to describe the group of yarns that the papermaker knows as the machine direction yarns.

WEFT

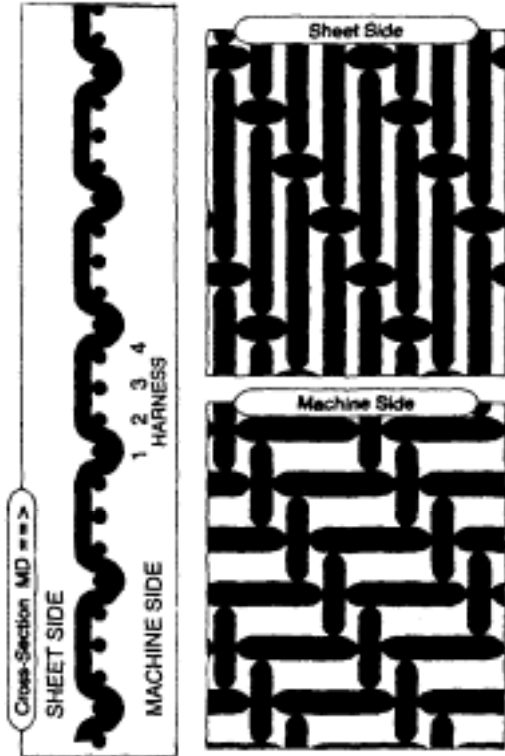
Weft is a textile term to describe the group of yarns that the papermaker knows as the cross machine direction yarns.

HARNESSES (OR SHED)

Is again a textile term to describe the number of different lift sequences the weaving loom has to make for each pattern repeat. The higher the number, the more difference sequences of lifts that has to be made before it is repeated.

Examples of the minimum number of harnesses for various weave patterns are:

Plain Weave	2 Harness	
1 x 2 Twill	3 Harness	
2 x 2 Twill	4 Harness	
1 x 3 Twill	4 Harness	
1 x 4 Twill	5 Harness	
7-Harness (or Shed) Standard Double Layer		7 Harness
8-Harness (or Shed) Standard Double Layer		8 Harness
7-Harness X-Pick Double Layer		7 Harness
8-Harness X-Pick Double Layer		8 Harness
Triple-layer Plain Weave Top & Bottom		Total 4
Triple-layer Plain Weave Top & 4-Harness Bottom		Total 6



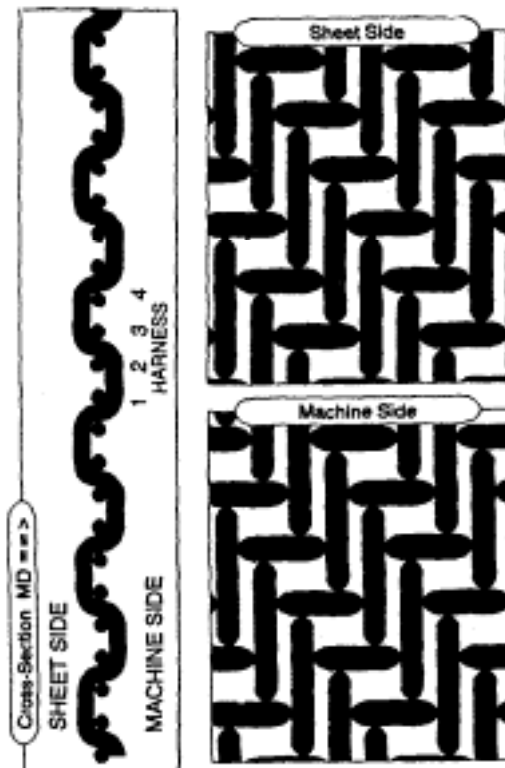
1 x 3 Twill

The machine direction cross section of this weave pattern is shown at far left. The repeat is over 1 under 3. It requires 4 harnesses to weave.

It can be seen that this weave pattern produces a very heavy diagonal twill pattern, which reflects itself in sheets formed on it.

It has one small hole and one very long machine direction hole.

This fabric is not co-planar on either side in that its CMD yarn knuckles are much higher than the MD knuckles.



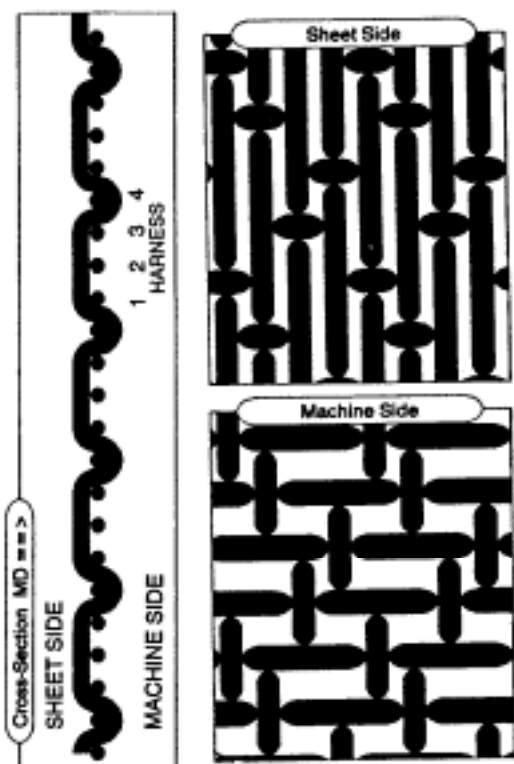
2 x 2 Twill

This is a very simple weave requiring 4 harnesses. The two over two under weave pattern gives a very heavy diagonal twill, which is also reflected in sheets, formed on it.

The sheet and machine side are mirror images of each other.

This fabric has one cross machine direction hole and one machine direction hole.

This fabric is not co-planar on either side. Again, the CMD yarn knuckles are higher than the MD knuckles.

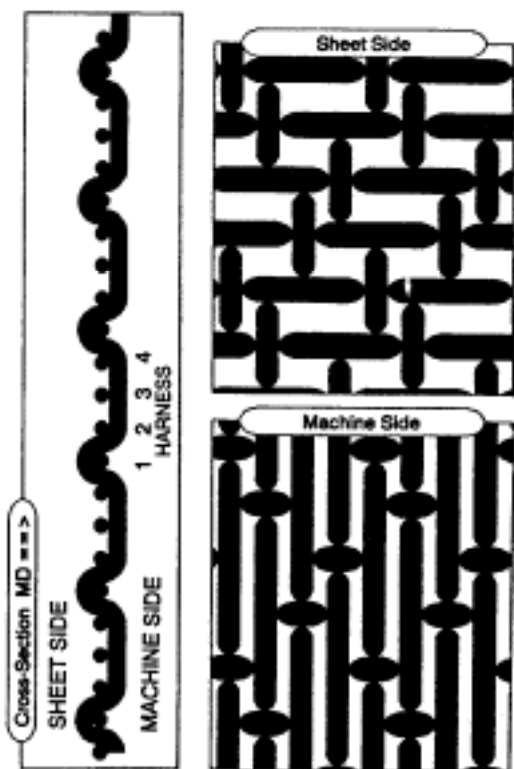


4-Harness Satin Weave (Run Normal)

Requires 4 harnesses for weaving, however, the sequence of weaving each yarn is changed from the 1 x 3 twill in order to break up the twill mark.

This fabric sheet surface is very MD yarn predominant and it has 3 machine direction oblong holes of quite different dimensions.

The fabric is not co-planar on either side. The CMD yarn knuckles are higher than the MD knuckles.

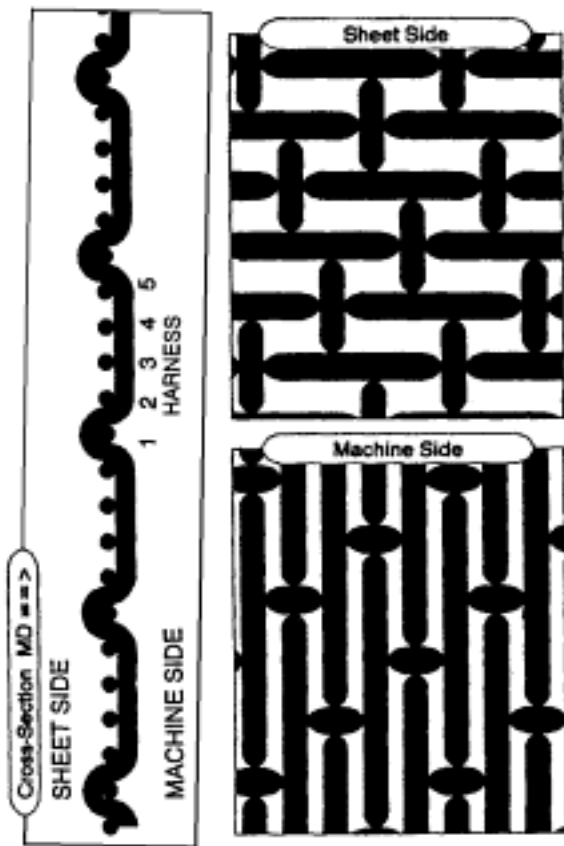


4-Harness Satin Weave (Run Inverted)

This weave is exactly the same as above but run inverted to the normal way of running.

This way of running presents a high predominance of cross machine direction yarn support to the papermaking fibers as they come out of the headbox. The 4-harness satin weave inverted was used on open draw machines to give better couch release.

Again there are three different holes in the surface but in this case they are CMD directional oblong holes. This fabric is not co-planar on either side.

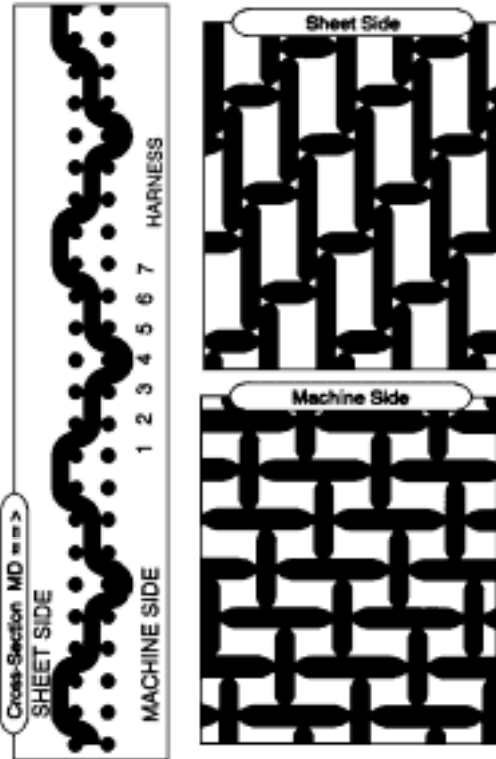


5-Harness Inverted

This fabric requires 5 harnesses to weave and is mainly used in the tissue market (run inverted). It has high CMD support and two quite uniform hole sizes compared to the 4-harness satin weave.

This fabric gives high wire mark when run inverted and low wear volume on the machine side.

This fabric is not co-planar on either side.

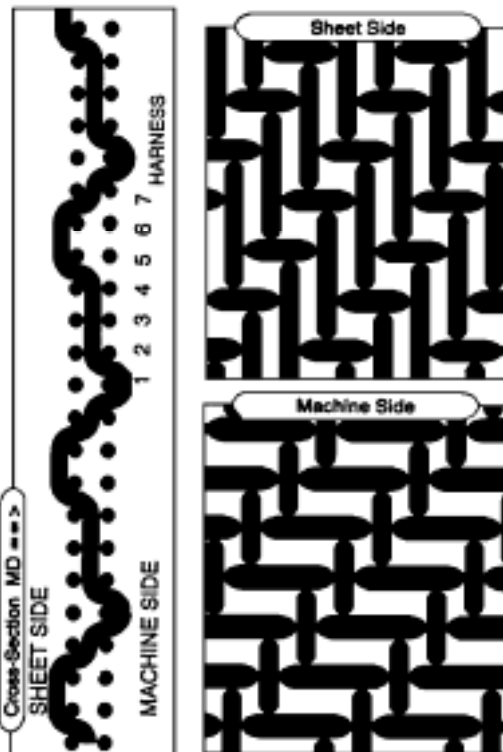


7-Harness Standard Double-Layer E-Weave Pattern

The machine direction cross section of this weave pattern shows that it floats over two on the sheet side through two in the center plane then down and under one bottom side yarn coming back up to the center plane and floating two in the center before repeating the float on the top two.

The sheet side surface of this fabric has one very large machine direction hole and a second hole that is so small it does not play any role in drainage and should therefore be ignored. The diagonal twill shows up in most sheets.

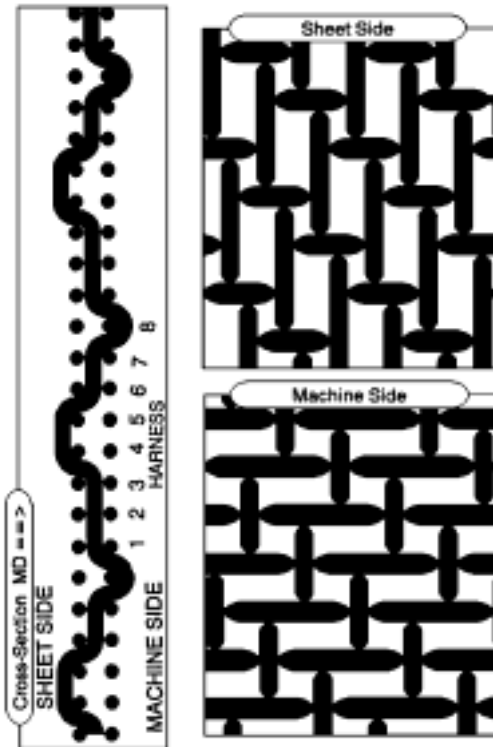
The top surface yarns can be finished to be co-planar.



7-Harness Standard Double-Layer G-Weave

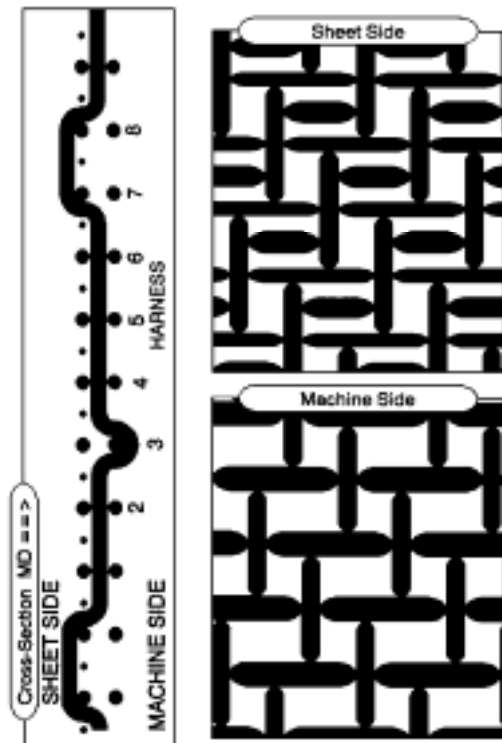
This fabric is woven on 7-harness the same as above but with a slight variation in weave pattern. The center floats through one and three instead of two and two as in the E-weave. This produces a quite different top surface in that there are two quite uniform holes – one MD and one CMD. As the sheet side knuckles are co-planar, this surface is superior to single-layer fabrics and reduces the twill marks that appear in sheets made on this fabric compared to single-layer fabrics with a twill.

The wire mark of this design is considerably less than the E-weave above and is one reason why it was used for producing European Rotogravure.



8-Harness Standard Double-Layer H-Weave

The 8-harness version of the standard double-layer floats over 2 on the top through 2 in the center, under on the bottom CMD yarn then back through 3 in the center and back up to the top for the pattern repeat. This fabric pattern gives one large MD hole and another hole considerably smaller. Again the top surface is finished to be co-planar.

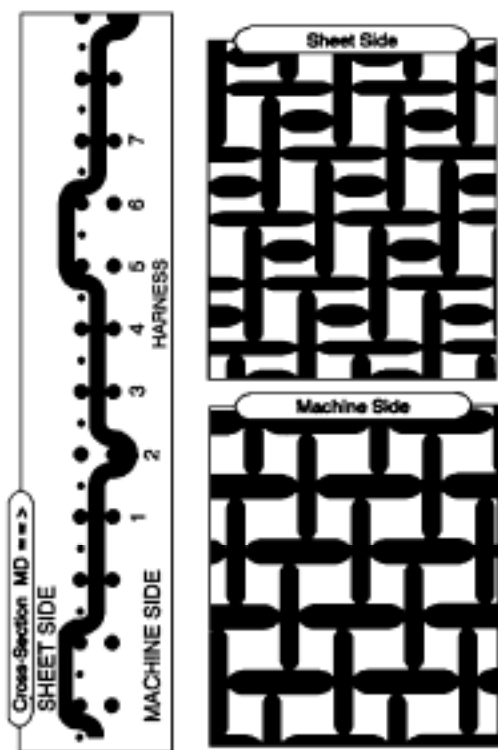


8-Harness X-Pick Double-Layer H-Weave

The basic weave pattern is exactly the same as shown above for the 8-harness standard double layer. The only difference is that an extra pick is put in the top surface that is held in place by the two knuckle top surface MD float and kept up on the top surface by the outside ends knuckles of these same two knuckle top surface float.

This produces a fabric that has twice the number of sheet surface CMD yarns (which Beran puts a big value on) and a very open bottom surface where yarn diameters can be increased for stability and life.

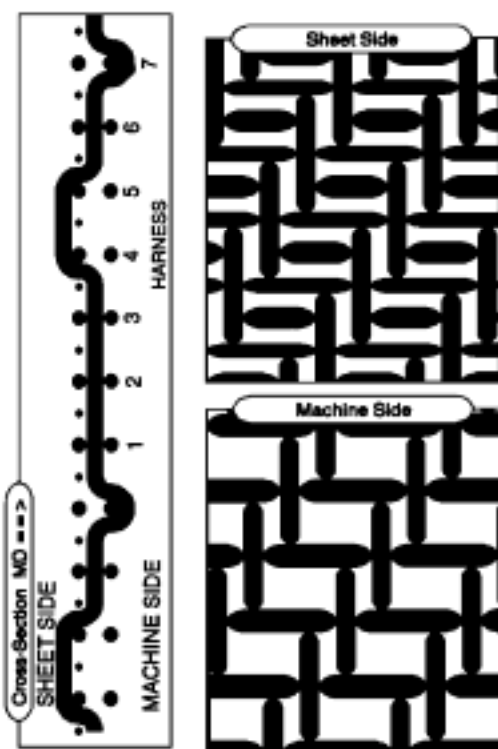
The sheet surface is co-planar and is made up of repeats of 1 large MD hole and a pair of smaller CMD holes. The twill of the large MD holes tends to show up in sheets produced on it.



7-Harness X-Pick Double-Layer E-Weave

Again, this weave is the same basic pattern as the standard double-layer E-weave with the extra pick in the top surface.

The top surface is co-planar and made up of one large MD hole and a pair of smaller CMD holes. The twill of the large MD holes shows up in sheet samples made on this fabric.

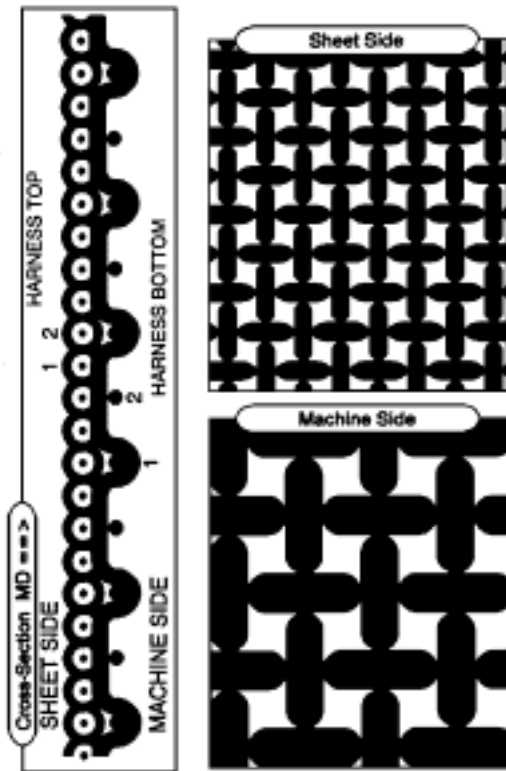


7-Harness X-Pick Double-Layer G-Weave

This weave uses the basic weave pattern of the standard double-layer G-weave with the extra pick in the top surface.

The surface is co-planar and made up of one MD hole and a pair of CMD holes. The important point with this weave pattern is that all three holes are very close to being the same size which gives uniform drainage rates.

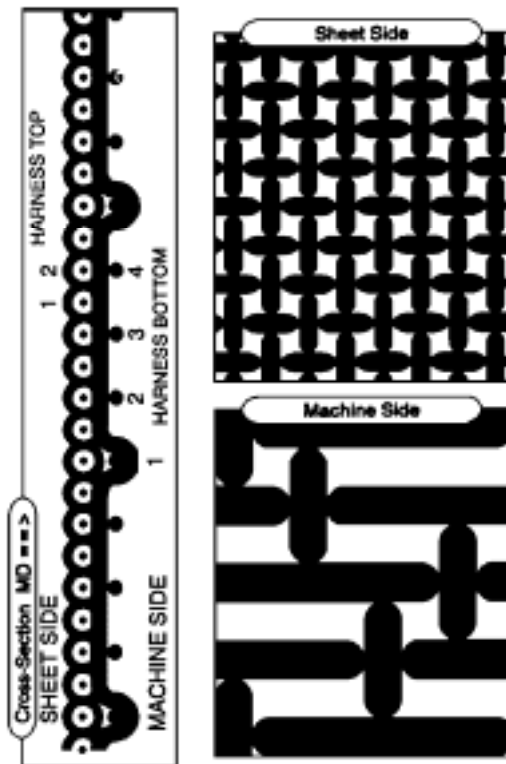
When using very short fiber, the twill mark in this weave pattern shows up in the sheets on high turbulence positions. However, the twill is less severe than that of the E-weave and H-weave X-pick double layer.



Standard Triple Layer- Plain/Plain

The standard triple layer is woven such that it has two completely separate fabrics – a plain weave top and a plain weave bottom. The two fabrics are stitched together during weaving with a CMD yarn. The number of harnesses required is two for the top fabric and two for the bottom.

By careful selection of yarn materials, this fabric can be woven and finished to be co-planar on the top surface. It has only one hole size over its whole surface, which makes it a very uniform top surface.



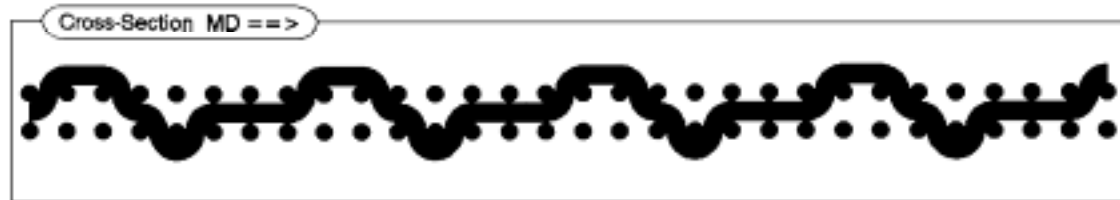
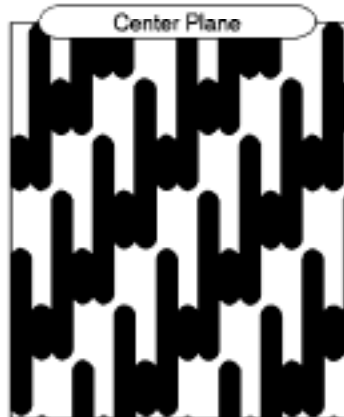
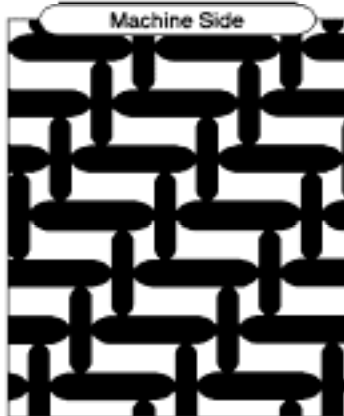
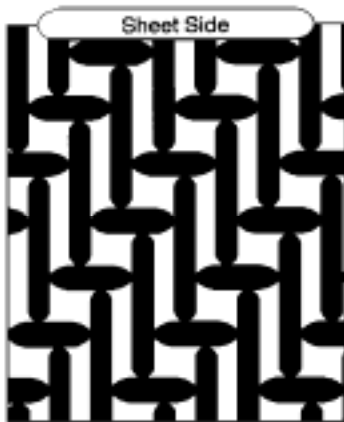
Standard Triple Layer – Plain/4-Harness

The top surface of this standard triple layer is plain weave, the same as the above fabric. However, the bottom surface is woven 4-harness which gives it a higher wear volume.

Again, the top papermaking surface can be made to be co-planar.

Fabric Surface Analysis

G-Weave Standard Double-Layer 7-Shed



General Information

Customer : 09-September-1992
 Division/Mill :
 Machine/Position :

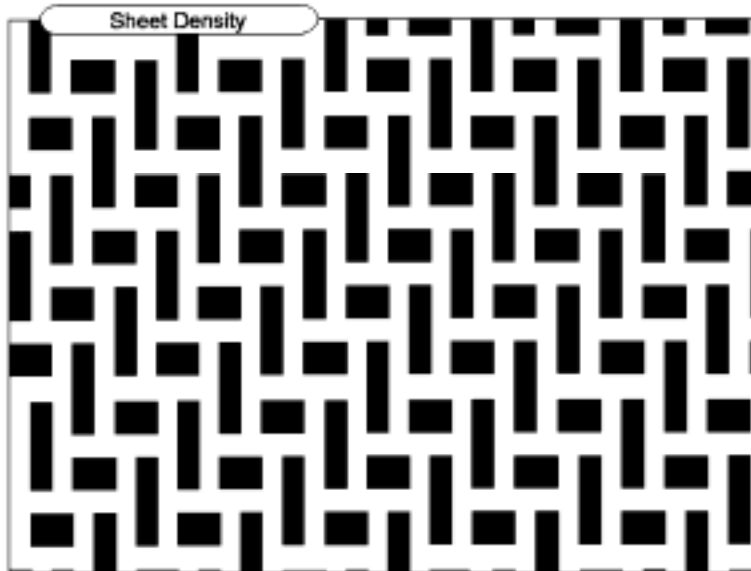
Fabric Description

Design : Scale : 20:1
 Mesh : 150 x 110
 MD Diameter(s) (mm) : ■ 0.17
 CMD Diameter(s) (mm) : ■ 0.20
 ■ 0.22

Comments : STANDARD DOUBLE LAYER 7 HARNESS G WEAVE

Open Area : 38.46 %
 # of Holes : 2357 /in ^ 2
 MD Support Length : 64.29 in/in ^ 2
 CMD Support Length : 39.29 in/in ^ 2
 Support Ratio CMD/MD : 0.61
 FSI : 95.2

Hole #	Length (mm)	Width (mm)	Area (mm ²)	Open Area %
1	0.724	0.169	0.122	39.02
2	0.262	0.338	0.088	37.72



FABRIC SURFACE ANALYSIS

The “**Fabric Surface Analysis**” program was developed to make forming fabric design and selection much more of a science than it once was.

It is a PC computer program that takes, as its input, any weave design including new ones never woven before, any mesh and yarn diameters. From these inputs, it generates a picture to scale of the top surface on which the sheet is formed – the machine side on which all the wear will be taking place – the center plane which gives an indication of the drainage passages through the fabric – a cross section of the fabric showing the path of the machine direction yarn as it will be woven in the loom – the sheet density patterns which simply represents the heavy areas in the sheet formed over the holes in the fabric and the light areas in the sheet formed over the knuckles. This part of the printout represents the wire mark that the papermaker will see in the sheet.

The program also calculates the percentage of top surface open area which gives the papermaker the total drainage area or drainage capacity of one multi-layer fabric compared to another, the number of drainage holes per square inch and the length of support per unit area that the MD and CMD knuckles give to the sheet. This is then shown as a ratio of CMD support over MD support. Fiber Support Index is also calculated. Finally, the dimensions of each top surface hole are also calculated together with its unit area and percent (%) top surface open area. When these numbers are compared and used in conjunction with the sheet density portion, they show why heavy twill marks can occur in a sheet of paper.

The purpose of the Fabric Surface Analysis printout is to help the papermaker understand the relationship between the fabric he buys and the sheet that he will produce on it. Work is also under way which will show further relationships of the fabric structure to final print quality.

Fabric Surface Analysis Comparisons

The Fabric Surface Analysis computer-generated program comparison sheet (attached) shows the sheet side of three (3) different single, standard double, X-pick double and a triple-layer fabric structure. These are all printed to the same scale, hence direct comparisons can be made. The table (also attached) is the numbers generated from the analysis of each one of these printouts.

The mesh and yarn diameters have been chosen such that a direct comparison can be made between weave patterns.

An explanation of the table of results is necessary to point out the highlights.

- **% Top Surface Open Area**

% Top Surface Open Area for single layers has been shown in brackets because the top surface of the fabric is not co-planar which means that these open areas are not truly correct and is why papermakers use CFM to compare these fabrics. However, CFM is not a reliable indicator of drainage on multi-layers whereas % top surface open area is. This is shown up in practice where the 7-shed "G"-weave, if woven with the same mesh as a 7-shed "E"-weave or 8-shed "H"-weave as shown in the example above, would not drain as well because it is 38.5% open area compared to 44.6 and 46.1% open area. This is the reason why 7-shed "G"-weaves are usually lower mesh than the other two designs. The same applies to the "X"-pick double-layer structures. The standard triple-layer structure shows a closed up 29.0% open area which explains why you never see this fabric being used on high velocity, slow draining positions.

- **Holes Per Square Inch**

The number of holes per square inch, together with the change from the top surface yarns being non-co-planar on single layers to co-planar on double and triple layers, shows the reason for the evolution of fabric designs from single layer to triple layers - 1900 holes/square inch single layers, 2300 standard double layers, 2600 for X-pick double layers and 5000 for triple layers.

- **% Open Area for Each Hole**

These numbers assist in assessing the uniformity of drainage of the top surface of each fabric. This is important as experience has shown that the more uniform the hole size the more uniform will be the resultant sheet density. The plain weave triple-layer is the most uniform of all as it has only one hole size.

- **MD/CMD Fiber Support Length**

This is a total of the length of the top surface of every knuckle that lies in the machine and cross machine direction, which directly supports the sheet. In this case, it is expressed as inches length per square inch of fabric surface.

- **Fiber Length Support Ratio**

Takes the above numbers of support length and expresses it as a ratio CMD/MD.

- **Beran Fiber Support Index**

Is calculated using the standard Beran equation, which uses the MD and CMD fiber support lengths given above. However, it gives double the value to CMD support compared to MD support. This number has proven to be very useful in comparing fabrics, however, it does not indicate the uniformity of that support which is known to be very important.

Fabric Comparisons for Papermakers

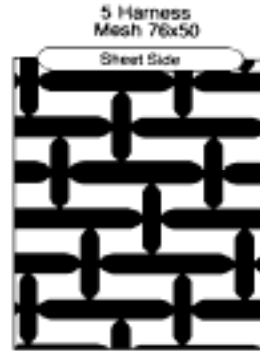
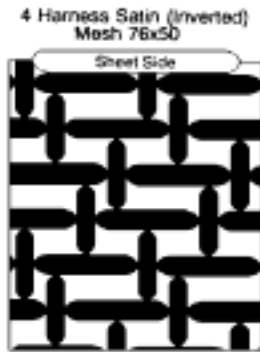
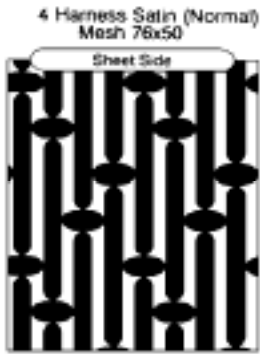
The key factors that are required for good fabric comparisons:

- Weave Pattern
- Mesh
- Yarn Diameters
- % Top Surface Open Area
- Holes/Square Inch
- Hole Uniformity Dimensions
- Beran Fiber Support Index

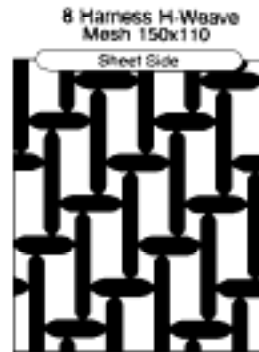
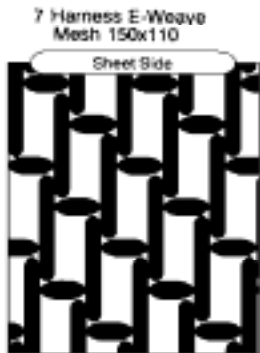
FABRIC SURFACE ANALYSIS COMPARISON

	SINGLE LAYER			STANDARD DOUBLE LAYER			X-PICK DOUBLE LAYER			TRIPLE LAYER
Weave Pattern	4 HS Normal	4 HS Inverted	5 Harness	7-Shed E-Weave	7-Shed G-Weave	8-Shed H-Weave	7-Shed E-Weave	7-Shed G-Weave	8-Shed H-Weave	Plain Weave
Mesh	76 x 50	76 x 50	76 x 50	150 x 110	150 x 110	150 x 110	150 x 123	150 x 123	150 x 123	$\frac{72}{70}$ 36 x 35
Co-Planarity	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Top Surface MD Yarn Dia. Top (MM) Bottom	0.20	0.20	0.20	0.17	0.17	0.17	0.17	0.17	0.17	0.15 0.34
CMD Yarn Dia Top (MM) Bottom	0.23	0.23	0.23	0.10 0.22	0.20 0.22	0.20 0.22	.20 .13 0.22	.20 .13 0.22	.20 .13 0.22	0.17 0.36
% Top Surface Open Area	31.1	38.3	41.6	44.6	38.5	46.1	42.5	37.9	43.0	29.0
# Holes/Sq. Inch	1900	1900	1520	1178	2357	2063	2636	2636	2306	5040
% Open Area Hole #1 Hole #2 Hole #3	31.1 34.1 21.9	43.8 38.3 21.9	38.3 43.8 --	52.0 0.22 --	39.0 37.7 --	52.1 28.2 --	52.6 35.0 --	39.3 37.3 --	52.6 37.4 --	29.0 -- --
MD Fiber Support Length Inch/Sq. Inch	76	38	30	64	64	56	43	43	37	72
CMD Fiber Support Length Inch/Sq. Inch	25	50	50	31	39	34	64	70	67	70
Fiber Length Support Ratio	0.33	1.32	1.64	0.49	0.61	0.61	1.50	1.64	1.78	0.97
Beran Fiber Support Index	84	92	87	85	95	83	114	122	114	141

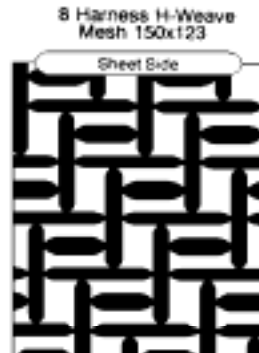
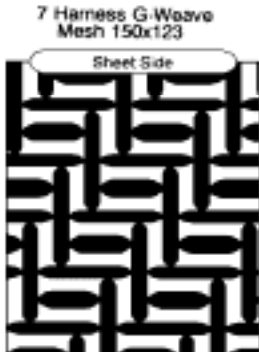
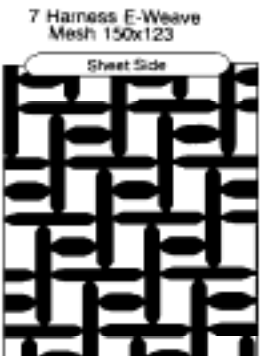
FABRIC SURFACE ANALYSIS COMPARISON



Standard Double-Layer Fabrics



X-Pick Double-Layer Fabrics



Standard Triple-Layer Fabric Top Surface Mesh 72x70

