Sidedness
Wire and Felt Side of Handmade Paper

- Direction of mould movement
- Pulp (aka stuff, furnish)
- Deckle
- Mould
- Laid lines
- Chain lines
- Fiber alignment at screen surface
- Fines, aka white water - finely divided matter: cellulose, hemicellulose and additives (MgCO/three, fillers, pigment, etc.)
- Using fines and fiber grain to determine wire side vs felt side:
  - During sheet formation, pulp (furnish) flows across the mould in a direction perpendicular to the laid lines covering the mould. Initially, when the pulp begins to impact the mould surface, the fines fall through the screen; very quickly thereafter a fiber mat starts to form, trapping the fines on the upper side of the sheet (the felt side). The vatman shakes the screen side to side and forward to back, creating a multidirectional 'grain.' A more pronounced grain direction is found on the wire side and a more random fiber orientation is found on the upper, felt side.

  - Note: Machine-made paper is only shaken side to side, creating a more pronounced grain directionality.
  - Note: Freer pulp retains less fine matter (cellulose and mineral fines) than highly processed pulp.

- Under a Microscope:
  - Wire side:
    - Chain lines indented (if visible).
    - Fibers are more aligned, like combed hair (in parallel to the swirl of pulp in the vat, combined with the direction of the vatman's dip).
    - More fibrous due to fewer fines.
  - Felt side:
    - Fibers more random;
    - More fines result in areas where the "normal" fibers are hidden by or mixed with smaller, shorter fibers.

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Characteristics of wire and felt side in a finished sheet of paper
SIEDNESS
WIRE AND FELT SIDE OF HANDMADE PAPER

Donald Farnsworth
2018
Contents

Introduction 1
Paper’s two-sidedness: defining wire and felt side 3
Look-through 5
The two-sidedness of papermaker’s felt 6
Determining wire or felt side...vatman & coucher drips 9
Case study: determining wire or felt side from drip evidence 10
Wire or felt side: drip watermark characteristics 13
Wire-side-up 14
Folded, glued edges an indication of the wire side 15
Back mark as indication of sidedness 17
Spurs hung on treble-lines create back marks 18
Using manufacture flaws to identify wire and felt side 22
Wire and felt side color & value shift 28
Wire or felt side: destructive method 26
Wire or felt side: Torn edges 28
Wire or felt side: Graphite toning 29
Overview – Characteristics of wire side & felt side 31
Acknowledgments 32
Introduction

In early 2017, Timothy Barrett and I were invited by Marjorie Shelley to present at the Paper Conservation Symposia on Technical Art History at the Metropolitan Museum of Art. There we described the current state of our research regarding early European paper. Tim’s presentation, Aesthetic Considerations in Making Paper and mine, Recreating 16th century Drawing Papers for Contemporary Artists, described our findings and hopefully shed light on some of the many issues surrounding early European papermaking. Eventually, at the close of our presentations, a conservator in attendance posed a paper-sidedness question to which neither Tim nor I had a satisfying answer, despite it being a relatively straightforward question that two seasoned papermakers, I thought, should have found easy to field; namely, what are the various techniques for distinguishing a sheet’s felt side from its wire side in a non-destructive manner? We, of course, had the conventional answer of casting raking light across the sheet to gauge which side the laid lines appear most strongly. But this method is not a universally effective solution, since not all early papers have a strong surface laid pattern. Having pondered and researched this question over the ensuing 18 months, I can now say that this seemingly simple question is not so “straightforward” as I first imagined. This document therefore represents my attempt to describe the parameters of sidedness and to begin formulating answers to that question, though it by no means can be said to be a fully comprehensive response. The ideas presented here will, with luck, spark others to shed light on the endlessly intricate question of the sidedness of handmade paper.

Donald Farnsworth
2018

1 Timothy Barrett: Director, Center for the Book, University of Iowa
2 Marjorie Shelley: Sherman Fairchild Conservator in Charge, Paper Conservation, the Metropolitan Museum of Art
The term “wire” side (aka the right side) in handmade paper refers to the side of the paper that touches the mould’s wire covering when the sheet was formed and therefore, the side that is face up after couching (transferring the paper from the mould to a felt).

With the exception of French drawing papers and counter marks, watermarks are sewn wrong-reading to the mould’s wire surface so that when couched onto a felt, the watermark is right-reading. Most likely, if you hold a sheet to the light and see a watermark right-reading, you are looking at the wire side (aka the right side) of the sheet. The downward-facing side, the side touching the felt as it was couched, is called the felt side (aka the wrong side).

There are textural differences between the wire side and the felt side which can be either very obvious or extremely difficult to discern. Often, under a raking light, the wire side reveals its laid lines more prominently than the felt side. The degree to which the laid lines show depends upon many factors including the processing and composition of the furnish and the weight of the paper. Felt hair marks, if present, can be seen on both sides but tend to be stronger on the wire side (see p. 6).

All sheets in post and pack pressings are oriented with the wire side facing upwards (right side up). After pack pressing, the stack of wire-side-up sheets are folded onto the “T” (separately or in spurs) and hung on treble lines (horse hair rope) so that the wire side is touching the rope.

Therefore, when the paper is dry and taken down from the rope treble lines, the wire side and arc of the “back” are on the inside and likely to be sewn into the signature wire side up for “good draping.”

When paper is formed on a laid mould, the initial dip starts with the lead (long) edge of the mould pulled towards the vatman from the back of the vat through the furnish. As water rushes across the laid lines in a perpendicular direction, fibers alight
Parallel to the chain lines and lay (like a fine screen) across the laid lines, preventing the fibers from tangling in the slots between each laid line and helping the coucher make a clean transfer of the newly formed sheet from mould to felt. Initially, when the pulp first impacts the mould surface, the fines fall through the screen; very quickly thereafter, a fiber mat starts to form, trapping the fines on the upper side of the sheet (the felt side). The vatman shakes the screen side-to-side and forward-to-back, crossing the grain. A more pronounced grain direction will be found on the wire side, while a more random fiber orientation is found on the upper, felt side.

As the sheet is formed, draining “white water” follows the path of least resistance, flowing through the spaces between the laid lines and pulling fibers that follow the water’s movement. Therefore, we find that a thinner mat of fiber accumulates on the chain and laid line wires as more fiber builds up in the spaces between the wires. This choreographed dance and flow of water and fiber happens in a mere eight seconds of sheet formation as fibers are swept along, following the white water as it drains through the sieve slots of the screen. The flow of draining water draws fibers in the flow direction, away from the wires into the thick-and-thin pattern which creates the light and dark image of the watermark and laid lines when the paper is held up to the light. A further complexity occurs when the draining water, having made it past the laid screen hits the wood ribs to which the chain lines are sewn. Like a rushing river pounding against a protruding rock, water flows around the ribs, depositing fiber in its wake and causing a shadow line of thicker fibers seen on either side of the chain/rib lines (Figure 8, left).

Examining a paper held to light reveals many signs of its manufacture. One might find vatman or coucher’s drips, watermarks, laid lines, production flaws, wove screen pattern, or possibly “wild” or “cloudy” textures. Each of these marks has a story to tell.

In general, furnish for paper with a “good look-through” – i.e., a visible laid pattern and watermark – must contain shorter fibers that have been beaten for a longer duration, in a less dense suspension, and with more fly-bar to bed plate pressure to promote cutting and shortening of the furnish fibers. Shorter fibers provide a better look-through because they readily accumulate and settle in accordance to the topography of the watermark and laid lines, creating a sharper image. Long and unruly fibers with higher tear strength do not build up in the low points of the screen nor thin out in the highs points as do shorter fibers, but rather drape themselves across the wires of the screen (during formation), diminishing wire pattern detail. When held up to the light, a sheet made from long-fiber furnish will appear cloudy or, as some say, “wild.” In such a sheet laid lines, chain lines and watermark are unresolved and hard to distinguish. Meanwhile, despite the attractiveness of a paper with a sharp clear laid pattern and watermark, it may not be the strongest paper one could choose, as measured by a robust tear strength. Still, such a paper often has a nice rattle and good tensile strength. Like fine wine makers, papermakers blend their pulps to create a furnish that will yield a paper with the characteristics we have come to expect – a fine balancing act indeed.

Figure 8: Furnish flow on the laid mould covering causes a heavier build-up of fibers washed to the drainage spaces (between the laid lines and on either side of the ribs). Those varied fiber densities generate the visible shadow of the laid lines and the thick/thin profile of “antique” laid paper.
Traditionally papermaker’s felts (blankets) have two sides: a finer nap on one side and coarser on the verso. Felts are placed (thrown) one at a time to build up the post coarse-side-down, fine fleece up on each successive couched paper. The sidedness of felts is important in two ways: first, the coarse fleece side ensures efficient dewatering when under pressure as the post is pressed. Second, the fine fleece side holds the sheet to the felt with more surface tension and entanglement than the coarse side. Because of this temporary adhesion, couching is done on the finer nap side* to ensure that after pressing, as felts and sheets are “parted,” the exposed sheet remains on the lower felt of a post rather than sticking to the underside of the felt being lifted.

In an ideal Renaissance papermill, with felts in good condition and both layer and coucher laying felts properly, the fine and coarse felt hair marks impressed into the sheet will provide another clue as to sidedness. As mentioned above, when paper is formed on the mould, the fibers touching the laid screen create the wire side and the opposite side, soon to be inverted (couched) onto the felt is the felt side. Since felts are thrown fine side up, the felt side will take on the impressions of the finer fleece and the wire side will remember on the impressions of the coarser fleece. The page shown above is the wire side, as indicated both by its indented chain lines and coarse felt hair marks – coarser and stronger than the felt-side opposite page which shows the finer felt hair marks.

* The fine wool fibers, found on the couching side of the papermaker’s felt, have a lower micron value than the coarse fleece on the verso. The finer fibers make a denser felt mat, with more surface area, hence the “clingier” side of the felt.
While it is easy to tell at a glimpse that Georges Seurat chose the wire side for his chalk works on Michallet paper – evident by the strong laid lines present in his conté drawings – in other cases it can be difficult to discern the wire and felt sides from one another. A close examination of the phenomenon known as *vatman’s drips*, when present, may help us to determine which side an artist used. Vatman’s and coucher’s drips occur when droplets of white water fall onto the surface of a newly formed or couched sheet. The size and clarity of this round watermark is determined by the height from which it falls, the volume of the drop, and at what stage of the papermaking process it landed. Hitting the paper with force, the drop pushes fibers aside to form a crater-like dent, round and thinner than the rest of the sheet. The vatman’s drips fall on the felt side, dripping from his hands or arms and from the deckle as it is being removed. It is easy to do: the vatman passes the mould to the coucher by pushing the mould with the inner left corner of the deckle, sliding the mould along the stay while at the same time raising the far end of the deckle to free it from the mould. The deckle will be used on the second (paired) mould to form a sheet as the previous sheet is tilted on the asp and later couched. During this transfer, when the deckle is lifted dripping wet from the mould, droplets often fall on the sheet as it is passed to the coucher. Meanwhile, the coucher throws a felt (coarse side down) to cover the previous sheet, takes the mould from the asp. Holding the mould almost vertical to the post, the coucher plants one long edge of the mould onto the felt and in a smooth, arcing action, presses the loaded mould onto the felt, transferring the sheet from mould to the fine nap side of the blanket (couching). In this repetitive dance, drops can also fall from the mould as a sheet is couched. Unlike the vatman’s drips that fall on the felt side, these coucher drips would be falling onto the wire side of the newly couched sheet (wire side up).

Knowing at what stage of paper formation these drips occurred can lead us to draw conclusions about which side of the paper was disrupted and therefore, at which side of the sheet we are looking.

The vatman is depicted here using the lower left (inner) corner of the deckle to push the mould along the stay towards the asp (also “ass,” “horn” or “drainage horn”) while retaining possession of the deckle. The coucher, having just delivered the empty paired mould to the bridge, will next grasp the loaded mould and tilt it to drain on the asp.

The outer corner of the mould and the inner corner of the deckle are both reinforced with bronze panels to withstand the repetitive impact of placing the deckle onto the mould.
For example, let us consider a single leaf from a quarto dating to the 1730s. In the first image on the opposite page (1), we can see the crater topography and the fiber disruption. In the second image (2), a backlit view of the same area, we can clearly see visible laid lines that have not been disrupted by the vatman’s drip, indicating that the falling drop of water landed on the top surface of a newly formed sheet, which would later become the felt side after couching. Further, we note no disruption or crater dimensionality in the verso image (3), the wire side.

In this example, the force of the falling water – combined with the build up of fiber and fines, along with the accelerated evaporation along the ridges of the crater (greater surface area) – accumulated more pigment, fines and impurities to the rim of the crater, yielding the darker, tidemark-like edge to the drip mark. This edge pigmentation is more likely to happen on the felt side – the side with the greatest concentration of fines.

Case study: determining wire or felt side from drip evidence
Wire or felt side: drip watermark characteristics

The vatman’s drips (above) make their mark on the felt side surface of a draining sheet that is still very wet. In this situation the drips produce a soft-edge displacement of fiber divots. Once dry and finished, these will appear as ‘soft focus’ drip watermarks. Notice that the laid lines are not interrupted.

A coucher’s drip makes its mark on the wire side surface of a couched sheet. These drips fall on a sheet that has already been drained and couched. With less water (furnish) to absorb the force of the impact, these drips displace fiber like a meteor colliding with the moon, producing a rim-edged crater. When dry and finished, this drip watermark will have a hard-edged rim and the laid lines will be disrupted.
Handmade sheets that are dried unconstrained tend to curl towards the wire side, arcing parallel to the chain lines. This is due to the surface grain directionality of the wire-side fibers. As the sheet is formed, the fibers that make contact with the laid screen of the mould are lined up in parallel to the dipping motion of the vatman, while fibers that do not come into contact with the wires are distributed more randomly.

During drying, fibers tend to shrink and become narrower in diameter. Since the fibers on the wire side are parallel, not randomly distributed, the shrinkage is more pronounced on that side. The net result is a contraction of the paper inward toward the surface of the wire side, causing a wire-side curl effect.

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**Wire-side-up**

**Folded, glued edges an indication of the wire side**

**Three indications we are looking at the wire side in the example above:**

1. Due to handmade paper’s predilection for curling toward the wire side as it dries, from time to time we find sheets with fixed, folded corners as seen in the image above. The paper’s curl in waterleaf and sized sheets can be very tight and spring-loaded, making it difficult for the sizing and finishing departments to flatten. It is not uncommon to find the insistent curling of the sheets’ edges fixed in place by sizing and compressed into permanent folds during the finishing pressure of the standing press. Most folded edges that arise in this manner are trimmed off by the book binder’s plow; those that remain are most often curled or folded to the wire side.

2. The concave back mark troughs visible at the top of the page, denoting that this was the rope side when the spur was hung to dry, known to be the wire side. (See “Back marks as indication of sidedness,” p. 19.)

3. Not shown here: when backlit, the right-reading watermark also corroborates our wire side conclusion.

John Locke, 1691 manuscript, quarto, watermarked antique laid paper. Note the folded corner upper right and concave back mark across the top of each page.
Back mark as indication of sidedness

Back is the word handmade papermakers use to describe the arch or ridge formed in a spur when it dries hung over a rope or pole.

With this drying loft process in mind, and the understanding that the “back” refers to the dried paper’s arch, it follows that the “back mark” refers to any marks left as a result of the formation of a back during drying or, more accurately, while “breaking” and flattening out the back. The back mark forms and appears rather suddenly as the spur is splayed and forced flat. A convex topography of ridges appears on the top of the back’s arch, while concave, furrow-like textures form along the back’s inner or underside arc.

Knowing how Renaissance papers were couched, pressed and hung to dry allows us insight into how the back mark was formed and how sidedness can be determined from remaining evidence of a back mark.

Spurs hung to dry

Spurs hung to dry on horsehair rope

Dried spur, unbroken (showing back)

Spurs pulled down from drying ropes, separated, broken and stacked already demonstrate a good drape and conformity to the codex format.
Spurs hung on treble-lines create marks
Hanging sheets after pack pressing – Wire side in, touching the horse hair rope

1. After forming, couching and pressing, the sheets are oriented wire side up.
2. A “T” is placed off-center on the “pack” of pressed sheets.
3. The top sheet (or spur*) is folded over the T.
4. The T is lifted, separating the sheet(s) from the pack.
5. The sheet or spur is hung to dry on the treble-lines (horsehair rope) wire-side-in.

Did papermakers, accidentally or otherwise, ever flip the paper at some point during the pressing or hanging stages, so that the felt side was facing inward when hung on treble-lines? Not likely, since the choreographed movement of forming, couching, pressing and drying paper tends to follow the path of least resistance, minimizing the risk of damaging newly formed paper.

To wit:

- Forming and couching wire side up is a given.
- Flipping the post is impossible.
- Flipping the sheet during parting would be more likely to damage the sheet and an unneeded motion.
- Flipping the pack before or after pack pressing is dangerous and unnecessary.
- Sliding the T under the paper rather than folding the paper over requires extra steps and can damage the sheet.

Therefore, I remain firm in my position that the wire side is always on the inside, closest to the treble-line loft drying rope and the felt side is on the outer side facing out from the rope or pole. This is the drying position of Renaissance paper as the back forms.

*Spur: multiple sheets pressed together to dry as a group (generally 3 to 8 sheets)
The diagram on p. 18 provides a clear picture of how paper was dried; what arched position the paper was in when the unbreakable hydrogen bonds were formed; and in what orientation the wire and felts side were at the time of drying.

**Back mark sidedness:** The two sides of a sheet bearing a back mark will express the mark differently. The side closest to the rope (wire side) exhibits a back mark with a series of **concave** striations, like miniature dry riverbeds. Meanwhile, the opposite side (felt side) exhibits the inverse: a reticulated and raised, series of **convex** ridges like a tiny mountain range.

**Excluding back mark impostors:** The back mark’s parallel wrinkles are in directional agreement with the surface grain (on the wire side) of the paper and also in alignment with the chain lines, the “T” as it lifted the paper to the horsehair rope treble-lines on which the paper was hung. Therefore we may safely assume that any fold, crease, join or wrinkle not in linear agreement with these artifacts — i.e., marks skewed or perpendicular to the chain lines — were not caused by drying loft ropes and are not back marks.

Further scrutiny reveals that back marks are integral to the paper; they are part of the birth of the sheet, not comprised of broken, cracked or torn fibers.

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**Felt side example: Convex back mark**

Carle van Loo, French 1705–1765, Male Nude Standing with a Writing Tablet, 1742 (and detail) Nationalmuseum, Stockholm

**Wire side example: Concave back mark**

Annibale Carracci, Nude Study of a Young Man on his Back, Nationalmuseum, Stockholm. Note: Perpendicular creases within the back mark (towards top of this detail) suggest that the drying loft rope was loosely hung.
Using manufacture flaws to identify wire and felt side

A case study sans microscope

Conservators, archivists and connoisseurs use various non-destructive approaches to determine whether the wire or felt side of sheet or leaf was used in 14th to 18th century Western works on paper; this knowledge can provide a more detailed description and documentation of a work on paper, incunabulum, or codex. The following example demonstrates three features found in one leaf which can be used to decisively determine sidedness. To provide maximum visual information, the leaf was photographed backlit and in raking light.

Learning from backlit (show-through) information:

A1. Finger-sized abrasions on the sheet are our first clue. The scratches interrupt the laid lines, suggesting that the paper was distressed on the wire side (probably by the coucher).

A2. In this backlit view, we can easily note the location of the chain lines.

A3. There is little to learn from the back mark in this backlit view.

Three indicators informing us that this is the wire side:

B1. The abrasions are dimensional on this side of the sheet; given the information offered by the backlit photo (opposite page) we can determine that this is the side that was abraded. Because the abrasion obliterated the laid lines, this must be the wire side.

B2. A visible indented chain line is additional evidence that we are looking at the wire side.

B3. Indented, concave back marks on the quarto edge are the third identifier of the wire side.

Evidence of felt side:

C1. The abrasions are not evident on this side of the leaf.

C2. No visible chain line.

C3. A convex back mark, decisively identifying this as the felt side.
As a sheet is formed on a paper mould, water drains through the wire side taking longer fibers out of suspension while “fines” (tiny particles of finely divided cellulose and hemicellulose) wash through the slots of the laid screen. As the sheet builds up, fewer fines fall through the laid wire gaps and are trapped in the subsequent buildup of fiber. Such fines possess exposed oxidation sites as a result of beating and processing. They are no longer intact, encapsulated fibers; having broken off from the beautiful and intricate helically wound cellulose structure, these cell wall fragments and severed polymers – their monomers now broken and exposed – are prone to degradation from environmental acids and microbial excrement, and are likely to turn brown (and brittle). We can therefore predict that the accumulation of fines on the felt side will oxidize at a faster rate than the longer, intact cellulose fibers of the wire side (with comparatively fewer fines). In short, we can theorize that the presence of fines in the felt side of a handmade sheet will cause it to grow progressively darker with age than the wire side.

While such a value discrepancy may not be discernible to the human eye, it is light work indeed for a sphere spectrophotometer. * To test our hypothesis, we took spectrophotometer readings from both sides of 20 pre-Industrial sheets of paper from my collection. The sidedness of each sheet was determined using the methods described above and corroborated by the following criteria (viewed backlit or under raking light):

- Back mark concave and convex ridges
- Watermark indentations, right reading watermark
- Countermark indentation
- Chain line indentation on wire side
- Laid line texture on wire side.
- Coucher drip disrupting wire side
- Felt hair marks stronger on felt side
- Microscope analysis of fiber alignment

Without exception, the wire side Lab measurements were lighter and less colorful than the felt side (i.e., the wire side L values were higher and the a and b values were closer to 0), as predicted.

In addition to this discoloring and darkening from oxidation, if the paper were pigmented (blue paper, for example), the colorant, along with fines, would be concentrated on the felt side, lowering the “L” value and elevating the a and b values (in both the positive and negative direction – away from 0.00). The presence in some papers of an antioxidant like MgCO₃ could minimize this shift in value and color sidedness, but combined with the other previously discussed techniques, the sidedness of paper is likely easy to discover.

*X-Rite iC64 Sphere Spectrophotometer and some of the sheets measured for reference*
Wire or felt side: destructive method

Beautiful “look-through” (the attribute of showing discrete laid lines and watermarks in a well-formed sheet of handmade laid paper) is caused by a buildup of fibers on the wire side of a sheet like a miniature landscape of parallel mountain ranges. It is possible (though destructive) to remove these features by placing the paper on a light table, then using a one sided razor blade held vertical and perpendicular to the laid lines, shaving the paper thinner on each side. Scraping the wire side will remove the darker (thicker) aspect of the laid lines, whereas scraping on the felt side will not.

After forming and couching, this sheet was allowed to air dry without pressing, showing us the surface laid pattern topography of the wire side.

Wire side scraping has removed laid lines

Felt side scraping has removed not laid lines

Hamnersmith, Kelmscott (1892) Wire side scraping has removed laid lines on this thin sheet.

Scraping or shaving the surface of a laid paper 90° to laid lines, on hard, smooth surface.
If there is a tear in a document with a skived or sloping edge tapering to the back or front side, one can determine felt side from wire side by observing the feather of the edge. The wire side will have greater feather (fewer fines, more fibers).

Wire or felt side: Torn edges

Using a pad of thick paper wrapped with suede and rubbed with graphite creates a nice pad for accentuating the textures of a sheet. Holding the pad perpendicular to the paper and toning it by rubbing in circular motion brings out the surface texture of the paper, and can even indicate sidedness.

Wire or felt side: Graphite toning
Fines: particles found in white water: finely divided matter; cellulose, hemicellulose and additives (i.e., MgCO3, fillers, pigment).

- Chain lines and laid lines indented (if visible)
- Wire side fibers are more aligned, like combed hair (tending to be more parallel to the chain lines combined with the swirl of pulp in the vat during the vatman’s dip)
- Fewer fines* - more fibrous when viewed under a microscope
- With fewer fines, the wire side tends to be a lighter value.
- The curl (if any) is towards the wire side (parallel to chain lines)
- Couching on the shorter nap (finer wool) side of the felt and laying (throwing) subsequent felt coarse-hair-side-down on newly couched paper produces stronger felt hair marks on the wire side.
- Concave back mark topography

*Fines: particles found in white water: finely divided matter; cellulose, hemicellulose and additives (i.e., MgCO3, fillers, pigment).

Overview:
Characteristics of wire side & felt side in a finished sheet of paper

Wire side:

- Fibers more randomly arranged when viewed under a microscope
- More fines - areas where the “normal” fibers are hidden by smaller, shorter fibers
- With more fines that oxidize faster, felt side is the darker side
- Couching on the shorter nap (finer wool) side of the felt produces finer felt hair marks on the felt side.
- Convex back mark topography

Felt side:
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