Drop Spindles

Lady Ose Silverhair, OM
Concordia of the Snows

Introduction

Why is a tool made one way instead of another? What makes a tool good at its task? Why would a person prefer on kind of tool over another? These were the kinds of questions that were important to me as I explored creating thread and the clothing made from it.

From the spring of 2010 through the spring of 2011, I conducted a study to increase my understanding of the physics of spinning. The study was sparked by a question I asked myself – were the spindles found in Bronze Age burials used by the women to spin the thread for the clothing they were buried in? I became so fascinated by the complexity of this extremely simple tool, that I am still continuing my experiments, although at a slower pace.

Tools for processing fibers were a woman's work horse. It was most important that they fulfill their use efficiently. But what makes a particular tool efficient? I found that the only way to come to any conclusions was to experiment with a variety of tool designs. I began by determining the limits of thread gauge that I could produce with my modern rim-weighted high whorl spindles. The study was then expanded to include artifacts – whorls I had purchased dating from the Bronze Age through the Middle Ages. To spin with these whorls I had to create new shafts. I experimented with both bamboo skewers, and shafts that I carved from sticks. In the third part of the study, I created my own ceramic whorls, in order to be able to test specific shapes from the archaeological record.

This paper discusses a few of the ceramic whorls and shafts I made and the thread produced on them.

Even a quick overview of spindle whorl shapes over time will show that they were very different from modern commercial spindle shapes. While they came in many shapes – sphere, cone, bi-cone, disc, etc, they were almost always smaller than modern spindle whorls. This is not surprising when one considers that most spinning was done to create thread to weave fabric. The thread produced on these spindles tends to be more tightly spun (with a higher angle of twist) than thread produced on a modern drop spindle.

Variables that Affect Thread Production

For a spindle to operate efficiently, **it must be balanced**. This does not mean it needs to be a circle, but that the mass needs to be evenly distributed around the center of gravity. If it is not balanced, it will tend to wobble and stop spinning. With a drop spindle, gravity will work to bring the spindle back into alignment with its axis, so slight variations in balance still will allow the spindle to work.

The function of a spindle is also affected by its **mass**, or weight. The force required to start or stop the rotational motion of the spindle is equal to its mass. The momentum – the tendency to stay in motion – is acted upon by the force of the spin, the twist energy of the yarn, and gravity. The heavier the spindle, the greater its momentum. It will spin for a longer time than a lighter spindle. Two spindles of the same diameter will behave differently if they have differing mass. Two spindles of the same mass will behave differently if they are different shapes.

Moment of Inertia is an object's resistance to changing its rotation. It varies depending on the mass of an object and how far the mass is from axis. In the case of a spindle, the shaft is the axis, and the whorl is the mass (yes, that's a bit of a simplification). The farther the mass is from the axis, the greater its rotational inertia – in other words, the more force is needed to spin it. I tested spindles with the same mass but different shapes, and the same shapes but different mass. A spindle with the same mass, but a larger diameter whorl will require more force to set it spinning. If two spindles have the same mass but a different shape, the one with the mass closer to the shaft will spin faster. The moment of inertia of a spindle changes constantly as the thread grows and the cop is wound onto the shaft. But spinners learn to overcome this by instinctively changing the force exerted on the spindle. In this way it is possible to get the same diameter thread from different spindles, although they may spin at different speeds. What may be different for these two threads is the angle of twist.

The **shape** of the spindle impacts its use because it changes the distribution of the mass. A broader whorl will spin more slowly, imparting less twist to the fiber. A whorl of the same weight, but narrower, will impart more twist. (Think of an ice skater who pulls her arms in to spin faster.) A barrel shaped whorl will produce a thread with a greater angle of twist than a disc shaped whorl of the same weight. The shape of the spindle also changes how one interacts with it – is it high whorl or low whorl, center-loaded or rim-loaded, where is the cop wound, how is it set in motion, how is the thread attached, etc. I find that the distribution of the mass around the axis (the actual whorl shape) is more critical than the overall spindle shape.

The function of the spindle is also affected by the **type of yarn** one is spinning. To spin a thick yarn, one needs a heavier spindle. Thicker yarn has less capacity than thin yarn to hold twist. A heavier spindle is better able to resist the tendency to back-spin because it has a higher moment of inertia. This also makes it more difficult to start – more force is needed to start its motion. Conversely, to spin a thin yarn one needs a lightweight spindle. A lightweight spindle will spin very fast, allowing twist to build up quickly. This is important to build up the strength of the yarn so that it is able to support the weight of the spindle.

The choice of spindle also is influenced by the **staple length of the fiber**. It is important to keep the growing thread under tension when spinning. Long staple wools spin well with a heavy spindle, since the weight of the spindle helps to stretch out the fibers. Short fibers require a lighter weight spindle, so that the weight does not pull the fibers apart too fast, breaking the thread. This is also why spinners often use a supported spindle for fibers such as cotton, or flax tow.

The spinner must understand the properties of the fiber being spun in order to choose the proper tool. The more I attempted to spin thick and thin yarn, the more convinced I became that a woman <u>always</u> would have chosen the right tool for the task at hand. In other words, chose a spindle that optimally creates a thread that matches the need. When a woman's ability to clothe and furnish her family depended on her efficiency as a spinner, no one in her right mind would choose a spindle that slowed down the task of spinning. Too much was at stake. I found that it took me up to 3 times as long to spin a thread that is not suited to the spindle. At that rate, someone would have gone naked! In addition to taking longer to spin a less than optimum thread diameter, it is more difficult to keep a consistent thread diameter throughout the course of spinning a full cop.

Period Spindle Whorls

As **I studied the variety of spindle whorls from the Stone Age through the Middle Ages**, I found that the only way to know the attributes of a particular shape was to reproduce it myself. I created a series of my own ceramic whorls, based on shapes found in Denmark, Turkistan, Switzerland, Poland, and ancient Troy.

Spinning was already a highly developed skill in Denmark by the Bronze Age. This is borne out by the high quality of the textile remains in the archaeological record. The **oldest spindle whorl found in Denmark**, at a burial site in Høje Taastrup, dates from the late Bronze Age [1]. Margrethe Hald notes that the Høje Taastrup whorl is 4.8 cm in diameter and 1.9 cm thick [2]. While she does not mention the material, the ceramic whorl I made to these dimensions weighs 54 grams. With it I produced thread of 12 to 36 wraps per inch (wpi).

Ribe, Denmark was established as a trading town. The variety of coin finds in the archaeological record confirms that trade was well developed by the early 8th century. Examination of the soil remains indicate that large numbers of animals were kept. The presence of numerous remains of adult sheep bones, particularly from wethers, along with the spinning and weaving artifacts, points to wool production and textiles as important trade items in Ribe. The Viking Museum in Ribe has 34 spindle whorls in its collection that date from the 8th century. The shapes include discs, bi-cones and many cones with slightly rounded bottoms. The Ribe artifacts range in size from 2.2 to 4.3 cm diameter, and 1.1 to 3.0 cm high. The weights range from 14 to 38 grams [3]. None of my reproductions match exactly the whorls shown in the Ribe Excavations book, but all fall within the total range reported for the artifacts. My whorls range from 2.2 cm to 3.7 cm diameter; 1.7 to 2.8 cm high. My spindles weigh from 15 to 38 grams. The thread I produced with these whorls ranged from 13 to 82 wpi.

I then attempted to **recreate one of the textile artifacts from Ribe**. I determined that whorl #3, a cone, could spin thread similar to that recorded for artifact D6010. The threads are described as "very fine and tightly spun," woven at 10/12 threads per centimeter. The warp threads are Z-spun and the weft is S-spun. The artifact is tabby weave [4]. While the description does not give the actual diameter of the threads, the threads needed to be less than a millimeter in diameter in order to weave at that density. My "reproduction" thread is 14 wpc, S and Z spun. The piece is 4.5 centimeters wide and 19.5 centimeters long. With that thread I was able to create a piece that has 9-10 threads per centimeter warp and 8-9 threads per centimeter weft. While my thread is fine and tightly spun, I suspect that the thread used in the Ribe artifact was not as "fluffy" as the combed Jacobs roving which I used. I could have made my thread smoother by oiling the roving prior to spinning. If my thread were smoother, I would have been able to pack the weft more tightly. Fulling the finished piece would also pull the threads closer together.

Reading Elizabeth Barber's book, Prehistoric Textiles, I became fascinated by her discussion of the **hollow spindle whorls from Anau**, in Turkestan. These Neolithic whorls are very different from other whorls from the same time period. Her hypothesis for why they are hollow bullet shapes is to allow them to function not only as spindles, but also as weaving shuttles, allowing the thread to be used without having to wind it off. It is not only the shape of the spindle whorls, but also the enormous number of them that have been found that lead her to this conclusion [5]. Her hypothesis is logical, but I wondered if there was also a difference in how the spindles would spin. I made a spindle similar to one she illustrates, and also one of the same shape and size that is not hollow. Since these hollow whorls seem to me to be very like the modern rim-weighted whorls, I wondered if they would behave like those.

I spun a variety of yarns with the bullet-shaped spindle whorls. The hollow whorl (#13) weighs 26 grams. With it I easily spun a yarn of 23 wpi. The solid whorl of the same shape (#14) weighs 33 grams. With it I spun an optimum yarn of 16 wpi. The finest thread I can spin with whorl #13 is 46 wpi; the finest I can spin with whorl #14 is 45 wpi. The optimum thread I spun with the hollow bullet matched my optimum result with the modern rim-weighted 21 gram spindle.

I then tested for angle of twist. The resulting yarn is 18 wpi for whorl #13, and 17 wpi for whorls #14. With nearly identical yarn diameter, whorl #13 produced the yarn with the higher angle of twist – 71 degrees. The twist for whorl #14 is 68 degrees. This leads me to conclude that while Elizabeth Barber may be correct in her hypothesis regarding spindles with bullet shaped whorls being used as weaving shuttles, this hollow shape also produces a yarn which is very well suited to warp thread. Whorls of this shape could have been preferred due to their ideal suitability to a variety of tasks.

Conclusions

During the course of my experiments, I spun the same combed Shetland roving on more than 50 spindles, including artifacts, modern spindles, and my ceramic reproductions. My goal was to see what range of thread gauge could be produced from any one spindle. I also was interested in comparing the threads I produced to textile remnants, to understand what types of spindles would have been likely to have been used to create the cloth. For information on cloth, I sampled data from Margrethe Hald's Ancient Danish Textiles from Bogs and Burials, Else Ostergard's Woven into the Earth, as well as Ribe Excavations, Volume 3.

While I have spun with a large number of whorls, an experienced spinner would not need so many to produce the same variety of thread gauge. **One can obtain the full range of results with just 2 or 3 spindles.** There is quite a bit of overlap in the capacity of the various spindle weights. Many of them will spin a thread between 20 and 40 wpi, which is ideal for fabric intended for clothing. A graph of my results is appended. A spinner can produce thread and yarn for all her household needs with a small variety of spindle weights. This compares favorably with the variety of spindle whorl weights found at archaeological sites.

To spin efficiently it is important to choose a spindle sized properly for the intended thread. The more experienced I become at spinning, the greater the range of thread size I can get from a spindle (this is no surprise). But every spindle (and spinner) has its limits. When spinning to spec, a properly sized tool will make it easier to create a large amount of thread at the desired diameter. The output of a spindle is not only a function of the efficiency of the tool, but also the skill of the spinner, particularly when approaching the limits of the spindle.

In addition to a variety of weights, spindle whorls come in a variety of shapes. I found that **the shape of the spindle makes a difference to the spinning outcome**. Sometimes the difference is difficult to see in the yarn, but affects the finished product. To make a high twist thread or yarn, the shape of the spindle is more important than the weight. A center weighted spindle, such as a cylinder or bi-cone, will spin faster, easily putting more twist into the fiber. The hollow bullet-shaped whorl seems to combine the best attributes of center-weighted and rim-weighted whorls - spinning quickly, since the weight is near the shaft, but maintaining its spin longer than the cylinders or bi-cones. To produce a yarn with low twist, a greater thread gauge is needed. This requires a heavier spindle. The task is made even easier with the rim-weighted shapes. Due to the long staple length of the Shetland wool, it was fairly easy to produce a low-twist yarn with many of my spindles. A low-twist yarn is more difficult to produce with a short staple fiber. More twist is required to keep the fibers together.

To have the best thread result it is important to use well prepared fibers. Dirt or grass left in the roving; short cuts; "abuse" during processing resulting in felting, are all problems that will impact both the efficiency of spinning and the evenness of the thread produced. Just as a weaver takes time to carefully warp the loom, first the spinner must carefully prepare the fleece, in order to create a quality thread for a quality cloth. Inattention anywhere in the process, from raising the sheep to removing the cloth from the loom, will impact the quality of the finished piece.

There is no single answer to what attributes make a versatile spindle. The unique combination of weight, shape and size affect each other. Spinning with the cone and bi-cone whorls that I made, I have found that I can spin a much finer thread than I anticipated, given the weight of the spindles. The heavier whorls spin both fast and long, Disc spindles of similar weight spin consistently "bulkier" fine threads. A fine thread can easily be made with the cone and bi-cone shapes without approaching the spindles' limits. This result reinforces for me the perfect suitability of these shapes to their intended products (fine cloth). Whether a spindle is a high-tech modern tool, or a simple stick or rock picked up at the side of the road, it can get the job done. It took less effort than I expected to make an efficient tool. I suspect that in many cases, both shafts and whorls were made on an as- needed basis.

Each of the sample spindles is shown with a sample of wool spun on the spindle. Appended are charts showing the full results of my study.

Notes

1. Hald, Margrethe, Ancient Danish Textiles from Bogs & Burials, translation by Jean Olsen, National Museum of Denmark, Copenhagen, 1980, p. 134.

2. Hald, Margrethe, Ancient Danish Textiles from Bogs & Burials, p. 134.

3. Bender-Jørgensen, Lise, Jensen, Hans Arne (ed.), Ribe Excavations 1970-76, Volume 3, Sydjysk Universitetsforlag, Esbjerg, DK, 1991, p. 65.

4. Bender-Jørgensen, Lise, Jensen, Hans Arne (ed.), Ribe Excavations 1970-76, Volume 3, p. 61 and 78.

5. Barber, E.J.W., Prehistoric Textiles, Princeton University Press, Princeton, NJ, 1991, p. 303-310.

Bibliography

Barber, E.J.W., Prehistoric Textiles, Princeton University Press, Princeton, NJ, 1991

Franquemont, Abby. Respect the Spindle, Interweave Press, Loveland, CO. 2009

Hald, Margrethe, Ancient Danish Textiles from Bogs & Burials, translation by Jean Olsen, National Museum of Denmark, Copenhagen, 1980

Jensen, Hans Arne (ed.), Ribe Excavations 1970-76, Volume 3, Sydjysk Universitetsforlag, Esbjerg, DK, 1991

Mainman, A.J., and Rogers, N.S.H., Craft, Industry and Everyday Life: Finds from Anglo-Scandinavian York, The Archaeology of York, Volume 17: The Small Finds, Council for British Archaeology, York, Great Britain, 2000

Ostergard, Else, Woven Into the Earth, Aarhus University Press, Aarhus, DK, 2009

Rogers, Penelope Walton, Cloth and Clothing in Early Anglo-Saxon England, Council for British Archaeology, York, Great Britain, 2007

Wild, J.P., Textile Manufacture in the Northern Roman Provinces, Cambridge University Press, Cambridge UK, 1970

Spindle as weaving shuttle?

Spinning with rocks

Ceramic Spindles	Shape	Diameter / Height	Weight	wpi upper limit	wpi lower limit	optimum wpi/wpc	Notes
one	bi-cone	22 mm x 17 mm	6g	76	21	56/22	
two	cone	28 mm x 20 mm	15g	78	15	38/15	like Ribe whorls w/round bottom
three	cone	29 mm x 25 mm	19g	70	18	31/12.2	like Ribe whorls w/round bottom
four	bi-cone	26 mm x 21 mm	15g	82	14	40/15.8	like Ribe whorls
five	bi-cone	29 mm x 18 mm	21g	66	20	26/10.2	like Ribe whorls
six	cone	36 mm x 25 mm	26g	36	16	25/9.9	like Ribe whorls w/round bottom
seven	bi-cone	37 mm x 22 mm	38g	76	16	22/8.7	like Ribe whorls
eight	bi-cone	28 mm x 28 mm	22g	78	13	20/7.9	like Ribe whorls
nine	disc	28 mm x 7 mm	8g	70	14	30/11.8	
ten	disc	48 mm x 3 mm	15g	58	21	29/11.4	
eleven	disc	48 mm x 8 mm	32g	56	16	23/9.1	
twelve	disc	45 mm x 8 mm	29g	74	16	25/9.9	
thirteen	bullet	35 mm x 30 mm	26g	46	12	23/9.1	hollow - like Turkistan whorls
fourteen	bullet	35 mm x 30 mm	33g	45	12	16/6.3	solid Turkistan type
fifteen	sphere	28 mm x 25 mm	23g			32/12.6	spins much finer than plano-convex - due to weight closer to shaft?
sixteen	plano-convex	33 mm x 20 mm	24g			24/9.5	
seventeen	cup (convex)	48 mm x 11 mm	24g			24/9.5	like Bronze Age Swiss whorls. After a quick start, spins slowly for several seconds before stopping
eighteen	bullet	38 mm x 43 mm	35g			22/8.7	hollow - like Turkestan whorls
nineteen	bi-cone	40 mm x 25 mm	36g	50	16	26/10.2	
twenty	star/disc	43 mm x 24 mm	26g	64	18	30/11.8	like neolithic Switzerland whorl
twenty-one	barrel	25 mm x 38 mm	31g			30/11.8	like neolithic Switzerland whorl
twenty-two	bi-cone	27 mm x 31 mm	22g	80	24	44	like Ribe whorls
twenty-three	cup (convex)	40mm x 20 mm	30g	64		36	like Bronze Age Swiss whorls
twenty-four	bi-cone						
Hoje Taastrup reproduction	disc	48 mm x 19 mm	54g	36	8	16/6.3	oldest Danish whorl found
heaviest artifact reproduction	disc	60 mm x 27 mm	150g	20	6	9/3.5	due to weight lost during firing I put 2 whorls together to equal 150g

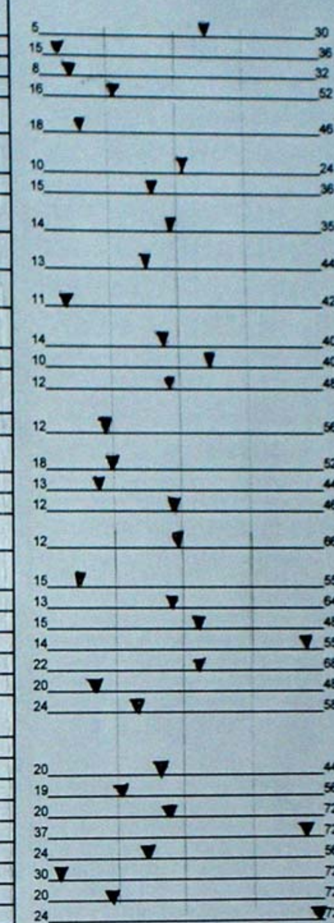
Upper limit: the thinnest thread that can be spun without constant thread break.
The thread will tend to break before the spindle is full.

Lower limit: the thickest yarn that can be spun without constant back-spin.

Optimum: the point where spinning can be done efficiently -
without frequent stopping to fix a thread or twirl the spindle

2010 Results of Tests of Spindle Versatility

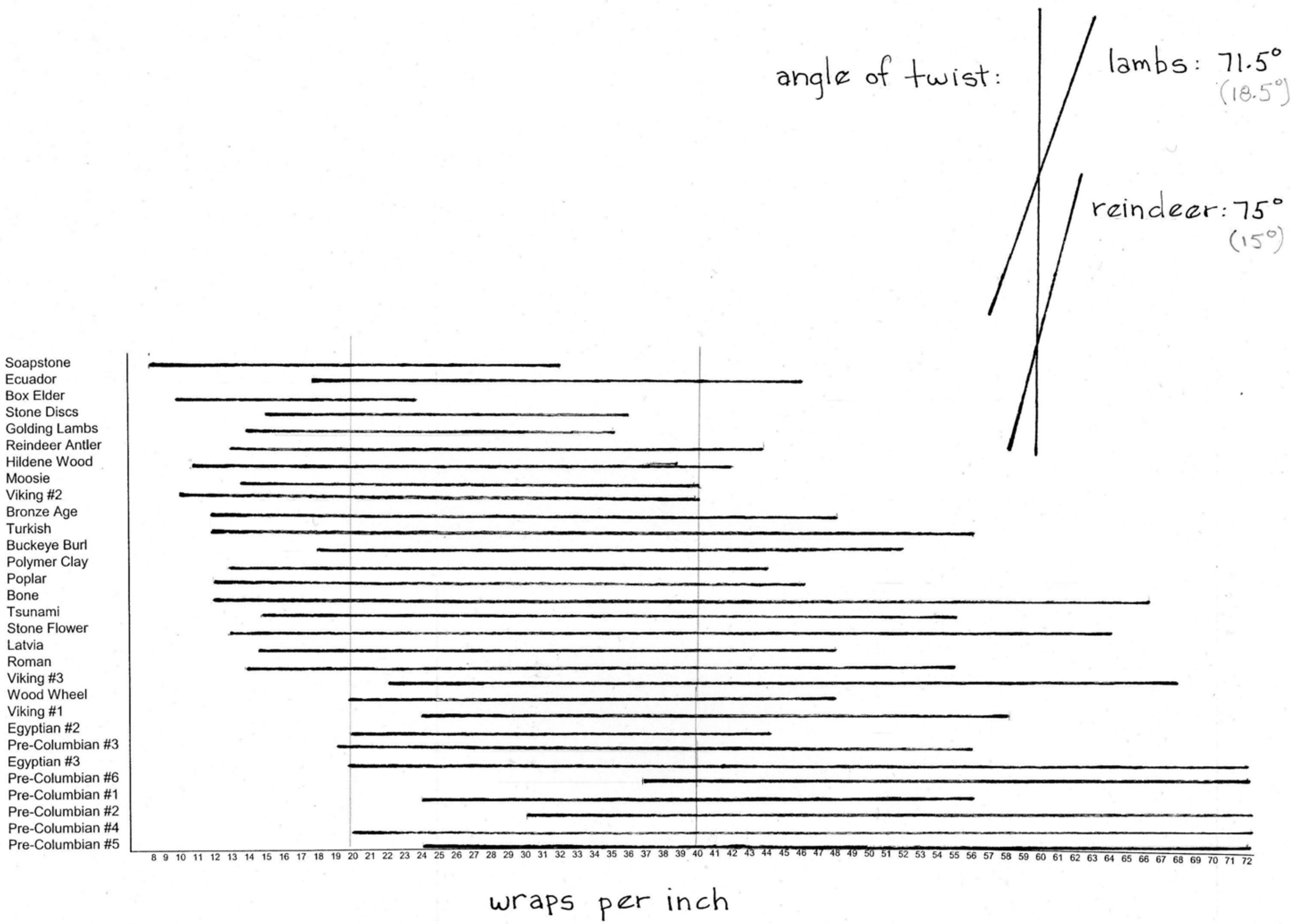
Spindle	Type	Diameter/Height	Weight	wpi upper limit	wpi lower limit	optimum wpi/wpc	Shape	Notes
scrimshaw	high	90 mm x 20 mm	111g	30	5	15/5.9	rim weighted disc	spins VERY slowly
purple wood	low	69 mm x 22 mm	75 g	36	15	16/6.3	disc	spins quickly
soapstone	low	40 mm x 18 mm	68g	32	8	10/3.9	cone	spins slowly
brown wood	low	69 mm x 22 mm	56g	52	16	26/10.2	disc	spins quickly
Ecuador whorl	low	50 mm x 22 mm	55g	46	18	26/10.2	plano-convex	well balanced; long spinning; spins quickly for size
box elder	low	70 mm x 20 mm	47g	24	10	18/7.1	disc	spins slowly; wobbles w/short leader due to shaft diameter; will also work as hi-whorl
stone double discs	high	50 mm x 14 mm	45g	36	15	23/8.3	disc	
Golding lambs	high	67 mm x 10 mm	43g	35	14	24/8.6	rim-weighted disc	long spinning
reindeer antler	low	30mm x 36mm	43g	44	13	23/8.3	cylinder	
Hildene wood	high	65 mm x 13 mm	40g	42	11	13/5.1	rim-weighted disc	
moosie	high	50 mm x 15 mm	36g	40	14	25/9.9	rim-weighted disc	
Viking lead whorl #2	low	25 mm x 7 mm	35g	40	10	30/11.8	disc	from York; spins easily at all gauges
Bronze Age ceramic	low	35 mm x 18 mm	33g	48	12	28/11 38/15	spheroid	 35% more wpi with oiled fibers
Turkish	low	120mm x 12mm	32g	56	12	22/8.2	cross	center pull difficult w/thinnest gauge; oiling may help
buckeye burl	high	60 mm x 22 mm	31g	52	18	25/9.9	plano-convex	
polymer clay	high	52 mm x 6 mm	25g	44	13	17/6.7	disc	
poplar	high	50 mm x 20 mm	25g	46	12	28/11	bi-cone	
Brid's bone Celtic Reproduction	low	33 mm x 15 mm	24g	66	12	38/15	plano-convex	
tsunami	high	50 mm x 5 mm	21g	55	15	19/7.5	rim-weighted disc	
stone flower	high	45 mm x 4 mm	21g	64	13	36/12.9	disc	
c. 1000 AD ceramic whorl	low	28 mm x 14 mm	19g	48	15	35/13.8	bi-cone	from Latvia
Brid's stone Roman whorl	low	25 mm x 15 mm	15g	55	14	50/19.7	cone	only spins well for very thin thread
Viking lead whorl #3	low	14 mm x 8 mm	14g	68	22	48/18.9	disc	from York. More difficult to spin than similar weights
wood wheel	low	38 mm x 12 mm	13g	48	20	24/8.6	disc	
Viking lead whorl #1	low	20 mm x 6 mm	13g	58	24	35/13.8 48/18.9	disc disc	from York 36% more wpi with oiled fibers
Egyptian #1	high	22 mm x 15 mm	10g	50	x	32/12.6	spheroid	gave to Katie Lass
Egyptian #2	high	22 mm x 15 mm	10g	44	20	28/11	spheroid	not well balanced
pre-Columbian ceramic #3	low	20 mm x 20 mm	9g	56	19	28/11	pear	well balanced - spins easily
Egyptian #3	high	24 mm x 11 mm	8g	72	20	36/14.2	cone	
pre-Columbian #6	low	19 mm x 22 mm	8g	72	37	68/26.8	cone	
pre-Columbian #1	low	23 mm x 12 mm	7g	56	24	35/13.8	spheroid	
pre-columbian ceramic #2	low	24 mm x 11 mm	7g	72	30	32/12.6	cone	
pre-Columbian ceramic #4	low	18 mm x 19 mm	7g	72	20	30/11.8	pear	not well balanced
pre-Columbian #5	low	18 mm x 18 mm	6g	72	24	72/28.3	pear	is 72 wpi the limit for this wool?



upper limit: the thinnest thread that can be spun without frequent thread break
the thread will tend to break before the cop is full

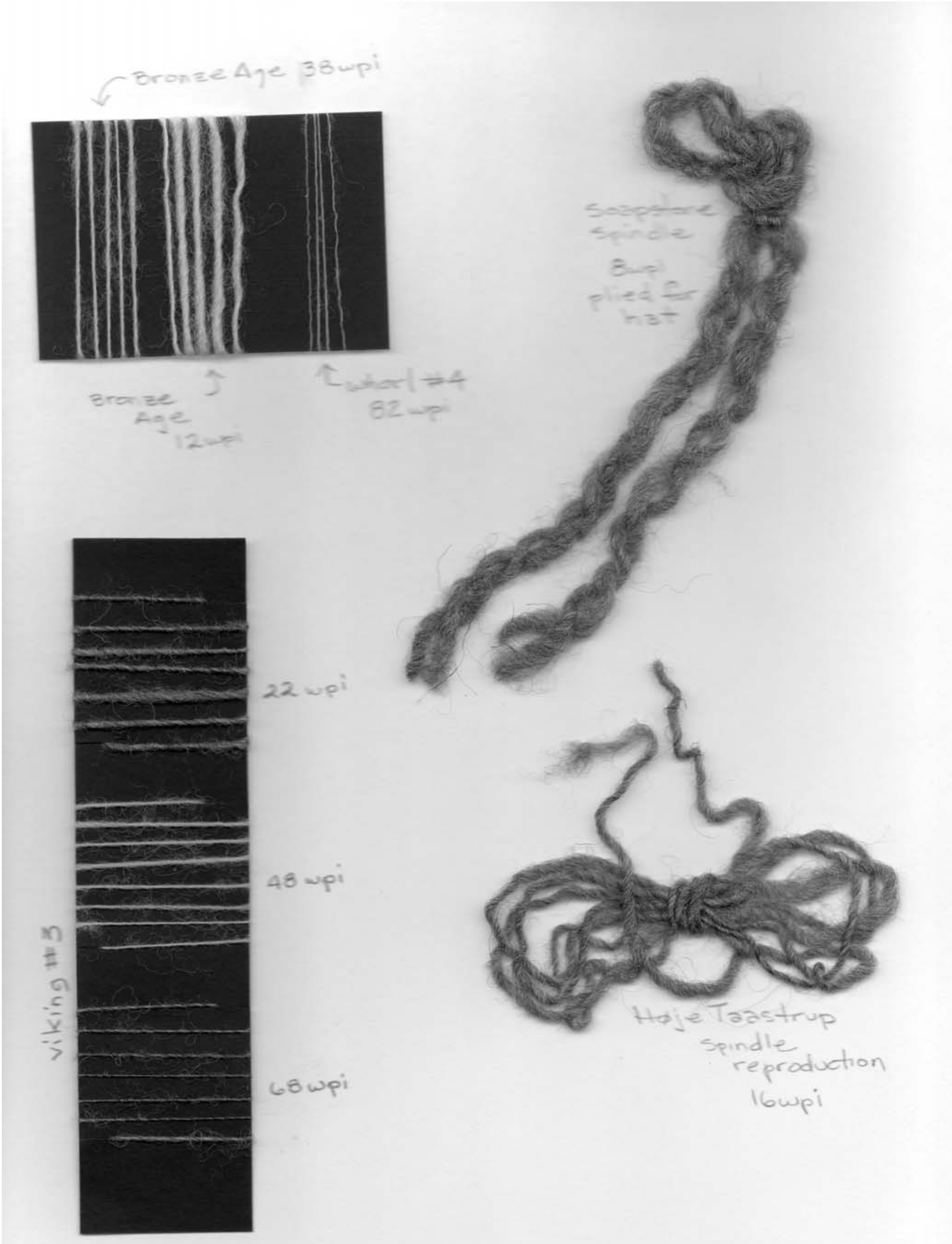
lower limit: the thickest thread that can be spun without constant back-spin

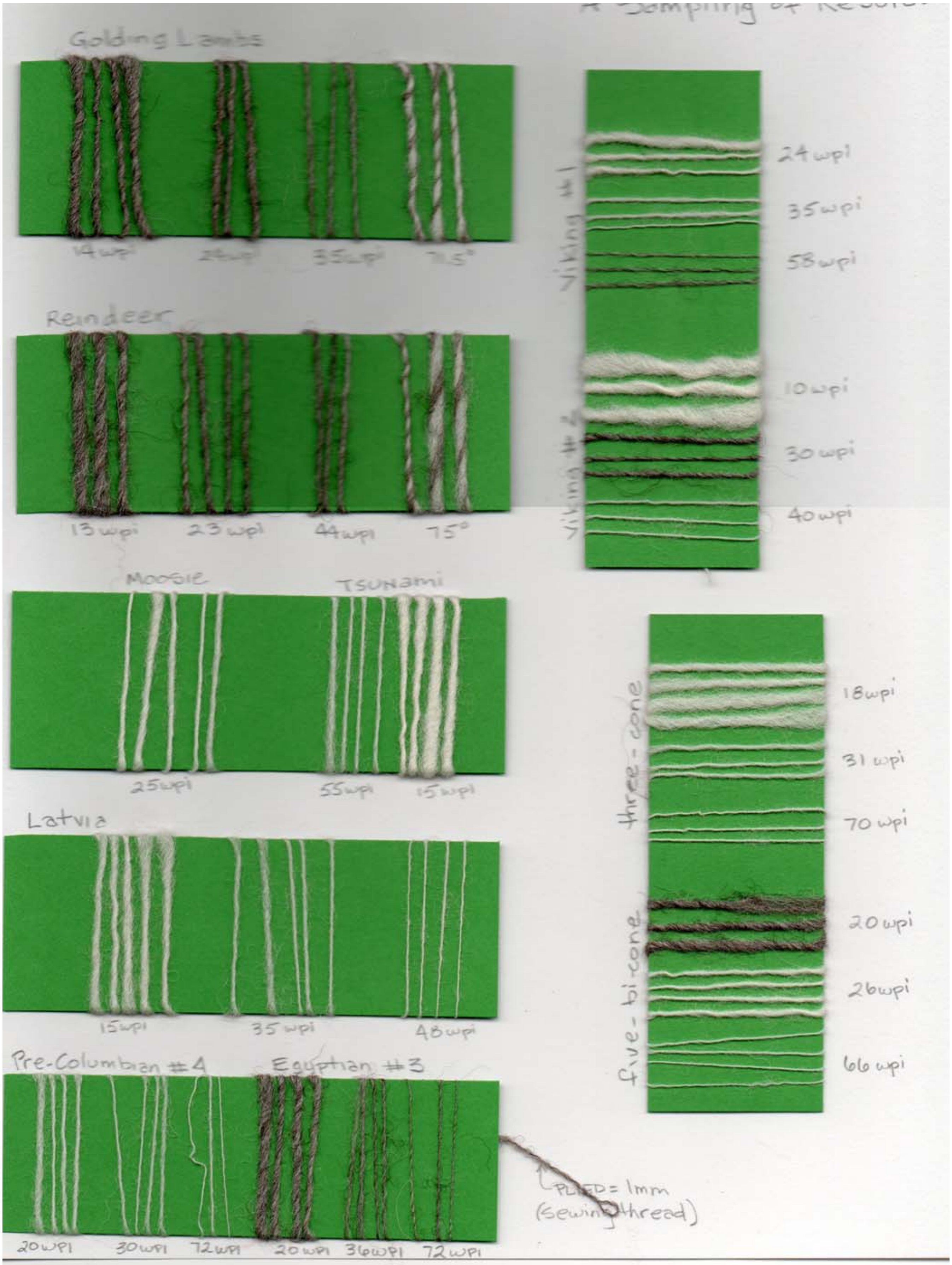
optimum: the point where spinning can be done efficiently -
without frequent stopping to fix a thread or twirl the spindle
the number shown is an average of a range

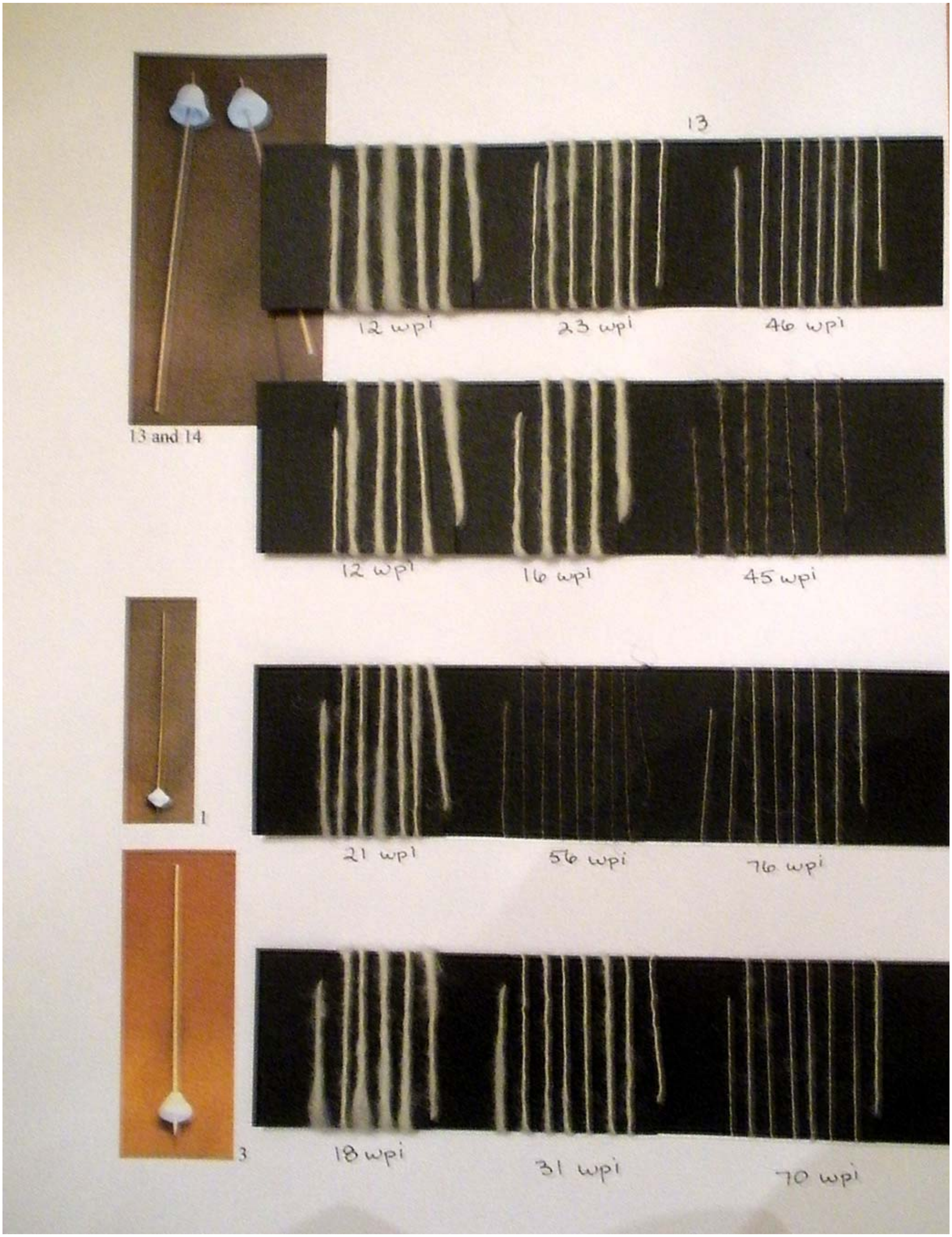

angle of twist:
lambs: 71.5°
(18.5°)
reindeer: 75°
(15°)
Soapstone
Ecuador
Box Elder
Stone Discs
Golding Lambs
Reindeer Antler
Hildene Wood
Moosie
Viking #2
Bronze Age
Turkish
Buckeye Burl
Polymer Clay
Poplar
Bone
Tsunami
Stone Flower
Latvia
Roman
Viking #3
Wood Wheel
Viking #1
Egyptian #2
Pre-Columbian #3
Egyptian #3
Pre-Columbian #6
Pre-Columbian #1
Pre-Columbian #2
Pre-Columbian #4
Pre-Columbian #5
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
wraps per inch

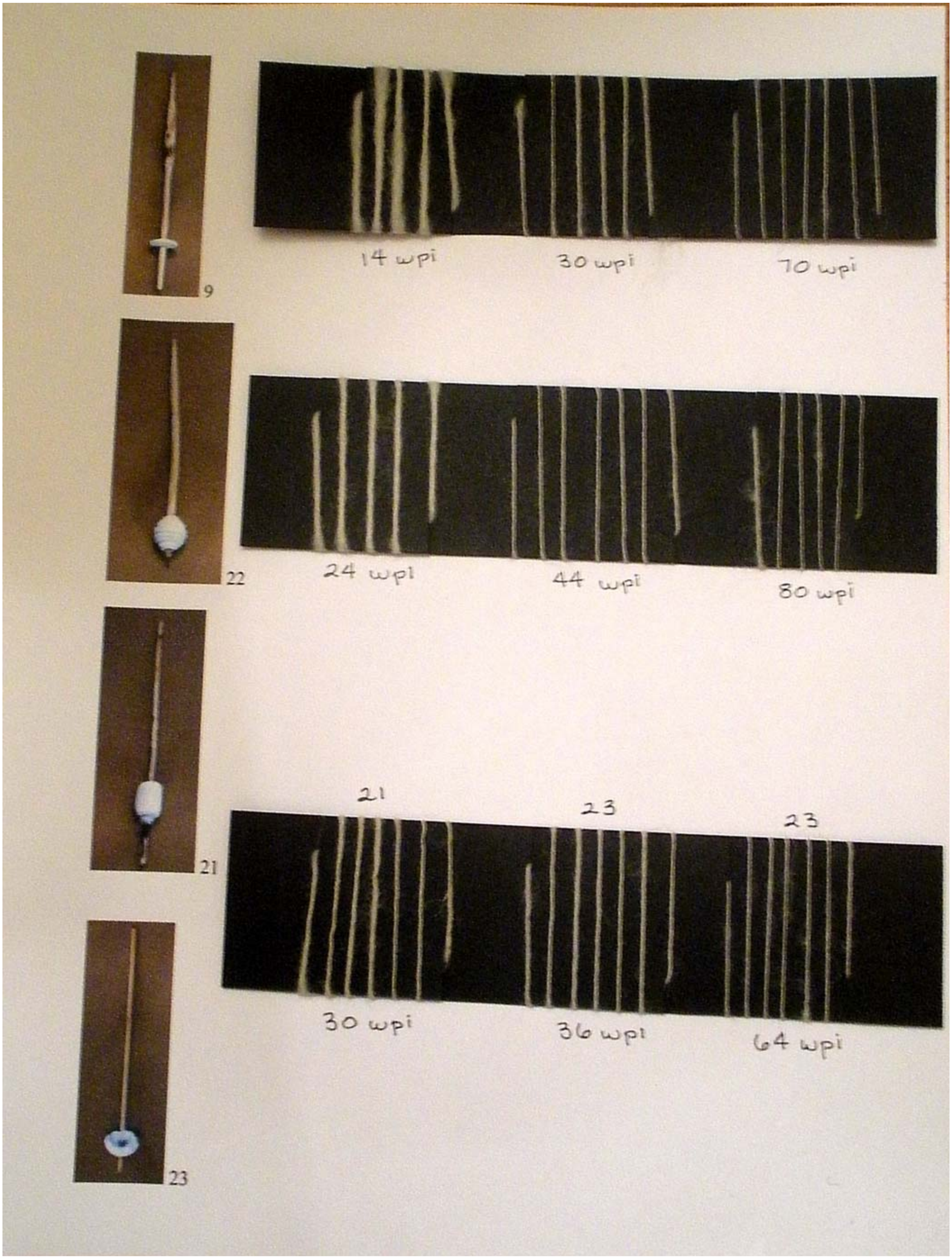
Left: woven with 17 wpi thread from Høje Taastrup reproduction spindle.
Right: attempt to reproduce Ribe woven artifact.


WOVEN ON A PIN LOOM
USING COMBED SHETLAND TOP, Z-SPUN
BOTH WARP + WEFT
28 WPI / 11 WPC
BRONZE AGE SPINDLE
8 THREADS/cm WARP
20 THREADS/cm WEFT


Bronze Age 38wpi
Bronze Age 12wpi
whorl #4 82wpi
Soapstone spindle
8wpi plied for hat
22 wpi
48 wpi
68 wpi
viking #3
Høje Taastrup spindle reproduction 16wpi


Golding Lambs
14wpi
35wpi
Reindeer
13wpi
23wpi
44wpi
75°
Viking #1
24wpi
35wpi
58wpi
Viking #2
10wpi
30wpi
40wpi
Moosie
Tsunami
25wpi
55wpi
15wpi
Latvia
15wpi
35wpi
48wpi
three-cone
18wpi
31wpi
70wpi
five-bi-cone
20wpi
26wpi
66wpi
Pre-Columbian #4
Egyptian #3
20WPI
30WPI
72WPI
20WPI
36WPI
72WPI
PLIED = 1mm
(sewing thread)


13 and 14
13
12 wpi
23 wpi
46 wpi
12 wpi
16 wpi
45 wpi
1
21 wpi
56 wpi
76 wpi
3
18 wpi
31 wpi
70 wpi


9
14 wpi
30 wpi
70 wpi
22
24 wpi
44 wpi
80 wpi
21
21
23
23
30 wpi
36 wpi
64 wpi
23

15

16

15 16 19

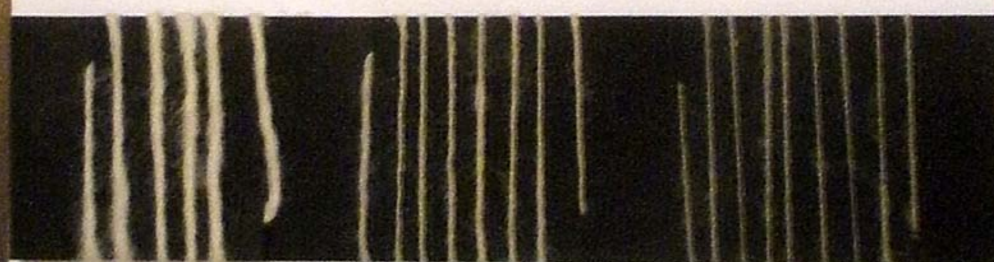
32 wpi 24 wpi 26 wpi

19

16 wpi 50 wpi 11 wpi - plied

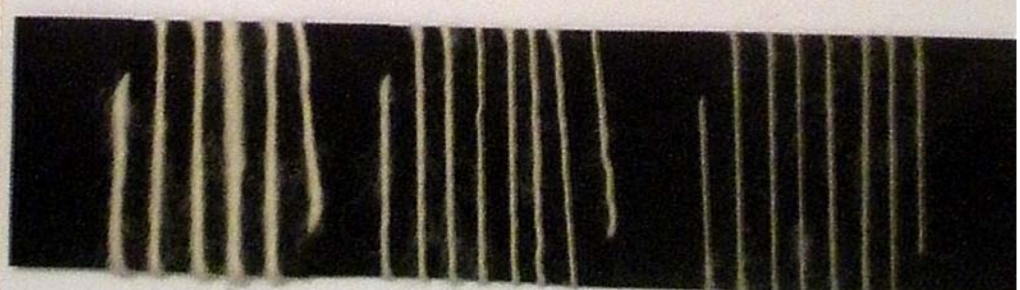

8 wpi | 16 wpi | 36 wpi

Høje Taastrup

20

18wpi | 30 wpi | 64 wpi

6

16 wpi | 25 wpi | 36 wpi


Scrimshaw


Purple Wood


Soapstone (reproduction)

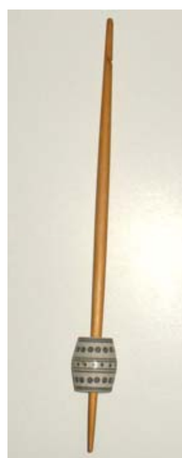

Brown Wood


Ecuador Whorl (artifact)


Box Elder


Stone discs


Golding Lambs


Reindeer Antler (reproduction)


Hildene Wood


Moosie


Viking #2 (artifact)


Bronze Age (artifact)


Turkish


Buckeye Burl


Polymer Clay


Poplar


Celtic Bone (reproduction)


Tsunami


Stone Flower


Latvia c.1000 A.D. (artifact)


Roman (artifact)


Viking #3 (artifact)


Wood Wheel


Viking #1 (artifact)


Egyptian #2 (artifact)


Pre Colombian #3 (artifact)


Egyptian #3 (artifact)


Pre Colombian #6 (artifact)


Pre Colombian #1 (artifact)


Pre Colombian #2 (artifact)


Pre Colombian #4 (artifact)


Pre Colombian #5 (artifact)