HISTORIC AMERICAN ENGINEERING RECORD

SEE MASTER PROJECT RECORD FOR CAPTION

Watkins (Woolen) Mill
4 miles Southwest of Lawson,
6 miles North of Excelsior Springs on
County Highway MM
Lawson Vicinity
Clay County
Missouri

MO-1-1

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Heritage Conservation and Recreation Service
Department of the Interior
Washington, D.C. 20243

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HISTORIC AMERICAN ENGINEERING RECORD

WATKINS (WOOLEN) MILL
HAER MO-1

Location:	Watkins Mill State Historic Site, 4 miles SW of Lawson, Clay County, MO, on County Highway MM
Date of Construction:	1860-1
Present Owner:	Missouri Department of Natural Resources PO Box 176 Jefferson City, MO 65101
Present Use:	State owned and interpreted industrial museum open to the public.
Significance:	The Watkins (Woolen) Mill contains the finest collection of mid-19th century textile machinery *in situ* in North America and includes some of the most significant textile artifacts known to survive. The physical plant provides important information about the wool cloth making process, the history of machinery manufacture, industrial development, and the working life of men and women in a rural, mid-western factory.
Historian:	Laurence F. Gross, Curator Merrimack Valley Textile Museum September 1978

In 1940 Robert Moore, a Director of the Clay County Missouri Historical Society, wrote to the Davis and Furber Machine Company of North Andover, Massachusetts: "We have been investigating the historical importance of the Watkins Wool Mill located here which was constructed and operated as a complete woolen manufacturing mill prior to and up to about forty years after the Civil War. When the manufacture was discontinued the mill was simply locked up and still remains with all the original equipment and machinery intact and in a rather excellent state of preservation." The Treasurer of Davis and Furber, a textile machine manufacturer founded in 1832, was not particularly impressed: "We doubt if a mill that kept altering its machinery until 1900 has any historical value at the present time. We have, for instance, a card here in our shop that was made before 1800, that of course, does have historical significance." He grudgingly allowed that, "As time goes on a mill such as you describe would undoubtedly gradually obtain historical value.... We do not know of any mill that has been treated exactly the same as yours, that is, when the mill stopped the doors were locked, etc. Most of these mills today, when they stop, have the machinery salvaged or scrapped in order to get the last dollar out of them." The hauteur of the collector who has cornered the market on eighteenth century(?) machinery is apparent, but there are also false assumptions operating in conjunction with this snobbery. Fortunately, the friends of Watkins Mill were not easily deterred.

In the thirty-eight years since these letters were written, no one has discovered a more complete mid-nineteenth-century woolen factory than Watkins Mill, nor is one likely to appear in the future. Furthermore, though alterations to the machinery continued during the mill's years of operation, replacement was anything but extensive and much of what remained dated from nearer the mill's

1861 founding than 1900. Without arguing its 1940 status further, it may safely be stated that Watkins Mill contains the finest collection of nineteenth-century textile machinery in situ in North America and includes some of the most significant textile artifacts known to survive. Given this situation it seems safe to allow that the Treasurer would reevaluate his judgement if he were still with us.

Watkins Mill State Park, Lawson, Missouri, contains a three and one-half story woolen mill erected in 1860, the house of its owner-operator, Waltus Watkins, as well as a church and school he had constructed. The State restored the factory building's exterior, thus protecting the diverse collection of machinery Watkins purchased to accomplish the complex task of transforming wool into finished cloth of various types. The machinery and building can provide modern viewers a great deal of information about the cloth-making process and about the history of machine-building, industrial development, and the working life of the men and women who worked there.

In order to make this description of the mill and its contents as useful as possible to a diverse audience, it will follow the path taken by raw wool as it moved through the mill and was acted upon by a succession of people and machines. By following the wool through the process which took it from fleece to finished cloth, we will encounter both the sequential steps of fabric production and the machines involved in each stage in the process.

Wool moved through the building following a complex pattern. Raw wool entered the first floor where it was sorted and scoured, or washed. The clean wool went to the second floor picker room where it was oiled and broken into small clumps by a machine called a picker. Various types or colors of wool could also be blended at this stage. Picked wool moved to the third floor where carding machines gently separated the tangled fibers until no clumps remained. Roving, the product of the cards, was carried across the floor to spinning jacks, long machines which drew and twisted the roving into yarn. The yarn was taken back down to the second floor where it could be plied, two or more yarns twisted into one, or wound onto warp beams to be placed in one of the looms there. The looms made yarn into cloth, which then returned to the first floor where it was finished by fulling, cleaning, napping, shearing, and pressing. Tentering, or stretching, in the attic interrupted these last processes, requiring one last trip from the bottom to the top of the mill and back.

Power for these operations came from a steam engine located in a shed on the back end of the first floor. A system of shafts and pulleys ran throughout the building, transmitting power from floor to floor and from pulley to machine by means of flat leather belts turned by pulleys of various sizes and, therefore, speeds.

RAW MATERIAL

Sheep's wool, the mill's raw material, presented manufacturers with an infinitely variable substance with which to begin. Research into its properties, their causes and effects, has been continuous.

Wool varied significantly according to the breed of sheep and the soil, feed, and weather where it was produced. Quality also varied between individual animals, as well as according to the part of the sheep from which the wool came. Today an expert grader categorizes fleeces according to the fineness of their fibers, and manufacturers can order wool to fit their needs. Watkins, relying on a local supply, had to evaluate the quality and appropriateness for his purposes of the large quanity of wool the factory consumed.

After the owner procured the wool, but before the manufacturing process could begin, each fleece had to be sorted. Ideally this operation took place in an area well-supplied with north light in order that the sorter could distinguish between the various divisions (as many as eleven) into which each fleece could be separated. European mills producing fine goods required a four-year apprenticeship for this highly-skilled position. The amount of skill required and the number of divisions made varied with the type and quality of a factory's output. Obtaining the highest quality production possible from the various sorts of wool available obviously contributed to a plant's profitability. Wool suitable for Watkins' fine cassimeres or doeskins would be wasted in blankets, just as blanket wool would be unsuitable for fine cloth.

Since the mill produced a wide variety of fabric Watkins would have required the services of a competent wool sorter. He would have worked at a large sloped table or open frame with rope divisions, wooden lattice, or metal screen which held the fleece while he separated the several sorts and removed as much foreign matter as speed allowed. Equal sorts would be tossed into bins or piles, while dirt fell through the table's openings. The mill contains no appropriate table, nor can an area be identified as having served that purpose.

Once the sorter completed his work, the separated sorts were taken to the scouring room, where they were rid of as much dirt and vegetable matter as possible before chemical cleaning, or scouring, began. The mechanical process began with the box duster or willower.

SCOURING

The willower at Watkins Mill rests in the second floor picker room, apparently moved from some more convenient location. Although the brick first floor has been rebuilt, it has sunken again in at least two areas west of the fulling mill, quite probably indicating the original location of scouring tubs.

The willower should have appeared between the sorting area (location unknown), and this site, likely on the first floor, although it could have been placed near the picker.

Watkins' willower carried the legend, "A. Jenks, Bridesburg," the first of a series of names used by the textile machine company founded outside Philadelphia by Alfred Jenks in 1810. Though iron-framed, the willower was built mostly of wood; it knocked the clumps of wool apart as they were carried around a drum 24" in diameter on one of six sets of four iron teeth (see photo #1), which passed by a similar set of fixed teeth at the back of the box. Dirt and other foreign matter freed in this process dropped through the iron grate beneath the drum. The coating of dirt and grease on the drums and the inside of the open cover are easily visible. No feed or delivery mechanisms remain.

The primitiveness of this machine, its absence from the A. Jenks catalog of either 1853 or 1867, and the fact that the company had probably changed its name to A. Jenks and Son by the 1850s suggest it was either old when Watkins bought it or built from old patterns. Since names were easily and regularly changed on casting patterns, an early date of manufacture seems more likely, suggesting Watkins may have purchased second-hand equipment.

Broken apart into small clumps and cleaned of some of its attached dirt, the grease wool was taken to the scouring bowls. Although the scouring process was mechanized during the 1870s and Watkins inquired about such equipment, he apparently used only the simple wooden tubs of the older system in which the wool was manipulated by hand with wooden poles. Cleaning the wool in a series of successively cleaner bowls readied it for further treatment.

Wool grease and salts from dried prespiration (suint) represented more than 40% of the weight of medium or fine wool. When they were removed along with the dirt, shrinkage could equal more than 50% by weight. A combination of soap, alkali (for instance, soda ash or sodium bicarbonate), which aided in the formation of natural soaps, along with pure, soft warm water cleaned the wool without damage. Any misjudgement regarding the proportions of wool, soap, alkali, and water left the wool in a poor state for further processing, however. Ideally, a very small quantity of grease was left in the wool. Obviously, skill in scouring represented one of the bases of quality production.

After scouring, the wool was dried before further processing. It could then be dyed (dyed in the wool), the technique for producing the fastest colors, or it might move directly to the mechanical processes. Since dyeing by the skein or the piece (in the cloth) represent alternative practices used at Watkins Mill, dyeing will be discussed as a part of the finishing process.

OPENING

The dried wool went to the picker room on the second floor where various sorts and/or colors were blended, and where the clumps and knots were reduced to sizes manageable in the delicate action of the carding machines. Colors or sorts were mixed by laying them out in layers on a clean floor or cloth before feeding them to the picker; further intermixture could be accomplished in the bin into which the picker sent the wool.

PICKING:

Photo #2 shows the picker room, with the picker, cover propped open, in the center. The drive pulley for the entire second floor is at right; power moved from right to left to the pulley and belt at center top whereby it traveled to the line-shaft, fore-top, one pulley on which drove the picker, via pulley and belt to the jack-shaft, top, through a figure-eight belt (visible in photos #2, 3, 4), right of picker, which received the power to turn at some 1000 revolutions per minute as well as to feed itself. The speed was determined by the sizes of the several pulleys involved.

Made by A. Jenks and Son, the picker appears to be identical to that advertised in an 1867 catalog. The wooden lattice (photo #3, 4) brought the wool to the iron feed rolls, counterweighted to maintain a firm (but flexible) hold on the wool while the whirling teeth pulled it apart into small clumps. With 22 teeth in each of seven arms, traveling at high speed, the wool was quickly caught at the feed rolls and divided quite efficiently. It was then blown through a hole in the back of the picker into a room where further blending might be accomplished.

Records indicate that in 1864 Watkins purchased a hard waste picker,[2] a machine similar to the above but capable of tearing apart rags or yarn in order that they could be reworked and used to produce cloth. Cloth made exclusively from reworked wool is called shoddy and has a short staple, or fiber, because of the violent action of the picker. The waste might also be mixed with new wool without seriously diminishing the quality of the product. The hard waste picker does not remain at the mill.

Picking was a hazardous but important process. The wool was oiled here, presenting a danger of spontaneous combustion if not immediately processed. The high speeds often threw out teeth in earlier machines, but these "cast steel hooked Teeth set in Bridles in wrought Iron Lags"[3] were well-secured. Danger from sparks (if a piece of metal accidentally entered the machine) persisted and even increased (with speed) during the century, and "the best insurance companies do not insure a mill unless the picker is absolutely detached from the main building."[4] For several decades major mills in the East had been isolating both picking and storage from the main factory because of the frequency with which they started fires (from sparks and spontaneous combustion, respectively).

CARDING:

From the picker, wool moved to the third floor for carding (photo #5). This process involved separating, opening, straightening, cleaning, and mixing the fibers. Properly done, carding completely opened out the clumps and tangles of wool, separating fiber from fiber. Care was needed to avoid damage, particularly regarding the length of the staple. By the action of the cylinders, the wool was spread on the card in a mixture of uniform density, with the fibers thoroughly mixed and evenly intermingled. Unlike cotton and worsted carding, the goal was to produce a mixture, not a parallelization, of fibers. In other words, wool coming to the card in small bunches was gradually separated fiber from fiber, leaving the strands free to be acted upon by the next process, spinning. At the same time they were being separated, however, they were also being intermingled and redistributed across the carding surfaces. Wool leaving the machine clung together but no longer contained knots or clumps which, if they survived this process, would persist into the finished cloth. An uneven and densely tangled mass of wool was made into an evenly distributed, loosely cohesive web or strand. Cotton and worsted carding aim at laying the fibers parallel to one another, after which several processes must intervene between carding and spinning. The loose intermixture of carded wool enables spinning to follow immediately after carding.

The carding machines, or cards, were made up of a feed, a series of wire-covered rollers of various sizes revolving in different directions and a delivery system by which the wool was finally removed. The wool generally proceeded through three cards, equalling one set, before it moved to the next process. Watkins Mill ran six production cards and was therefore referred to as a two set mill according to the standard frame of reference for size of woolen mills. Three other cards operated for special purposes related to domestic use in the local area.

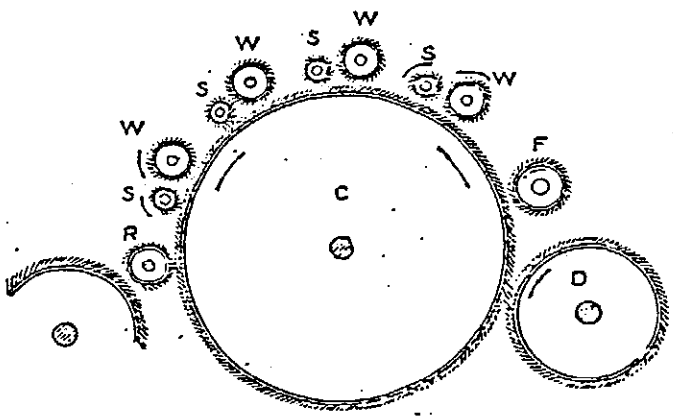


Figure 1: Diagram Showing Parts of Card.

The several cylinders of the carding machines were covered with bent wires called card clothing. The bend, or knee, in the wire enabled it to operate with the strength needed to pull the fibers apart without losing the resiliency required to avoid damaging them. The series of revolving cylinders moving in different directions and at different speeds were positioned so that only a slight space through which the wool must pass existed between them. The one large, or main, cylinder turned under a series of smaller tumblers, workers and strippers (see Figure #1). The main cylinder revolved rapidly, in the vicinity of 125 R.P.M. The wool came to it from the feed table, at left, via cylinder "R", the lickerin. The first worker, turning slowly, met the teeth of the main cylinder point against point and carding took place as the fibers were caught by the slower worker and pulled away from the main. The wool moved around the worker until caught by the rapidly turning stripper, the teeth of which met the worker's point against back, taking the wool from the worker and returning it to the main cylinder.

This process occurred repeatedly as the wool gradually progressed along the main cylinder; as it was untangled it lay lower in the clothing, thus slipping past the workers and continuing to the fancy (F). Its lighter, longer, brush-like teeth were the only ones which actually touched the teeth of the cylinder against which it operated. They penetrated 1/16" to 1/18" into those of the main and, operating back against back, lifted the fibers to the surface of the clothing into which they had sunken as they were carded. The final cylinder, the doffer (D), turned point against back with the main and stripped off the web or sheet of carded wool. A comb, a flat piece of iron notched to produce many small teeth, oscillated past the surface of the doffer and removed the wool from the card. The process repeated itself on the second breaker and the finisher. Successively closer tumbler settings provided increasingly thorough untangling and redistribution of the wool.

Watkins' smallest and simplest card represented a type made obsolete for industrial purposes in the mid-1820s but still available for producing wool for hand spinners much later in the century, (foreground, Photo #6, also photo #7). Marked "A. Jenks & Son, Bridesburg," with a carding surface 24" wide, the cylinders, starting from the wood lattice feed apron, were 2" iron feed rollers (all others wood), with a 3" stripper, a 6" roller, a 10" lickerin, 5 pairs of 6" workers and 3" strippers, on a 42" main cylinder with a 10" fancy, 21" doffer and a 12" fluted wooden cylinder which turned over a curved close-fitting breast. The lap of wool passed between the cylinder and breast of this roll-drum and shell delivery, thereby breaking into strips of wool 24" long and of a thickness determined by the distance (adjustable) between the drum and shell. These strips, or rolags, were pieced together, drawn and twisted by the hand spinner. Iron poppet heads with soft metal bearing surfaces held the various rollers. They were screw-adjustable in four directions in order to permit the precise spacings between cylinders, in the order of .025"-.035", the process required.

The main cylinder and doffer were covered with sheet clothing, pieces of leather into which wire teeth were set, which were then stretched across the cylinders and tacked in place. The rest of the tumblers were covered with fillet clothing, long strips of leather which were wound spirally onto the wooden cylinders and tacked at both ends.

The second card, also marked A. Jenks and Son, differed little from the first except in width: 31" wide (30" carding surface). The third, 48" wide, carries no name but so closely resembles the others as to leave little doubt as to its manufacturer (Photo #8, card #3 in foreground).

Immediately following the feed rolls these cards held an iron cylinder covered with garnet wire, a continuous piece of wire notched to produce teeth, (photo #9). Above it turned another iron roller with blades which, as it whirled, knocked burrs from the wool into the wooden pan just above the feed apron. Burrs were the bane of the carding and spinning departments. Their prickly covers were strongly held by wool and, if not removed, they led to bad spots in yarn or cloth produced later. American wool generally contained comparatively few burrs. More burry wool required special processing before it became usable.

These cards were covered with sheet clothing on the main cylinder only and used a simpler, more advanced Pitman comb run by a whip staff connected to a crank outside the frame and driven by the belt operating the strippers. The large wooden drum beyond the comb received the continuous web or lap which wound around it, compressed by the smaller cylinder turning above. When a certain quantity accumulated, the upper cylinder rose sufficiently to strike a sensor which rang a bell (see Photo #8), signaling the carder to cut the lap free. This thick, lightweight lap of wool, called a bat, or batting, provided a warm filling for quilts, comforters, or other similar items. Part of a side-draw condenser (discussed below) on the third card indicates possible use at one time as part of the factory process, but these cards as they now appear served household functions only and represented a dead end in terms of industrial production.

Watkins' two sets of factory production cards were essentially the same in basic construction. One set carries the A. Jenks and Son name and the other appears to be a product of that firm. Presumably one set represented the fulfillment of the January 7, 1864 order for two 40" x 42" (carding surface x diameter of main) side draw cards, $370 each, plus one finisher with rub for $470; two lickerins with creels cost $40.[5] This combination of sizes ceased to appear in the company's offering by 1867. Cylinders in these sets parallel in diameter those described above.

The carding process started when the operative took the picked wool and weighed out predetermined amounts onto a preset portion of the feed apron (Photo #10, with detail of a scale, #11). This operation, while not complex, required attention because of its significance for the quality of all succeeding products. If the amount of wool entering a card at any time varied, it produced a tendency toward unevenness in the amount of wool later delivered from the card and then in the yarn and ultimately the cloth produced from it.

In order to minimize the risk of inconsistent production, and to fight whatever parallelization of fibers carding might produce, the wool from the first and second breakers left the card through a side draw condenser (Photo #12-#14). Once the web was freed from the doffer by the doffing comb (note whip staff in Photo #12) it was drawn to one side and wound onto a bobbin. An 1864

United States Supreme Court opinion on a patent dispute described the process:

> The sheet of carded material, when stripped from the doffer, is taken away on one side of the delivery end of the machine, by means of two rollers, through a turning tube, or pipe to which a slow rotary movement is given by a band passing from a drum, actuated by the machine, and operating upon a pulley affixed to the tube.... The roving or sliver is condensed and wound round the bobbin... made to partake of the rotary motion communicated to the drum.... The roving may be evenly wound upon the bobbins, either by carrying it and the drum, backward and forward, or by passing it between guides affixed to a bar, to which a similar movement is communicated.[6]

The patent dispute involved the rights to the patents of John Goulding, inventor of some of the most significant innovations in carding in the nineteenth century. Photo #14 shows, at the very bottom, the specially shaped guide which, turning, moved the roving guide reciprocally during the winding-on process, known as balling. The revolving pipe, or trumpet, imparted a false twist to the roving which helped hold it together. Side-drawing became standard procedure by the early 1830s. By taking 20 to 40 filled bobbins and feeding their contents simultaneously into the next card, thick and thin spots tended to even out, greatly increasing the uniformity of product needed for quality production.

During the 1850s two new systems had come into use; both offered improved quality and reduced labor costs. The Apperly and Scotch feeds took the roving directly from the doffer or the side-draw condenser and carried it, without balling or human intervention, to the feed table of the next card, where it was laid transversely on the feed apron to produce a maximum of intermixture with a minimum of parallelization. That these intermediate feeds were not adopted at Watkins Mill although their use became common in this country by the 1870s indicates a willingness to accept a high degree of labor intensiveness and of limitation in the quality of the product. Similarly, the Watkins did not adopt the Bramwell feed developed about that time which automatically fed the wool to the card with greater precision than could be expected from workers, while eliminating all skill and most of the operatives' time from that process. George Bramwell's invention, however, represented substantial expense, whereas the Apperly feed, a comparatively simple device, won rapid acceptance on account of its efficiency, inexpensiveness, and potential for savings in labor costs. Watkins' failure to adopt it carries an implication of the availability of very inexpensive labor, but also a refusal to purchase the kind of equipment without which his position relative to other, more innovative, manufacturers could only slip backward.

As each bobbin was filled by the side-draw condenser, an attendant removed and replaced it. The filled bobbins were carried to a creel (Photo #15, wood, and Photo #16, wooden verticals with iron horizontals) from which the rovings were pulled into the card through a finger board with holes corresponding in number to the bobbins in the creel.

Delivery from the finisher, the third card in a set, posed a major problem for the woolen industry. Until the mid-1820s, the roll drum and shell represented the best, but still poor, solution. The short lengths, or rolags, produced required an intermediate process and mechanism (the slubbing billy) before they could be spun on a spinning machine. Goulding combined ring doffers, revolving tubes, and long bobbins called jackspools into a method for permitting the taking of endless rovings from the card. Instead of one doffer taking the entire web from the main cylinder, two ring doffers, cylinders covered with alternating strips of card clothing and plain leather, took off continuous strips of roving equalling half the web each.

By Watkins' time, rub-rolls replaced the revolving tubes but the principle remained constant. Each ring doffer (rope driven on the older rub) held 18 strips of card clothing (see Photo #17); since these rings alternated, together they took off the entire web broken into 36 ends. More sophisticated systems removed the waste ends, those taken from each edge of the card, and returned them to the feed. Roving from the edges tended to be thicker or thinner than the rest and was therefore unsuitable for further use.

Each group of 18 ends taken from a ring doffer passed into one of the two sets of rub-rolls. Watkins Mill employed two types, the earlier of which appears in Photo #17 and #18. Three-roll rubs, invented in the 1830s, produced a better false twist than had revolving tubes.[7] The several rolls revolved at increasing speeds, producing a small amount of draft, and at the same time oscillated longitudinally, producing a rubbing motion. By the mid-1860s 7- and 9-roll rubs had entered general use, although 3- and 5-roll rubs could still be purchased from some manufacturers. A. Jenks and Son offered only the 7-roll rub in their 1867 catalog.

One of the rubs at Watkins Mill closely resembles the 5-roll rub described in Jenks' 1853 catalog: "Rubber Condenser, with three top and two bottom rubbers of wood, geared, and covered with leather."[8] Watkins' rub utilized leather-covered tin tumblers on top, wooden beneath. I believe this rub to be the oldest of its type extant, at least in this country. It clearly represented an outmoded phase of the development of this type of condenser by the second half of the nineteenth century.

A large open gear received power from a pulley on the main cylinder shaft via the leather-covered pulley (bottom center Photo #18); this pulley drove the second and final large (4 1/2") roll in the bottom rub, and through the large gear, the other three large powered cylinders. The first two small rollers (2") were gear driven from a second gear on the shaft of the first large roller. The last two top rolls (2 1/2" and 2") turned by friction on the large rolls. Only the outer three top rolls oscillated; thus only one geared roller moved longitudinally as well as circularly.

The gear was keyed on but not fixed to its shaft. Reciprocal motion for these three rolls came from a rocker shaft (Photo #17) mounted eccentrically on a shaft below. Pivoting in a bracket on the side of the frame, it pushed and pulled on the top three rolls in each set of rubs as it itself moved up and down. The rub, therefore, came from the reciprocal movement of three of the five turning rollers. An earlier doffer drive (bevel gear on shaft from feed table) remained though no longer functional.

The second condenser, a seven-roll rub (photo #19 and #20), represented a later development of the type, one more suited to the time of production at Watkins Mill. The difference between the two is so great as to suggest that only one set of cards operated for a good deal of the mill's life; otherwise an incongruous disparity in the quality of production of the two sets existed.

Drive for this rub came from the doffer drive, through three 27-toothed gears to gears of 28, 26, and 22 teeth on the shafts of the four bottom rolls, thus increasing their speed as the wool moved away from the card and producing a little draft in the roving. The leather-covered tin rollers measure 2 3/4" in diameter. The gears on all seven were keyed to the shafts and held in place by their bearings, allowing the shafts (and rollers) to oscillate while they turned.

At the other side of the condenser, two bevel gears transmitted the rotary motion coming from the main cylinder to a vertical shaft holding four cams, each attached to a set of rolls. Photo #20 shows how frames holding the top and bottom rolls moved in opposite directions, greatly increasing the rubbing motion given the roving.

The earlier condenser not only contained only five rub-rolls, but also drove and oscillated only a fraction of them. Thus both draft and rub operated much less effectively than might have been expected with just two fewer rolls.

After leaving the condenser, the rovings were wound onto jackspools held in spool stands (see Photo #17). The spools rested directly on the drums which turned them; this friction drive insured a steady take-up speed regardless of the changes in the spool's circumference as it filled, thus guarding against breakage of the fragile rovings. Oscillating guide bars helped lay the rovings on evenly in order that they might be unwound easily on the jack.

The basic carding equipment at Watkins Mill compared at least adequately with that in use elsewhere during the 1860s. The heavy iron frames, curved spokes and lag construction of the large cylinders, whereby circular shapes are produced from many small blocks of wood (see Photo #2), presented a good basis for the degree of exactitude required for careful carding. The poppet heads were capable of fairly fine adjustment, and the best of the machines could have achieved high quality production.

However, there remained a great deal to be done after the machines were ordered before they could be put to work. Because of the fragility of the card clothing, cylinders were shipped bare. A book written in 1869 by W. C. Demond described the initial requisite steps:

TO CLOTHE FIRST BREAKER, MAIN CYLINDER

> First place the card-frame where the machine is to run, making it perfectly level. Next place the turning engine on the frame, on that side of the cylinder which is most convenient. Raise the engine high enough by the use of blocks, so that the turning-chisel shall stand as high as the center of the cylinder. Set each end of the engine an equal distance from cylinder-shaft and level with the same, making the engine fast to the card-frame. Set the chisel so as to cut a light shaving in all cases, and let all be done with caution to prevent accidents. Move the chisel very slowly, and avoid stopping it while the cylinder is in motion, as it will be

> very likely to cut a crease in the cylinder. Do not expect to make the cylinder true at first running, but run across several times if necessary. Be careful to remove all grit and tacks from the cylinder before turning. Set the chisel so as to cut smoothly as possible. Sometimes after turning cylinders there will be a fuzz left on the surface which may be removed by the use of sandpaper. There is an objection to the use of this. Some lags are harder than others and the sandpaper slipping over them, will very soon make the cylinder untrue. If sandpaper is used, place it on a block of wood or cork procured for the purpose, and use it with care.[9]

This and ensueing preparatory steps required care and experience. Changes in temperature and/or humidity would unavoidably alter the size of the cylinder, and these variables would magnify any deviation from perfection in the initial steps.

Once a cylinder was made true and smooth, it had to be clothed. Covering the main cylinder with sheet clothing required a knowing and precise hand. Clothing other cylinders followed a basic pattern:

BREAKERS DOFFERS

> Place the doffer-cylinder on the grinding-frame, make it true with the turning-engines and attach a crank on the end of the doffer-shaft. The clothing on all cylinders, except main-cylinder and finishing rings, is called filleting, and is of different widths according to the size of cylinder. For clothing with filleting, procure a drum made of wood, and the length of longest cylinder, and eighteen or twenty inches in diameter. The drum should have a friction strap on one end. This will regulate the filleting while straining on. Take a hook made for the purpose, and remove the teeth on left-hand side of the filleting, to receive the tacks. To ascertain how far to remove the teeth, take the end of the filleting to be tacked to the cylinder, and measure seven-eighths of the distance around the doffer, and mark by removing a few teeth. Then divide the spaces equally according to the rows of teeth in the filleting. This will give the right taper. Now wind the filleting around the drum, and tighten the friction-strap according to the strain you wish on the card clothing. The friction-strap should be made with a buckle on one end for regulating the friction on the drum. The drum should be made on a shaft with bearings on each end, and should be placed conveniently near the frame for clothing. Tack the tip end of taper on the left-

> hand end, on the surface of the doffer, then revolve the doffer with the crank, and press the filleting tightly together, turning the doffer the same way as in the machine, having the points of the teeth towards you. (We will call the doffer side the front, and the feed rolls the back side of the machine). When the doffer is clothed remove the teeth at the right-hand end, making the taper the same as the left-hand taper, but remove the teeth at right-hand side of filleting. Secure the tip end of taper well with tacks. Now trim the leather which may project over the end of the cylinder, replace the teeth which are out of order, and the doffer is ready to grind. Always handle card clothing with care.

Regardless of the care used in performing the two previous operations, the card clothing did not present a sufficiently even surface to be placed in operation. Before use, and periodically thereafter, each cylinder had to be ground. For all but the main, this operation took place off the card in a traverse grinder (Photo #22).

The grinder at Watkins Mill, marked "A. Jenks & Son", represented a comparatively simple and automatic means by which to accomplish the otherwise difficult and time-consuming task of card grinding. Sturdy iron ends and wooden cross-members provided sufficient stability for the requisite exactness.

The card cylinder to be ground occupied a seat on the machine at a distance from the grinder adjustable by a threaded rod. The grinding was accomplished by an emery-covered cylinder keyed to a shaft which it traversed longitudinally, thus the name. When the emery wheel reached one end of the frame, it struck a spring attached to the shaft holding belt-shippers for a straight belt and a figure-eight belt. These belts turned on the emery wheel shaft and two of the four pulleys on the drive shaft. The shippers were spaced to keep the belts separated by one pulley; the two center pulleys are idlers (not fixed to the shaft), the other two drive pulleys. Thus when the wheel reaches either end, it pushes or pulls the shipper handles, changing the belts from drive to idle or vice versa. Since one belt is in a figure eight, this change reverses the direction of rotation of the shaft which the grinder traverses, sending it automatically back and forth until the grinding has been completed. Generally, the grinder and the cylinder run in the same direction. The length of the process, its purpose, and possible difficulties were easily described by one with experience in the area:

> Let the friction be very light at first; after the card has ground a short time, then press up harder. Breaker doffers may be ground in two or three hours. Judgement and experience will enable those interested in this matter to act understandingly, and this work will help them to perform easily what might otherwise be accomplished only with toil and difficulty. The same kind of point is necessary on all cards, and the process of grinding is the same. This point is one which will catch the wool quickly and deliver the same easily. When you are familiar with card-grinding, you will have but little to do with finishing up by means of handcards or straps, as you will have learned to do most of the grinding with the emery-cylinder. In case a hooking-point is produced by over-grinding, it may be well to face the card a little, and then grind up anew, which will save time and trouble. More persons have failed here than in any other point in the card room.
>
> But the question may be asked if some portions of the card are sharp and likely to become hooking, while other parts are remaining dull, what shall be done. First move the card back from the emery, then reverse the driving-belt and run the card cylinder towards the point, then move up the card to the emery-cylinder. Let it strike the emery lightly at first as it will take hold of the card very sharply and may injure it. If proper caution is used you will find no difficulty. When the card is, in your judgement faced enough, reverse the motion of cylinders and grind up the card as at first. What has been said relates to the grinding of new cards and the matter of repairing old cards will be spoken of at another time. [11]

These directions indicate, generally, the amount of the time grinding all the cylinders on a set of cards would consume, as well as the purpose which it served. The difficulty of trying to perform the tasks "by the book," without experienced help, is obvious. The amount of experience a boss carder would need to perform competently also seems apparent.

Failure at any stage, particularly regarding grinding, produced something other than the needle point needed. Other shapes tended to hold the wool too firmly and break the fiber, or shorten the staple, and led to weaker roving which resulted in poorer quality yarn. Final touch-up of the teeth could be done with emery-straps, pieces of cloth (mattress-ticking) stretched on wooden handles onto which first glue, then emery, then more glue were applied (Photo #23 center, leaning and with tag attached).

Even after these chores, each full of opportunity for errors which would persist in succeeding steps of production, the cards were not ready until the various rollers were set, an exacting process later done with gauges accurate to the thousandth of an inch (and even then the carder's "feel" was important).

For Demond this important step relied almost entirely on the carder, as the instruction for two of the several tumbers showed:

> TO SET STRIPPERS
>
> The strippers may be set as close to the main-cylinder as they will run and not strike it. The cards will run more closely when the wool is in the machine than when empty, and should be set with the fact taken into account. The pressure of wool between the cylinders tends to spring the teeth and the leather is inclined to give and pull up. If the set is too close the machine will get dull very soon.
>
> TO SET WORKERS
>
> These, of course, should be according to the grade of wool. If it is quite coarse set them a little further from the cylinder. If the wool is very fine fleece, set thus: the first worker above fancy as closely as it will run and not dull against the main-cylinder, set it at the same time, as near the stripper as possible and not strike. Should they strike, the stripper will dull but not the worker. Be sure that they are set at each end the same distance from main-cylinder, and so on until all are set. Do not make the distance between the workers too great, as that would carry the last worker too far from main-cylinder. Be careful to leave the bolts and set-screws firm.[12]

If the cylinders were not set progressively as described, then those closest to the feed would card much more than their share of the wool. Increasingly fine spacing led to even wear and first rate results. The great reliance these instructions placed on "feel" in achieving settings which had to be the same at either end of every roller, and had also to progress by minute degrees from one worker to the next throughout the three cards in a set, indicates the degree to which individual skill, rather than achievement of predetermined measurements, governed this process. Although the craft skill of the hand carder had been replaced by the carding machine, the need for one very skilled person to oversee the process remained.

Once the carder completed the elaborate process of preparation, the cards were started and run empty for a time, then readjusted before production began. The precision with which these preparations took place significantly affected ensueing steps in the yarn or cloth-making process. Errors made here could not be corrected in subsequent stages of production.

SPINNING

Cards produced endless pieces of roving, narrow (pencil-size or less) strips of wool similar in appearance to yarn but virtually without strength. Wrapped around long bobbins, or jackspools, they were taken to the spinning jacks where they were drawn out and twisted into yarn.

Wool's particular properties enable the spinner to transform it into yarn in just one step. Its scaliness causes the fibers to cling together as the roving is twisted by the spindles on the spinning jack. Where the roving is thin, extra twist accumulates; where it is thick and less twisted, the draft, or stretching of the roving is accentuated, with the result that these two simultaneous processes make the yarn more even than the roving from which it is made.

Watkins Mill contained four spinning-jacks, also known as hand-jacks, each designed to produce yarn on 216 spindles (see Photos #24 and 25). The pair at the east end of the third floor (foreground, Photo #24 and 25) came from the Jenks shops and appears older, less sophisticated, than the two Furbush and Gage jacks at the west end of the floor.

The spools of roving rested on spool drums along the back of the jack. Rovings went between iron feed rolls and were attached to spindles on a movable carriage. When the machine ran, roving passed through rollers turning at the same speed as the spool drums (no draft). As the roving began to pay out, the spindles were also put into motion and the carriage carrying them started to move away from the fixed portion of the jack at a speed determined by the resistance of the jackspinner to the outward motion imparted to the carriage by a loose belt running from the headstock through the carriage to a pulley at the extreme limit of the carriage's motion. The spindles incline slightly toward the headstock so their spinning did not wind the wool onto them but twisted the strands as they slipped continually off the inclined tips. Since the movement of the carriage occurred at a speed greater than that given the roving by the feed, the roving was also drawn out, or drafted, as the carriage moved away. The roving thus attained as much as twice its original length and was twisted until it reached the desired degree of strength. (The strength of the yarn depended on the hardness of the twist and operated in inverse proportion to its softness).

The hand-jack spun on 216 spindles at once and harnessed steam-power for spinning and drafting. The spinner walked back and forth with the carriage, controlling the draft on its outward movement and providing power, by turning the crank-wheel, and guidance for the backing-off and winding-on motions. The spinners' travels were evidenced in the floor boards, badly worn in some cases (see Photo #24), replaced in others (as at Furbush & Gage jacks).

Spinning and drafting took place while the spool drums and the feed rolls dispensed roving. Near the end of the carriage's movement, the feed stopped while the spindles continued to turn and the spinner drew the carriage to the limit of the desired draft. At this point he (women virtually never operated jacks before the advent of the self-actor or automatic mule) pushed the carriage in slightly, "easing-up" the tension on the yarn so that it could be "wound-on" the spindles. As he turned the crankwheel with his right hand he controlled with his left the faller wires running the length of the carriage which guided the yarn onto the spindles in an up and down fashion in order to create a regularly shaped package, or cop, from which the yarn would unwind readily and evenly in succeeding operations. The operator had to combine skill, strength, and endurance to accomplish this task.

The Jenks jacks were driven from overhead pulleys through the head-stock, where the several motions were controlled. Power travelled from the drive pulley through pairs of bevel gears at the bottom and top of a vertical shaft and then via a horizontal shaft to two feed rolls on which turned, by friction, a third roll (see Photo #26 from above, and #27 from rear). These rolls did not impart draft but prevented the twist entering the yarn from moving all the way to the jackspools.

A pulley on the left end of the drive shaft carried a belt running through the carriage to a pulley at the limit of the carriage's travel. This belt assisted in the drawing out and, as it passed through the carriage, turned a tin drum (as long as the carriage) carrying the drive bands which encircled and turned a whorl on each spindle. The motion of the feed rolls was transmitted by a belt and gears at the end of the machine to the spool drums, which therefore turned at the same speed as the rolls. The horizontal shaft disengaged, through the action of a series of levers and weights, from the vertical shaft at a predetermined point in the carriage's outward motion. Similarly, the main drive belt moved to the idle pulley at a time determined by the gear engaged to the worm gear on the vertical shaft (Photo #27). The feed control adjusted through 30 possible placements for the disconnect indicator; the second indicator could be adjusted only by lossening a set screw and turning the entire mechanism. When the spinner pushed the carriage against the headstock at the completion of a draw (a complete set of the processes of drafting, twisting, and winding on), the levers were lifted into their engaged positions, the drive belt moved to the fixed pulley, and the process begun again.

The two Jenks machines were identical, with the one to the south (closer to the cards) now in better condition. Their crude system of weights and levers, the unpowered carriage return, and limited provision for adjustment indicate they were early and comparatively primitive attempts at mechanized spinning. Given the imminent introduction of self-acting machines, these could not have represented state-of-the-art equipment when Watkins purchased them.

The other two jacks carried the legend "Furbush and Gage, PHILA. PA.," on a plate on the frame, as well as "Moulton's Patent September 19, 1865" cast onto the headstock. Stencilled on the carriage appeared: "PATD. BY JOHN GOULDING, DEC 15TH 1826/RE-ISSUED JULY 29th. 1836/ EXTENDED AUG 30th 1862/NO. 265." Goulding's patent covered the friction drive for the jackspools and the rollers holding the roving.[13] The series of dates indicated the long period of disagreement over Goulding's rights and their originality and his eventual vindication by the courts.

Hamilton L. Moulton described the advantages of his spinning jack in his patent specification:

> My invention consists of certain improvements, fully described hereinafter, in jacks for spinning yarn, the said improvements having been designed with the view of insuring the simultaneous starting the delivering, stretching, and twisting operations, and of permitting the delivering operation to cease at any point during the outward movement of the carriage and while the stretching and twisting of the threads are continued, the mechanism employed having also been designed with the view of obviating defects alluded to hereinafter as being common to ordinary spinning jacks....
>
> In spinning jacks heretofore made the rollers for delivering the roping were stopped and started by moving the bevel-wheel I' in and out of gear with the wheel I, the shaft J having a movable bearing for accomplishing the purpose. This plan is very uncertain and inaccurate in its action, and involves the necessity of using two rollers on the carriage, one for the purpose of arresting the roping-delivery and the other for arresting the movement of the driving-shaft. By the peculiar arrangement of the bars R and R', the former only of which has a projecting rod W to be operated by a single roller on the carriage, the two movements are accomplished simultaneously and with precision.
>
> It is of the highest importance that the roping delivery and the twisting and stretching of roping should be commenced simultaneously; otherwise there is great danger of the threads being broken. In other spinning-jacks the starting of the delivery-rollers and the driving-shaft was accomplished by devices so independent of each other that a simultaneous action could not be always depended on - an evil effectually remedied by the peculiar arrangement of the two vertical bars R and R', the simultaneous lifting movement of which is certain.[14]

The contrastsbetween the Furbush and Gage jacks and Jenks' appear to bear out Moulton's claims.

These jacks were powered from pulleys beneath the floor. From the drive pulley (at left, Photo #28), power moved by a vertical shaft and two pairs of bevel gears through a horizontal shaft to the feed rolls; spool drums were turned through gears at the east end of the feed rolls.

The control mechanism for the feed (center, Photo #28) contained sixty-four holes in each of two staggered rows for easy and accurate adjustment. A pin placed in any hole struck and moved an iron piece supporting the counter, permitting it to fall out of mesh with the worm gear and simultaneously to shift, through levers, a clutch [visible, engaged and disengaged (as are control mechanisms) at lower left of Photos #28 and #29, respectively] which, when engaged, drove the vertical shaft to the delivery system. A parallel motion disengaged the drive belt through a belt shipper (missing from machine pictured), thus halting spinning. At this point the spinner eased off, then wound on as he returned the carriage to the headstock, which action lifted both control mechanisms back into mesh from their idle positions (see in Photo #28).

The headstock of these jacks represented an integral part of the back-beam of the jack, unlike the Jenks with the mechanical controls placed separately behind the jack. This machine not only permitted much easier and more exact adjustment, but also promised a smoother, more positive, more easily duplicable action on the part of the spinner during his many draws during a day, week, or month.

The jack clock atop each Furbush and Gage jack turned through a ratchet, one tooth per draw, by a pawl on the bar which lifted the two controls back into mesh. The clock indicated the number of draws and amount of yarn produced. [For a more detailed description (with illustrations) of the machines' action, see Moulton's patent, attached].

The Furbush and Gage jacks displayed a careful construction and ornate finish, with decorative outlining of many parts and decorative painting on the iron end frames (Photo #30). The jack to the south came as a result of an order for a larger package capability, offering greater distance between spindles so that more yarn could be wound on them before the filled bobbins had to be removed, or doffed.

This jack has long been said to have been operated by hand,[15] but little evidence to support the claim was discovered, while both primary and secondary evidence militates against it. A pulley found mounted below the jack would have provided it power, just as did a companion for the other Furbush and Gage spinner. The flooring in the area has been replaced, removing what must have been evidence of the considerable use one would expect to find there, as well as the evidence of belting from this pulley.

During the mid-nineteenth century, these machines were often called hand-jacks, but that usage differentiated them from the self-acting mules coming into general use. Moulton's patent clearly envisages only powered operation. A hand-powered multi-spindle spinner of this type would be related to the jenny of an earlier period, but even though designed for hand operation, with large drive wheels rather than the small crank wheel of the jack, they did not attain capacity comparable to these 216- spindle machines.

> In the census of that year (1820), the number of spindles per machine ranged from forty-four to one hundred and twenty, and the usual number between fifty and seventy. The limit then had apparently been reached; for with every added spindle it became increasingly difficult to control properly this hand-driven machine. The largest jenny to which I have found reference was one of a hundred and fifty spindles..., in 1824.[16]

Harold Catling, a leading authority on spinning mules, refers to jennies of "60, 80, and occasionally even 120 spindles."[17] Another writer in 1871 cited the power requirements of a spinning jack as .784 horsepower or 431 footpounds of torque for drafting and .657 horsepower, 361 footpounds of torque for spinning.[18] Since these actions are in part simultaneous, power needs at certain times would have been greater than either of these figures. For a person to generate such power and apply it through the small crank wheel in such a way as to attain the 4000 R.P.M. spindle speed associated with these machines[19] for even a minute, let alone the hours and days required, cannot be imagined.

Only one bit of evidence was found to support the concept of hand operation: the piece of wood which connects the twist disengagement mechanism to the belt shipper holds no shipper at this time, nor does it show any sign of having held one. Given the above arguments, however, it appears likely that a piece of wood was added to the machine either as part of some effort at reconstruction, comparatively recently, or that the machine was used, or an attempt made to use it, for some unknown purposes other than making yarn.

Another mystery remains: the mill contains no spool stand of the size required to hold the longer spools used on this large-package jack. The absence of spool stands of this size for the cards could be explained in several ways: 1) theft after the mill closed; 2) alteration to accommodate the shorter spools of any of the other three jacks; 3) failure to put the jack into use. The last seems unlikely since the jack was specially ordered and the floorboards later replaced where normal wear during operation would have occurred. The first cannot be evaluated at this time. The second would indicate that one of the other jacks was relied upon for the dwindling yarn production of the mill's last years. If the last were the case, it would support an explanation of the machine's lack of connection to the mill's power system based on disuse rather than hand operation.

In any case, the four jacks indicate another area in which quality was sacrificed and labor-intensive machinery retained at Watkins Mill after alternatives became available. Claims made in the reputable Bulletin of the National Association of Woolen Manufacturers in 1869 asserted that a self-operating jack (one which ran without worker participation in the routine operations) produced 20% to 50% more yarn of better quality with a 50% reduction in cost. The $350-$400 expense involved could be made up in about nine months.[20] Piecing of broken ends could be done without halting the machine, children could do much of the work, and one operative could operate two such jacks erected facing one another. Another account cited an attachment to make any jack into a self-actor for just $200.[21]

In both England and America self-actors were developed and purchased as a result of manufacturers' dislike of the collective strength of the highly skilled mulespinners. Automatic machines were looked to as means of replacing these men with less skilled, more easily controlled employees. This movement operated consistently with the desire to develop maximum control of all aspects of production by the factory owners, enabling them to minimize labor costs and worker independence simultaneously.

Watkins' willingness to continue with the hand-jacks implies that his relationship with the mulespinners may have been atypical. Clearly he did not find them intolerable, although whether they were, as part-time employees in a rural area, simply less militant, or whether he found their level of strength and organization reasonable cannot readily be determined, but by persisting with hand-jacks he demonstrated that he found their relationship comfortable.

The Watkins Mill building did not readily accommodate the jacks installed. Placed back to back, the headstocks of the four machines were so crowded as to make access very difficult. So little space remained between the two sets of jacks that the passageway between the two pairs, through which the bulky jackspools full of roving would have to have passed to the two machines at the northern wall, barely accommodated an unencumbered person. Spools could have been passed over the machines if one pair was idle, or holes in the northwest corner of the exterior walls could have held a platform across which full spools and bobbins were transmitted, but none of these arrangements would have permitted efficient operation.

A mill owner needed to plan ahead to avoid these sorts of difficulties. By way of extreme comparison, the Pemberton Mill built in Lawrence, Massachusetts, in 1853 was specifically designed to accommodate 10 608-spindle self-acting mules. An operation the size of Watkins Mill could but little better afford to overlook the space requirements of the machinery it was intended to employ.

Yarn from these jacks, if hard twisted, could have provided adequate warps for the looms, but records show that warps were often bought by the Watkins family. Yarn for weft, or for sale as yarn, generally was plied, or twisted, together so that two or more strands wrap around one another to become one.

At the west end of the second floor sat two twisters, one marked "A. JENKS & SON," (Photo #31 and 32) the other "BRIDESBURG MANUFG CO. PA" (Photo #33), indicating it probably represented the fulfillment of an 1875 order for a twister costing $225.[22]

The two twisters were virtually identical and served to ply the single strands of yarn from the jacks into combinations suitable for filling (weft) or for knitting by the mill's customers. Bobbins of singles yarn rested in the table of the machine, with yarn running through eyelets above, down between iron feed rollers, then down to one of the bobbins. The twisting action took place between the feed rollers and the bobbin as the yarn passed through a light metal traveler carried around the polished steel ring which gave the machine its names: a ring frame twister. The bobbins were turned by rim bands, or cords, running from a tin drum to a whorl on each spindle. The rings and travelers rested on a counter-balanced builder-rail which was moved up and down, independent of the bobbins, by a worm gear turning a cam which imparted the builder motion which shaped the package of yarn on the bobbins.

The strands of yarn were twisted together in the opposite direction from that in which they were spun. Two-, three-, or four-ply yarns were commonly produced for industrial and domestic use. In the latter case, the bobbins moved to the skeiner (Photo #34), a simple apparatus to wind the yarn into skeins of a prescribed length, at which point a mechanical counter would ring a bell to signal an operative to remove the yarn. One of the sides of the reel was then collapsed, allowing easy removal of the skeins. On both the skeiner and the twisters shipper handles extended nearly the length of the machine, permitting a worker to disengage the drive from any spot while tending to broken ends or other malfunctions. A comparable but hand-operated skeiner rests in the picker room.

Skeins of yarn went to a skein-twister, either a homemade treadle-operated one producing 5 3/4 revolutions per cycle, (Photo #35; note hole worn in floor by operative's foot, and crutch, used for support while treadling, hanging on post) or the powered hanker marked "J.F. MCAFEE PATENTED FEB 6 1883 PLEASANT HILL MO," (Photo #36) in which the spring-loaded clutch disengaged every 11 1/2 turns. The presence of this powered hanker, probably the last machine purchased for the mill, implies a limit to the tolerance of workers or owners for this position. The hanks from either source were placed in the baler (Photo #37) where a ratchet and lever compressed the hanks in preparation for shipping.

Yarn to be used as weft had to be wound onto bobbins of the proper size to fit the shuttles of the loom for which they were intended; this operation took place on the 30-spindle quiller, now quite incomplete and stored in the attic (Photos #38 and #39). Bobbins or spools of yarn rested on the fixed spindles at the front of this A. Jenks machine, and a tin-roll provided power to spindles holding the bobbins for weaving. A heart-shaped cam (Photo #39, L) shaped the package by oscillating the yarn guides (visible at top of #39, next to cast iron bobbin holders). The quiller appears identical to that in Jenk's 1853 catalogue.

A spool stand and creel (Photo #40) for transferring yarn from bobbins to jackspools also rests in the attic. Although the mill contains no spool stands of the proper size to take roving from the carding machines for the large package Furbush and Gage jack, this apparatus did accommodate the 39" spools for that machine. Spooling generally took place in preparation for warping, twisting, or skeining, but none of these processes used jackspools at Watkins Mill. Conceivably yarn from bobbins was spooled in preparation for a return to the jack, but the purpose of such a time-consuming operation remains unclear.

WEAVING

"Weaving is the forming of a textile by the interlacing, at right angles to each other, of two sets of yarns, one running lengthwise in the loom and termed the 'warp' and the other running crosswise in the loom and termed the 'filling' or 'weft'."[23] This process required the performance of a number of actions, some consecutive, others simultaneous, which had to be performed with accuracy, speed, and gentleness. The irregular character of this operation, as opposed to the basically circular motions required elsewhere in the textile process, presented great obstacles to inventors attempting to mechanize weaving in the late eighteenth and early nineteenth centuries. Furthermore, the fragility of woolen yarn, compared to cotton, delayed introduction of power looms into the wool manufacture, and not until William Crompton's 1841 invention of a woolen fancy loom were the intricate weaves of fashion materials woven by power.

The separate mechanical operations required for weaving at Watkins Mill included:

1) Shedding-, harness-, or head-motion to separate the warps according to the pattern of the cloth being woven.

2) Picking-motion, to insert the weft yarn through the opening made by #1.

3) Beating-up or lay-motion, to push the weft against those inserted previously (to form a tightly constructed cloth).

4) Letting-off motion, to deliver the warp yarn, under tension, as cloth was produced.

5) Taking-up motion, to accumulate the cloth as it was made. In addition to these basic necessities, there were also:

6) Automatic stop-motion, to halt the looms when one of the first group of motions went awry.

7) Box-motion, on fancy looms, to provide the shuttle (carrying the weft) holding the proper color of yarn when more than one color of filling was required.

Before the yarn produced on the spinning jacks on the third floor could be used in the loom it had to be prepared for use as either warp or weft. Weft yarn generally was plied and then wound onto bobbins on the quiller before insertion into the shuttle which carried it back and forth through the changing openings, or sheds, in the warp. The warp was prepared in the warping mill (Photo #41). Workers arranged full bobbins in the creel, left, according to the requirements of the patterns; the yarn was drawn off onto the reel, at right, by the systems of belting and shafting visible on the ceiling. The "clock" visible at the left end of the reel measured the accumulation; a reed, a comblike device attached to the reel, assisted in the process of drawing the yarn onto the reel evenly. The contents from a number of bobbins were required to form the long (preferably several hundred yards) warp without which power-weaving became uneconomical. Once the reel held the prescribed length, the ends were attached to the warp beam (center) of a loom and wound on under tension.

There must also have been equipment, no longer present, for dressing, or applying sizing, to the warp as it was wound. This flour- or potato-based starch solution smoothed and coated the yarn, temporarily eliminating the wool's fuzzy nature and enabling it to move through the loom with less resistance and more strength.

Once the warp was prepared, and the sizing dried, it was "drawn in" to the harnesses which raised or lowered groups of threads to open the shed and thereby produce the structure and pattern of the cloth. These simple rectangular frames

(Photo #42) held numerous heddles, each of which contained an eye through which one strand was drawn in accordance to the pattern being woven. The several harnesses, then, held every warp yarn as part of one of the groups they controlled. Once each of the several hundred ends typically involved had been put in its place, the warp beam and harnesses were placed in the loom, the ends drawn through the reed mounted on the lay, or batten (Photo #43), and attached to the take-up roll. A shuttle holding a bobbin wound with weft yarn was placed in the shuttle-box at one end of the lay, and the loom was ready to run.

Three of the simplest, and among the earliest, looms at Watkins Mill stand next to the twisters, along the north wall. Supplied, like so much of the mill's equipment, by A. Jenks and Son, these cam looms wove plain fabric with a single weft color. The looms illustrate all the major motions but the last (shuttle-box motion); these functions will be discussed in the order originally presented.

Power came to the loom from an overhead shaft connected by a leather belt to a set of 16" pulleys: the ilder, loose on the shaft, and the drive, fixed to the shaft (far left, Photo #42). An 11" gear on this shaft meshed with a 21" gear below which drove both shedding and picking motions.

Treadles pivoted at the back beam, a wooden cross-piece at the back of the loom, and were held in place for vertical motion by an iron grate (bottom center, Photo #43) at the front. Each of the up to six treadles was attached to one harness by a leather strap. Another strap rose from each harness, passed around a roller losse in a frame above the loom, and then down to another harness. The two cams (bottom center, #42) alternately depressed and released the wooden treadles as they rode over iron top-pieces sloped evenly away from a central peak, producing an even and fairly gentle manipulation of warp yarns. The straps over the rollers cause the depression of one harness to raise another, thus producing the shed, or opening, through which the shuttle passed.

An unusual pattern device enabled the two cams to act on up to six treadles. Cylindrical iron pieces into which convoluted paths were cut were attached to the cams and keyed to the shaft on which they turned (see Photo #42). In the photograph the knives which controlled the pattern were set at the outside edges of the cylinders, holding them in one position where the cams act on two treadles. The knives could be set into either of two repeating paths, one of which moved each cam in and out across two treadles, the other across three, thus permitting a narrow range pattern; with short repeats to be woven on this loom. With the exception of the pattern device, this type of cam-operated harness motion remained common for many years. The mechanism appears to be that invented in 1847 by Richard Garsed and described by him:

> In the weaving of twilled fabrics it is known that the sets of harness to be shifted in succession whether consisting of three or more, commencing with the first then the second, then the third, etc., and back again to the first; this has generally been done by a series of cams, one for each treadle, requiring the cam shaft to move very slowly and rendering an additional cam shaft necessary either for the harness cams or the shuttle cams. To obviate this I make the harness cams to slide endwise on the shaft, and provide them each with a cylindrical hub, the periphery of which has as many grooves cut in it as there are treadles to be worked by it in succession, these grooves run in the direction of the circumference nearly the whole circuit, but towards the end the first takes a diagonal direction and runs into the second, and in like manner the second into the third, and the third then crosses the second and runs into the first; the inclination of the grooves uniting the third and first and crossing the second, being greater than that which unites the first and second, and the second and third. These grooves receive a feather which turns on a stud pin projecting from the frame, so that as the cam shaft rotates, (supposing the feather to be in the first groove), the first groove runs on the feather, and when it becomes diagonal, to run into the second, the feather turns on the stud and runs into the second groove, thereby shifting the cam to the second treadle. In like manner it is shifted to the third, and then back to the first, the ends of the turning feather being rounded to prevent catching on the fillets between the grooves where the third groove crosses the second to run into the first.

> Claim.______ I do not claim as my invention, simply giving a reciprocating motion, by means of a grooved cylinder, as that has been frequently done in mechanics; but what I do claim as my invention, and desire to secure by letters patent, is shifting the cams of looms by means of three or more grooves, running back into the first, and crossing the others, while the cams do not touch the treadles, in manner and for the purposes substantially as herein described.[24]

The picker motion, on the other hand, represented an early style not extensively developed in the United States, one not known to have been used by other manufacturing companies in this or later periods. Treadle-like wooden pieces, or arms, pivoted at the back beam and extended to the front of the loom. Pick-balls attached to the same shaft as the cams transferred motion to these arms by striking iron ridges set into and bolted to them (see #42). The ridges began as a gentle slope, then rose suddenly to a peak so that once the picker was set in motion the violent force required to drive the shuttle quickly across the loom occurred. The front end of the arm passed through a leather strap attached to an iron wheel (nearly 6" in diameter) mounted on an iron rod connected to the lay and holding a wooden lever, or picker stick 16 3/4" long (see #43). A leather strap ran from the picker stick to a hard leather pick hammer sliding on an iron rod behind the shuttle box, into which it extended. When the pick-ball drove the arm down, it suddenly pulled on the wheel, and thus the picker stick, yanking the pick hammer toward the center of the loom, sending the shuttle across the race plate on the lay to the shuttle box on the far side; a length of weft was left in the shed. A spring connecting the bases of the two picker sticks returned them, and the arm taking the blow, to their original positions. Somewhat inefficiently, the shuttle entering the box pushed the pick hammer back to its original position.

The Jenks catalog of 1867 advertised a loom of this type as operating at 130 picks per minute. Imagining each picker motion operating 65 times per minute. with 130 changes of harness positions, suggests the precision with which these actions had to be timed and operated. Adjustments could be made by varying positions of pick-balls, cams, and drive gears.

Between the 130 shots of weft each minute, each strand of filling yarn had to be beaten into the cloth. Wooden arms attached to the crank shaft (#42) moved the wooden lay forward and back, and the reed (#43) it held pushed the weft into place. Hand-forged wing nuts held the 45" reed in place. Cloth of nearly that width could be woven, making this machine a "narrow" loom.

As cloth was produced, the warp yarns had to advance to the front. Weighted levers pivoting at the outside of the back beam provided warp tension through the ropes passing around the warp beam and attached to the levers (#42). Moving the weights inward increased the friction from the ropes and the tension on the warp. The yarn passed up over the whip roll and then horizontally through the harnesses and reed, over the front beam and down onto the take-up roll. Since the accumulation of cloth on this roll increased its effective circumference, a variable take-up speed was required. Two pawls rest on an 11" gear which, indirectly, turned the take-up roll (#43). The lower pawl simply held the ratchet gear from turning backwards as motion of the lay advanced the upper pawl. The number of teeth it advanced in a given motion was regulated by a counterweight which the weaver moved according to the amount of cloth accumulated.

Close attendance on the part of the weaver detracted, of course, from the profitability of power equipment intended to produce cloth with a minimum of worker skill and attention. Once capital was invested in machinery, it required maximum operation with minimum skill to maximize profit. As textile machinery evolved, efforts to reduce the requisite operative skill and amount of direct worker involvement were continuous.

A smash preventer on this loom represented one of the automatic mechanisms which, as they appeared, steadily increased the number of looms a single weaver, or loom-tender, could superintend. Photograph #43 shows most of this simple but important safeguard against a costly malfunction of the loom. If the shuttle failed to cross the loom completely, when the lay came forward it would drive it against the cloth. This event, a "smash," produced a large and irreparable defect in the piece, and could damage the shuttle and/or the reed. A protection rod mounted on the lay held a protection finger pressed against the binder, or swell (movable side), of each shuttle box by the protection spring. When the shuttle arrived in the box, it pushed the swell slightly outward; this motion moved the finger, thereby turned the rod, and lowered a dagger mounted at its center. If the shuttle did not arrive, the dagger did not drop, and when the lay came forward the dagger struck a receiver which threw the spring-loaded shipper handle out of the "on" position and slid the drive belt onto the idle pulley, halting the loom before the smash occurred. The metal binder which initiated the motion was adjustable by means of a set screw.

Indications exist to show the presence, once, of a weft stop motion which checked for the presence of weft yarn after each pick, or throw of the shuttle. When a bobbin ran out, this safeguard also stopped the loom. Only three pieces, two on the end frame and one on the arch, both at the drive end, remain.

Two temples, to hold the cloth at its full width, operated on the front beam. Inside them, a roller implanted spirally with pins turned against the passing cloth, gently pulling it toward either edge of the loom in order that the weft did not pull the warp together and produce narrower cloth than intended. On one of the three looms of this type, the patent date "Mar. 27, 1866" remains legible on the temple.

These three looms were virtually identical. Wooden cross-pieces and lays, in combination with iron end frames and most mechanical parts, added up to a solidly constructed and apparently serviceable loom. Oil holes were provided wherever one part turned on another and square nuts used throughout. Originally painted a dark color, the looms were decorated with red accent lines along the edges of the iron surfaces and openings within them. Certainly attractive, it may reasonably be supposed that they provided efficient production despite their unusual indirect picking motion.

Some of the crating from machinery from Jenks was used in minor interior construction. A board used in sheathing the main drive pulley carried a stencil (Photo # 94) which reminds one of the obstacles Watkins faced: "Not Contraband, 1 loom, Alfred Jenks & Son Manufacturers of all kinds of Cotton & Woolen Machinery, Bridesburg, PA." (italics and commas added). Putting a factory into operation during the Civil War complicated the Watkins' already difficult task.

Three other Jenks looms lie jumbled and apparently scavanged at the weave room's east end. Although incomplete, they offered little variation from the above looms except in their harness motion (Photo #44). Instead of cams which depressed treadles, heavy iron disks from which triangles 8" across and 3" deep had been omitted turned over the treadles. Each treadle rose in turn when an iron projection on it was met by a corresponding cut-out. Gear drive to this motion slowed it to a speed where five revolutions of the drive shaft produced just one revolution of the set of disks, thus providing one harness change per pick. A very strong, positive action, this motion was suitable for weaving a heavy twill requiring up to five harnesses. The difficulty of altering the pattern required large runs of one type of cloth to make it a practical piece of equipment.

Three Jenks broadlooms complete that builder's contribution to the weave room: marked "ALFRED JENKS * BRIDESBURG," an earlier name for the firm, these looms either represented older products of the company, reflected a willingness to permit the previous name to persist despite the ease with which it could have been changed when casting parts, or implied the existence of a large stockpile of loom arches with the old name. The style of the looms lends credence to the first alternative.

These looms were built more ruggedly than the narrow to handle the strain of weaving heavy goods (blankets) at widths of up to 110 inches. The large lay moved back and forth on vertical iron members (lay swords) outside the frame, rather than the wooden ones of the narrow looms.

The method of imparting motion to the lay, however, represented a significant difference, and another area where Jenks' method fell outside the mainstream of power loom development. Each lay sword (see #45, foreground) contained a curved (roughly crescent-shaped) opening; behind the opening, a solid iron disk (10") turned on a gear-driven shaft. A protrusion (3" x 1.8") on the wheel rode in the opening, providing forward motion without the crank mechanism generally used. It cannot be readily ascertained whether this technique represented an attempted improvement or simply an effort to avoid a patented motion. In either case, it represented a novel alternative to both the crank motion of the Scotch loom (applied first in Rhode Island in this country), and the cam-operated lay of the Boston Associates' loom developed in Waltham. The crank motion became the standard.

The harness motion combined the cams of the plain looms first described with a gear-drive similar to that of the scavanged models. Large protrusions on the treadles helped produce a strong action to open the large shed necessary to accommodate the bulky shuttles needed to carry sufficient quantities of the heavy blanket yarns. The take-up motions also incorporated added strength, using two passive pawls and an active one to create a more positive ratchet motion less prone to slippage under the strain of maintaining tension of the many warp yarns.

The smash preventor in these looms evidenced cruder construction than that on the plain looms first described. A wooden swell or binder extended into the shuttle box, providing a less exact device than the adjustable metal swells of the other Jenks looms. This cruder shuttle box could have seemed sufficient for the massive broadloom shuttle, but more likely represented an earlier version of the device. The system by which the shipper handle released also operated uniquely, suggesting that the mechanism on the narrow looms represented a complete and later redesigning of the stop-motion.

In addition to demonstrating alternate designs, the three Jenks broadlooms provide an instructive demonstration of the efforts of the Watkins Mill operation in attempting to avoid obsolescence without buying new machinery. All three were built with a picker motion like that of the narrow looms; the first loom in Photograph #45 carries an incomplete version of that style of construction. The other two looms, including the one at the western wall, which appears to have been used the most recently, were modified. Long slots were cut in the bottom of the shuttle boxes to allow the introduction of a picker stick. Mounts were rigged out from the pivot point of the lay to provide a rest and pivot for the picker. The picker motion inside the frames remained with the stick cut off and motion transmitted directly from the wheel to the picker stick by a heavy piece of leather. While this set-up remained some distance from standard procedure at the time (and after), it did apply power more directly through the picker stick to the shuttle. Apparently the motion Jenks designed proved sufficiently inferior to make these adaptations worthwhile. The original motion remained in evidence on the loom and was largely utilized despite the attempt to modernize it. Even the rod carrying the pick hammer remained in use, the simple pivot the operatives were able to devise being unable to provide the horizontal picker-motion desired. The tendency of a pivoting stick, obviously, was to move through an arc, so the rod held the picker to a horizontal direction while the picker stick moved through an arc pushing it.

These alterations point toward considerable knowledge and mechanical ingenuity on the part of the person responsible for them. Despite the mill's location and limited operation, it attracted able people to its workforce.

Two looms made by the Stafford Loom Company in Stafford, Connecticut (Photos #47, 48) represented more advanced designs for harness and picking motions. Watkins purchased two drop-box looms from C. Dickinson, who dealt in Stafford looms, in September, 1867, for $173.25.[25] The looms carried treadles and cams similar to the harness motion of the Jenks looms first described. At some point they were converted to a side-cam motion identified on a plate fastened to the arch:

R. W. ANDREWS PATENT
JAN. 18, 1853, EXT'D JAN 18, 1867
MANF'G BY THE
STAFFORD LOOM, CO. CT.

Given the looms' price, perhaps this modification occurred after they arrived in Lawson.

The new harness motion, invented by Robert W. Andrews, utilized a type of side-cam motion in which cams located outside the frame manipulated the warp. Long vertical levers, or jacks (#47), were attached at top and bottom to one harness by means of leather straps passing over or under a set of rollers. Cams with cutouts were turned by a set of bevel gears in a frame on the side of the loom. When, in its turn, one jack moved into the space provided by a cam, the top of the jack moved away from the loom, and the bottom toward it, and the harness attached rose, while the others depressed (the most distant jack in #47 holds one harness in the raised position). While this arrangement provided effective shed control its capability was limited to six sequential rearrangements of the harnesses, after which the pattern repeated (see Photo #47), and patent illustration attached).

The Stafford looms displayed another mechanism for increasing the complexity of the pattern, a multiple shuttle-box (Photo #48). Two shuttles containing different weft colors were used and automatically manipulated without the weaver's intervention. The control mechanism for this motion survived only in part, but originally a vertical rod raised and lowered the boxes so that the proper color could be thrown across the race and back, depositing a minimum of two shots of each color as it returned to the box from which it came. The control, therefore, needed to turn only once every two picks; that part located on the end of the drive shaft turned the gear held in a stand. The transmission of this motion to the boxes is missing, but only some simple, regular alteration of colors could have been achieved.

The shuttle boxes on this side of the loom represented an improvement over those previously described. Constructed entirely of iron, including the binders, or swells, which hold the shuttle and influence the smash preventer, they moved vertically within an iron frame. They appear identical to those on the Furbush and Gage looms (see below).

The picker stick on the side of the multiple boxes resembled in operation those adapted to the Jenks broadlooms. Power traveled from the ball to the treadle and then, by means of a strap passing over (but not attached to) a roller, to the picker stick. The picker itself passed through a slot into whichever shuttle-box presented itself.

At the single box, a picker operating in a shoe of the Stearns type, now long since a standard, is found marked:

W. M. STEARNS
PAT'D JULY
5 1859

The purpose of the device was to achieve a horizontal (called parallel, as in parallel to the race plate) picking action. William Stearns described his improvement:

> The nature of my improvement in picker motions to power looms consists in extending the picker staff down through the rocker and rail on which the rocker works so as to aid in holding the rocker in its proper position on the rail. And in arranging and constructing the rocker to receive the picker staff and permit it to be readily adjusted to remedy any defect on the underside of the rocker, to work through the rail and prevent the end of the picker staff from rising above the rail, when the loom is run fast. And further in making a stud for a coiled spring to work on, smaller in the middle than at the end so as to allow the spring to contract in diameter as it is drawn in working: lastly in making that portion of the stud surrounded by the stationary end of the coiled spring permanent, or stationary and that portion surrounded by the moving end of the spring, to revolve, to facilitate the working of the spring.[26] [See patent, illustration attached.]

Despite the comparative sophistication of some of its appurtenances, this loom (and a second virtually identical model), still utilized wooden lay swords and straight-spoked gears, not the curved spiders generally found in the machines of this period. The extent to which an earlier type of loom was modified by the addition of later improvements cannot be ascertained, but the looms' construction suggests considerable carry-over from an earlier period of manufacture.

Three fancy looms identified as:

FURBUSH & GAGE
BUILDERS.
PHILA.

represented the most complex weaving machines at Watkins Mill. Termed fancy looms because of their capacity to operate numerous harnesses in varying combinations and thus to produce complex patterns, these looms were further designated 3x3 looms for the number of shuttle boxes at each end of the lay. With one box always kept open to receive the shuttle, five weft colors could be used.

The loom closest to the mill's east end (and picker room) offered the earliest and most complete example of this type. To overcome the limitations of cams, which were both cumbersome and difficult to manipulate for changing patterns, as well as capable of producing only a small variety of materials, another form of shed control had to be devised. Until 1841, no one in England or America had woven fancy woolens on a power loom. At that time, however, William Crompton invented a loom capable of manipulating a sufficient number of harnesses with the gentleness required for the comparatively fragile woolen warp yarn for the Middlesex Woolen Mills, at Lowell, Massachusetts.

Crompton's son George soon began to manufacture them in partnership with William A. Furbush at Worcester, Mass. In 1859 the partnership was dissolved, with Crompton still producing for the eastern market, while Furbush moved to Philadelphia and manufactured a variety of textile machinery, including Crompton's loom, for more western manufacturers. He was soon joined in partnership there by Daniel T. Gage, previously a partner in the Davis and Furber Machine Company, North Andover, Massachusetts.

Watkins purchased two Furbush and Gage looms on July 16, 1867.[27] None of the three looms present carried a mechanism patented after 1863; the two looms to the east were virtually identical and carried no patent from after 1859; probably these two somewhat outmoded looms came in '67; since they lack the manufacturer's current patents, they must have been either secondhand or not top-of-the line models. The third, to the west, had the 1863 patent but can't be ruled out.

The harness or head-motion (Photo #50) on the two earlier looms could manipulate up to twenty-five harnesses, permitting far greater divisions of the warp and therefore the potential for vastly more complex patterns than the plain looms; the harnesses could be raised and lowered in any combination. Furthermore, the harness-motion had the capacity for a great many changes before it repeated itself. Not only could it perform all these operations, but its program could also be changed with ease. Thus the looms offered the capability for an entirely different sort of production than that of the other narrow looms.

A simple computer-like control mechanism directed each harness up or down at each pick. Rollers and spacers were placed on a bar, one bar per pick, in a chain of such bars. The length of the chain determined the number of picks made before the pattern repeated itself.

The patent cited on the head motion, from November 14, 1854, related only to the manner of constructing the rollers and bars:

> Heretofore it has been customary to cast pattern chain rollers solid and subsequently to turn them down to a uniform length, the hole through the center being bored to accommodate the rod upon which the rollers were strung.
>
> The object of our present improvement is to do away with both these operations and to enable us to use a roller which shall require no further labor than is necessary to dress off its rough surfaces, and our invention consists in arranging the rollers upon a previously formed wrought iron tube which is made of the exact length necessary to bring the rollers when strung upon the rods into the required position.[28]

The importance assigned this minor aspect of the construction of a loom containing hundreds of parts reflects the intensity of both competition and technological development in weaving machinery in this period.

The head motion consisted of two frames, one of which moved up, the other down, at each pick. It contained one lever, connected to jacks above and below, for each harness. The levers contained projections on both sides and were caught by one or the other parts of the frame each time. If a roller pushed against a lever, the frame pushed it down, raising its harness; if a spacer was present, the upward moving frame lifted it, pulling its harness down. Thus for each harness, at each pick, the roller chain mechanism, computer-like, directed the machine to perform one of the two possible operations.

All three machines were 3x3 looms, with three shuttle-boxes on each side. These boxes permitted a further leap in the intricacy of the cloth design which these looms were capable of weaving. Each carried the 1859 control invented by Furbush & Crompton. The device (Photo #51) utilized a roller chain (not present in the picture) similar to that used in the harness motion to raise or lower two levers (top left in #51) connected by wires to curved, two-pronged pawls acting on ratchet wheel which turned a cam which operated through a series of levers to raise and lower the shuttle-boxes. The inventors described their mechanism: (See illustrations attached.)

> In that class of looms for weaving plaids and other figured fabrics requiring a series of shuttle boxes and in which the shifting of the shuttle boxes is determined by a pattern chain or cylinder, it has been proposed to operate the shuttle boxes at both ends from one pattern chain or cylinder by having the two sets of cams that operate the two series of shuttle boxes mounted on one shaft, and to operate these cams in either direction by having two ratchet wheels on the said shaft and in reversed directions and two pawls so that one pattern chain cylinder could, when so arranged, shift the shuttle boxes at both ends so as to bring the several shuttles into action in any order desired instead of being limited in the changes to a regular succession, but under all the circumstances the boxes at both ends were operated alike, so that with three shuttle boxes at each end only three colors could be employed although these three colors could be brought into action in any order desired, and the series of shuttle boxes at each side of the loom have been operated separately by means of two pattern chains or cylinders and duplicating the mechanisms at each end, but in such cases although the two series of shuttle boxes could be operated independently, the mechanism was not such as to admit of shifting the several colors in any order desired. In view of this state of the art the desideratum was to produce a loom in which the series of shuttle boxes on each side could be shifted in any order desired, and in any order on either side independently of the order of shifting on the other side so that with three shuttle boxes the loom could

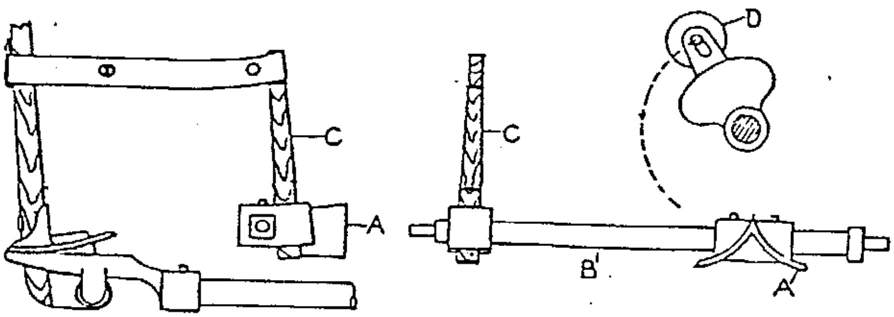
> have the capacity to work more than three colors and this we have accomplished by our invention the first part of which consists in the employment of two sets of ratchet wheels and appendages, each set consisting of two ratchets operating in reversed directions in combination with two sets of cams, one set of double ratchets and cams for each series of shuttle boxes, whatever may be the means employed for determining the periods of shifting the ratchets and our said invention also consists in combining the two sets of double and reversed ratchets and the two sets of cams and two series of shuttle boxes with one pattern chain cylinder so that with the one pattern chain or cylinder the shuttle at both ends may be shifted in any order desired, and in the same or in different orders on both sides.[29]

The program chain, by lifting or lowering each pawl, caused one, two, or no ratchets to be engaged and turned the 6-pointed cams, one on either side of the loom, so that the levers initiating shuttlebox movement rested in a hollow or on a point of the cam, moving the indicated shuttle-boxes to just the level of the raceplate of the lay.

Rollers of both wood and metal were used. As at the head motion a long program chain permitted a long series of manipulations of the warp colors before a repeat.

The selvages, or edges of the cloth, were woven in a plain weave controlled by heddles to either side of the harnesses. A wooden shaft mounted eccentrically at the drive gear transmitted a reciprocating motion to a shaft running across the front of the loom behind the lay. A parallel shaft lay behind the arch; each held rollers at the edges of the cloth, and straps passing around each roller held several heddles each. The reciprocating motion caused the sets of heddles held on either side of the rollers to move up and down, opening and closing a shed to produce the selvage while leaving all the harnesses free to develop the pattern. Another change from the plain looms provided more space for the harnesses: the crank motion for the beating motion lay outside the end frames (Photo #51).

The picking motion for a multiple box loom had to be indirect to allow one stick and one picker to act on various shuttles. The picker drive here, however, was of the more modern ball and shoe, or bat wing type (Photo #49, illustrated below); a ball struck the curved shoe, twisting the square shaft on which it was mounted, and through iron and wooden connections, yanked the picker stick toward the center of the loom.



Bat Wing Picking Motion. 30

This motion provided a quick, forceful but smooth pick with less opportunity for dissipation of force or gradual misadjustment than the arrangements or straps and wheels Jenks employed.

The take-up motion operated similarly to that of the other looms, but here a lever measured the increasing diameter of the take-up roll and gradually slid back a counterweight, causing the distance traveled by the take-up motion to remain constant by moving its gears less as its diameter increased. On other looms, the weaver was responsible for making this adjustment as required. Innovations such as this gradually permitted weavers to operate more looms.

The loom to the west, closest to Staffords, had an 1863 head-motion patented by Furbush alone but operating on the same principle as the others

(Photo #52). Its capacity of 13 harnesses limited it somewhat, but it could still produce a wide variety of materials. A cast frame, rather than one of crossmembers fastened to vertical rods, carried the knives which pulled the harness levers up or down. The inventor described the device:

> My invention relates to that class of fancy looms in which an endless roller chain is used for determining what warp threads shall be lifted and depressed by means of reciprocating bars, in combination with hook-jacks and levers connected with the heddles; and my invention consists in certain mechanism, constructed and arranged as described hereinafter, for the purpose of operating the heddle-levers and with the view of simplifying the complex machinery heretofore used for the same purpose.[31]

The operation was made clear by the specifications and illustration. (Attached)

The most modern looms at Watkins Mill were 2 broadlooms, marked "M.A. FURBUSH & SON, PHILA. PA". These looms utilized a new shuttle-box motion patented September 1, 1868, and assigned to Furbush and Gage by its inventor, Charles H. Knowlton of Camden, New Jersey. They were purchased after Gage left the partnership (1869) and indicated the ease with which names were changed on casting (first to eliminate Gage, later to add the Son). This mechanism substituted single pawls for the double ones used previously and added brakes to hold the cams securely at the level to which the program chain directed. A counterweight also aided in the work of raising and maintaining the heavy boxes.

The harness motion operated up to four harnesses as treadles were depressed by one of the cams, loose on the shaft but attached to the gear (at R in photo #54) through which they were turned one revolution per four picks.

These 3x1 looms closely resembled the Furbush and Gage looms except in terms of size and harness motion. Their reed width equalled 114". These looms offered greater potential for complex patterns with their three boxes (the single box on one side required two picks of a color, unlike the 3x3 looms) than did the Jenks broadlooms. Their picking motion and beating motion also represented mainstream developments in these areas.

The diversity of designs represented by the power looms at Watkins Mill indicated the degree to which innovation continued during the mid-nineteenth century after the basic types of loom had been developed. The Jenks looms often employed devices not incorporated thereafter, while the Stafford and the Furbush looms used mechanisms closely related to the standard methods of the time and the future. Merrill Furbush's early involvement in manufacturing with the Cromptons enabled him to provide the patented features of the Crompton loom. Jenks on the other hand could have tried to develop ways to avoid paying for patented concepts. However, the crank motion for beating was in general use when he manufactured his substitute on the broadlooms, and various picker motions other than that he provided and which someone at Watkins Mill altered also were in use. Furbush, furthermore, developed and acquired useful mechanisms after the dissolutions of his partnership with Crompton. He had trained at Gay, Silver and Company, a machine shop in Chelmsford, Massachusetts, renowned for the competence and innovative abilities of its machinists.

Weavers and loom-fixers working at Watkins Mill were confronted with a variety of looms, numerous different methods of achieving a single end (such as picking), and a range of styles among mechanisms performing one function. Thus although there were several cam looms, they included side-cam and under-cam types; the under-cam looms were divided according to direct acting and geared; within each type one found different types of cams; within a single type of cam, there were several different degrees, such as half or three quarters cam, which produced varying degrees of dwell, or pause, in the harness motion, and significantly affected the complexity of adjusting the timing of other motions in relation to the harness motion. In other words, this weave room represented a loom-fixer's nightmare. In many operations a fixer would have been responsible for a greater number of looms, but they would have been identical and producing similar cloth. Two types of broadlooms, three of plain, and two of fancy, for a total of sixteen different machines, would have disheartened the most able mechanic.

Problems associated with weaving did not affect the fixers alone, moreover; cloth inspection and repair presented further difficulties. An 1886 account in the Textile Record of America titled "Points in the Weave Room" contained this description of the abilities needed:

> When we bring this subject right down to details, it is readily seen how very few men are really qualified for such a position. Good eyesight is indispensable to begin with. A thorough knowledge of weaving must be possessed by the inspector. If not a practical weaver, how could he possibly locate an imperfection? He must not only locate, but look it up, and ascertain the cause, conditions and circumstances under which the mistake occurred. Then he must have judgement sufficient to place the fine, if any, at the proper figure. Whether the cause be gross neglect, carelessness or inexperience, he should at once be able to place the fine so that the company will loose the smallest possible amount, and yet the weaver not be too heavily punished. The overseer must and does ridgidly [sic] enforce the rules, and it is a fine point for the inspector to carry out his orders to the letter, and yet be on good terms with the weavers. In that position it is impossible to please all parties, and at times great tact is necessary to preserve peace.
>
> Besides all this, it is necessary at times, in order thoroughly to locate an imperfection, to have a knowledge of the design or weave. This goes a step further than even the fixers are competent to go. A broken pick, harness mispick, coarse filling, double thread or wrong draw, must each be properly and correctly located by the cloth inspector and further than that, we must know exactly what effect such imperfections will have on the finished fabric, for on that point alone, he must often base his claim and fix the fine.[32]

The variety of materials produced would have added to the difficulty of controlling quality. Operating a mill distant from the centers of the industry, with a limited staff, certainly made high quality production difficult. Attempting to produce a wide range of materials on diverse looms added significantly to the obstacles.

Initial inspection of the cloth took place in the weave room. A frame on the ceiling near the door at the west end of the second floor could have served to suspend the cloth and present an opportunity to view it against the light, an operation known as perching. During a second process, burling, knots and other bunches were pushed to the back of the cloth by an operative working at a sloped-topped table not unlike those found on the first floor at Watkins Mill.

Following inspection, menders repaired the faults identified, even re-weaving missing threads when necessary. High standards in earlier processes made the work easier. Menders could insure that the cloth equalled the potential quality provided by each previous department, but they could not raise quality beyond that achieved in earlier stages of production. Attention to inspecting, therefore, had to be on a par with concern for quality elsewhere, neither higher nor lower.

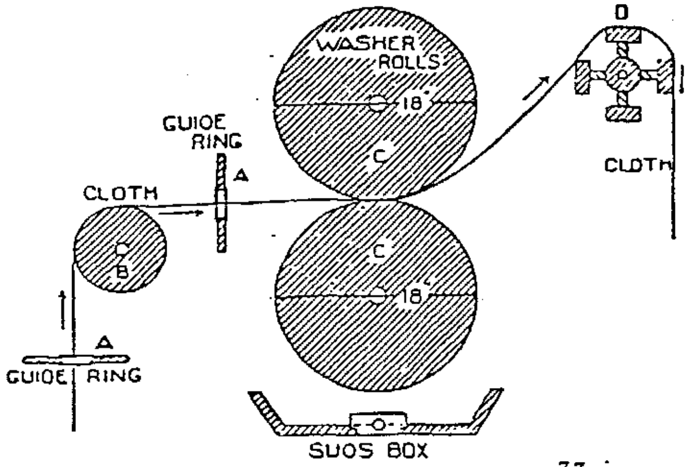
FINISHING

Once through inspection and repair, the cloth moved to wet finishing. The order in which these processes took place varied, but the same steps would occur regardless of their sequence.

SCOURING:

Cloth coming from the loom carried many impurities added during manufacture. Oil applied before picking, starch added as dressing to the warps, as well as dirt and grease accumulated as the wool moved through the mill now had to be removed, reducing the weight of a piece approximately 20%. This cleaning, or piece-scouring, could occur either before or after fulling.

Two machines incorporating tubs suitable for washing cloth remain at Watkins Mill (Photo #55). Both appear homemade; the one on the right closely matches descriptions of a washing apparatus which "consists of two heavy rolls, usually made of rock maple, and of one piece. These rolls serve to draw the cloth through the water and act as squeeze rolls at the time."



Cross-section of Washer.[33]

FULLING:

It is in fulling, however, that wet finishing really began. This process, peculiar to wool, depended on the particular properties of the fiber:

> The fulling or felting property of wool is peculiar to itself, unless we except fur, which is nearly the same: it is attributable to the scales and knots on the fiber noticed before; and, as some wools are nearly destitute of these fulling properties, we see the necessity of a thorough knowledge of wool in the beginning to avoid irreparable mistakes after the cloth is woven. The process of fulling is simply mechanical; the cloth being put under alternating pressure and relief, either by pounding or the friction of rollers. Each pressure brings the fibers of the wool nearer together, and the scales and knots on the wool prevent its receding when the pressure of friction is removed; so by continued pounding, or friction, the fabric attains the hard, leathery consistency we see, in cassimeres, meltons, and other cloth particularly fitted for men's wear.[34]

Yet even so simple a property required certain conditions before it would occur:

> To bring about the best conditions of felting, the goods must be put into a fulling mill, which is made on various principles; but the object sought is a continual pounding motion, which can

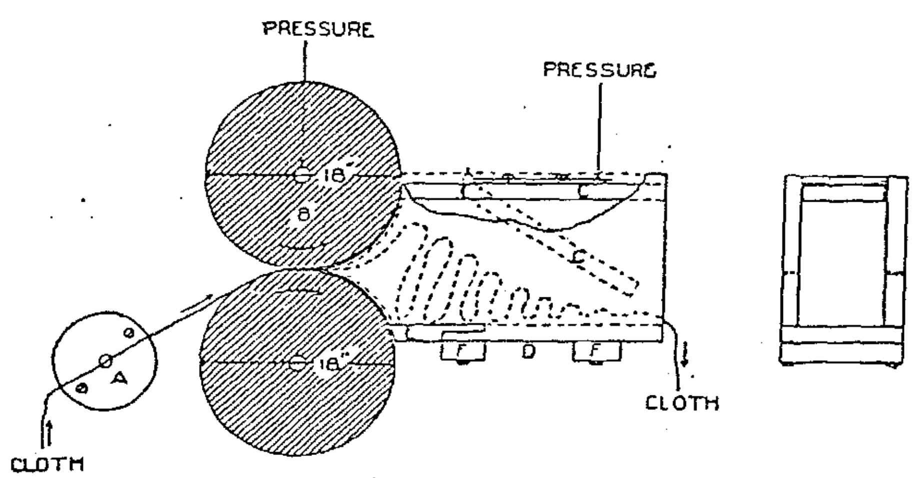
> be secured by hammers, or a combination of pulleys, over and through which the cloth is made to run. But the securing of violent motion is not all; it must be accompanied by a certain amount of moisture and given degree of heat. To make the above possible, a lubricant must be used, which in modern times is a soap, which should not be caustic enough to injure the fibre of the wool, and yet strong enough to start grease.[35]

As was the case elsewhere in the mill, expert knowledge regarding the combination of properties was a prerequisite:

> The art of fulling cannot be governed by fixed rules, and the same may be said of everything connected with the finishing department; experience, judgement, and care are the necessary qualifications of the operator. Should the soap solution be too hot, or too strong of alkali, or applied to the cloth unevenly, or should the temperature in the machine be too high, damage of some kind would be the result. It is here that the colors are ruined, cloths made tender, and numerous other evils occur.[36]

The process relied on the interrelated combination of pressure, moisture, and heat over a period of time in a rude device known as a fulling mill (Photos #56, #57).

Before fulling, cloth was folded in half lengthwise, face in and the edges sewn together in a process known as tacking. An end was then fed between the vertical guides and heavy horizontal wooden rollers and into the crimping box, or trap, behind them, down through the bottom of the mill and back to the front where the ends of the piece were sewn together forming an endless loop. Two pieces would be done at once in this machine.



Watkins' fulling mill was a crude but serviceable model. No springs pressed the large rolls together, so only the weight of the top roll created pressure on the cloth as it moved between them. Fulling with reduced pressure required more time in a process which could vary, depending on various factors, including the type of cloth, from a few minutes to several hours (generally, toward the latter).

The pressure from the rolls shrank the cloth as to width only; the crimp box, through pressure adjustable by adding or removing weights from a lever above, resisted the progress of the cloth through the mill, causing it to shrink lengthwise as well. The more cloth which packed into the box before pushing through it, the more shrinkage which was produced.

The soap applied lubricated the cloth and reduced the friction produced as it ran through the machine. Too much soap prevented sufficient heat build-up for effective fulling. Too little soap led to uneven results. Experience and careful attention enabled the fuller to properly manage the factors leading to proper fulling. Cloth properly treated was made stronger, denser, warmer, and ready for further finishing.

Fuller's earth, incidentally, is a natural clay-like substance used either in fulling or in a later washing. Known for its ability to absorb oil, grease, and soap, it provided for thorough cleansing of the cloth and provided a softness to the material.

A fulling hammer (Photo #55) found in the mill represents a different style of fulling which depended on the pounding of such hammers on the cloth instead of on roller pressure. This pyramidal wooden hammer, 30" wide at the base, 12" at the top and 11 1/2" wide, contains a 2 1/4" threaded hole in the top center. Raised and lowered by a simple cam action, such hammers were used in water-powered American fulling mills as early as the 1640s. Fulling was the first aspect of woolen manufacture to be separated from the domestic system, and such mills served handweavers into the nineteenth century. The origin of this piece is unclear, since it would have been an anachromism in a mill of this time.

DYEING:

The finishing department was also the scene of dyeing operations. Wool may be dyed several ways: in loose form, after scouring; as yarn, in hanks; or as cloth, in the piece. If dyed before processing, the colors must be strong enough to resist the ensueing treatments, thus "dyed-in-the-wool" as an expression of steadfastness. The absence of any apparatus for this work suggests a hand-operation using large tubs, perhaps in the scouring area of the first floor. Colors produced could have been mixed in picking or diluted by adding natural wool. Careful mixing at the picker or in the picked wool produced even colors. The hank dyer (Photo #55) offered a box within which yarn could receive the dye and a crank to twist out the excess before a hank was removed.

Piece dyeing was probably not carried on extensively, given the predominance of white and gray in the mill's cloth production. The box-like unit in the southeast corner of the first floor (Photo #55) could have served in this regard.

The theory of dyeing has continued to spark debate; certain requirements were clear, however:

> Every department in woolen mill requires deal of skill and experience, far more than that needed in a cotton mill. A successful dyer must be familiar with the nature of his dyestuffs, the effect they will have upon the stock he has to color, as used alone or in combination with other materials. He should be familiar with chemistry as applied to dyeing, the effect of heat and light upon colors, the chemical properties of his coloring matters, and the change and combinations to which they are liable.[38]

(Note the gratuitous but generally accepted belief in the superior skill of woolen mill operatives). Dyers used acid to enable the wool to better accept the color, mordants to create an insoluble combination of the colors, and pigments (usually dry powders) to produce color (Photo #58 shows containers for a number of dyes on a work table). Heated water and constant agitation of the material or the bath were also required.

The dye vat (Photo #55) contained eight 4 1/2" paddles, driven, which provided the necessary agitation as the cloth moved between them. Pigments such as fustic, alizarine, lead chromate, or indigo blue could have been used in combination with acid mordants, for example alum, tannic acid, sumac, or fatty acids, or with metallic mordants, usually oxides or hydroxides, to produce fast colors. The dyers handling of these combinations had a profound effect on the colors and their durability.

STRETCHING:

Once the woven cloth had been fulled, washed, and possibly dyed, it had to be stretched sideways to remove all wrinkles before succeeding processes could begin. A rare machine (Photo #59) for this purpose, marked "BROADRUP & CO. DAYTON, O." stands against the east wall of the finishing room. The cloth, wound onto the beam at lower front, passed up over a wooden roller into which were set pieces of iron angling outward, under a large roller spirally covered with sheet clothing, over a roller like the first, and down onto another beam. A small wheel (foreground) turned (through a worm-gear) a shaft with pawls at either end which raised both rollers, pushing the cloth up against the card clothing intended to stretch it out. Two levers off the drive shaft connected to gearing at the far end, and by a mechanism missing, shifted the power between front and rear beams, permitting the cloth to be run back and forth through the machine.

Friction brakes on the beams provided resistance, tightening the cloth.

RAISING:

Once the cloth became perfectly smooth and free from wrinkles, the surface of the cloth was raised, or gigged:

> As the name implies, the raising process consists of lifting out from the body of the fabric to the surface a layer of fibers which has been developed in fulling or from the yarn itself. This layer of fibers is variously termed nap, pile, or cover. Raising is distinctly a mechanical operation. The action is simply to entangle the fibers with the sharp points of teasels and to bring the fibers to the surface of the fabric. Objects of the raising process are:
>
> 1. To produce a nap, pile or cover on the surface of the cloth.
> 2. To secure softness and a lofty handle.
> 3. To conceal the weave or design, to soften the outline of the pattern and partially to blend the colors.[39]

This operation gave the woolen cloth its characteristic appearance and feeling of fuzzy softness.

At Watkins Mill, this raising occurred on a machine known as up-and-down gig (Photos #60-#62). Teasels are the dried flower heads of a thistle plant, the sharp hooked spines of which offer much stronger resistance than do ordinary thistles. The teasels were carefully arranged by size in frames, or flats, in order to present a uniform surface to the cloth.

Operatives fastened the cloth being finished to either the top or bottom winding drum of the teasel-gig, and turned the handle on the vertical shaft at the right front of the machine to engage the drive to that drum. Once the cloth was wound on, it was passed over rolls on projecting arms which provided for adjustment between the cloth and the teasels. After that it was fastened to the other winding drum and raising began.

The raising action had to be accomplished gently and slowly to avoid producing weak or "tender" cloth. The flats of the gig were first filled with old worn teasels, called "poor work," and the cloth passed across the revolving cylinder several times, with one complete sequence, from top to bottom and back, termed a run. Between sets of runs, generally six, the bits of wool, or "flocks," which had stuck to the teasels were removed with a hand card. Gradually flats of newer, stronger teasels, called "sharpwork," were introduced to provide further raising. After several dozen runs, during which the sharpwork was gradually introduced, the piece was given a final examination and removed.[40]

Skill was required in filling the flats with teasels so that a uniform flat surface was produced and in supervising the operation. Actual attendance at the process could have been by unskilled help.

Photo #62 shows the friction break on the cloth beams used to create tension and behind it, running up to the drive shaft, a mechanism causing the entire drum to oscillate in order to achieve the greatest regularity of finish by preventing a certain part of the cloth from being acted upon by a single row of teasels and possibly causing a streakiness in the nap.

DRYING:

Gigging concluded the wet-finishing; the cloth then moved to the attic, where drying took place on tenter-frames (Photo #63). Sharp right-angle hooks (thus the expression "to be on tenter-hooks" for agonizing waiting) held the top edge fixed while the lower frame was moved to stretch the cloth to hold it at its proper width. Located in the hot attic space at Watkins Mill, the tentering may also have been speeded by steam pipes.

Once dry, the cloth returned to the first floor finishing department for its final treatments. After tentering, the material had to be brushed to raise the nap for the shear (Photo #64, left). The shear removed enough of the nap raised by the gig from the surface of the cloth to produce the desired length and reveal more clearly the design.

SHEARING:

The shearer fed the cloth through the machine according to a complex pattern which brought it into contact with brushes before and after shearing, first to raise the nap, then to remove the wool, or flocks, shorn off. The ends were sewn together to form a continuous loop. The cutting took place as the helical blades turned against the ledger blade, much like the action of a reel-type lawnmower. The ledger blade was adjustable, permitting a gradual reduction of the nap. Drive was shifted from front to rear take-up by a handle at lower right (Photo #65). A stop-motion halted the machine when the take-up roll was full. It could not run long unattended, however, for the ledger had to be moved (by the handle, upper left, Photo #66) each time the seam passed. Shearing required close attention and skill in any case. The handle at center left (Photo #66) controlled the tension of the drive belt and thereby the machine's speed. The shearer regulated the gradual removal of fiber and also ground the blades and ledger frequently.

PRESSING:

Once shorn, the material moved to the press (Photo #60). Folded in two, the material was folded back and forth over specially prepared cardboard, hot iron plates, cardboard, and paper until a piece was complete, then the screw turned to create the desired pressure. A repeat operation was required to bring all faces of the cloth in contact with the papers and produce the smoothest finish: "Its object is the last leveling and flattening of the texture and, at the same time, pressing brings out the handle, luster, and appearance desired on the finished fabric. The basic factors controlling pressings are heat, moisture, pressure, and time."[41] Pressing time could run up to 12 hours; aside from the determination of the combination of the above factors, this operation could be carried out by semi-skilled help.

Also in the finishing area one finds a large stretching frame (Photo #67) for which the use remains unclear. It held cloth tightly by means of ratchets and cranks; hand operations such as gigging or shearing, conceivably, or possibly some sort of inspection and repair, could have been carried out on it.

A small workshop also shared finishing space (Photo #68, and #69). Heavy timbers supported a blacksmith's vise, a bench-mounted hand-powered drill and four-speed wood lathe, which enabled operatives to accomplish mimimal repairs on wood and metal objects.

POWER

Power for Watkins Mill came from a steam engine (Photos #70 & #71) in a shed at the east end of the building. This single cylinder engine (12" bore, 36" stroke) operated at approximately 72 R.P.M. and developed about 50 horsepower from 100 pounds per square inch pressure. A 6" octagonal shaft connected it to a 16' flywheel weighing about 8000 lbs.; a 10' wheel with a 20" belt face inside the building initiated the belting system. A "Gardner's Perfected Governor" (Photo #72) regulated engine speed.

The "Mississippi River type" wood-fired boiler, 46" x 30" was fired under the drum and back through four 12" return tubes (Photos #70 & #73). Boiler feed water was preheated in an engine exhaust heater; exhaust steam also entered the several floors of the mill through pipes for heating the building and processes. The engine also operated a water pump for its own and the mill's needs (Photo #74).[42]

MACHINERY BUILDERS

The bulk of Watkins Mill machinery came from two Philadelphia manufacturers, both of whom reflected the New England origins of the textile machine industry. In fact, one company could trace its roots to the very start of the American cotton textile industry, Samuel Slater's mill in Pawtucket, Rhode Island.

Alfred Jenks, part of a Rhode Island iron-working family, worked with Slater and David Wilkinson, a preeminent figure among early machinists in this country. Given the fledgling nature of the machine-building trade, this apprentice-like method of training represented an essential element in the education of a would-be manufacturer. By working with Slater, the first man to successfully adopt power cotton-spinning machinery in the new nation, and Wilkinson, who combined an inventive mind with an interest in both textile machinery and the metal- and wood-working machines on which it was produced, Jenks gained early entry into a field which prospered for decades as the textile industry expanded.

J. Leander Bishop's 1868 A History of American Manufacturers from 1608 to 1860 described Jenks' career after leaving Rhode Island:

> In 1810, Mr. Jenks removed to Holmesburg, Pa., taking with him drawings of every variety of cotton machinery as far as it had then advanced in the line of improvement, and commenced its manufacture. The first mill started in this portion of the State of Pennsylvania was supplied by machinery constructed by him, and was situated in Lagrange Place, near Holmesburg. In 1816, he built a number of looms for weaving cottonades for Joseph Ripka. Under the universal impetus to home manufactures during the last war, Mr. Jenks greatly extended his business operations, and in 1819 or 1820 removed to his present desirable location in Bridesburg, the increased growth of which is owing in no small degree to the personal efforts and enterprise of himself and importance of his establishment. Here, where he possessed the necessary facilities for shipping to his more distant patrons, he conveyed his old frame building from Holmesburg on rollers, which yet stands amid the more substantial and excellent structures beside it. When the demand first arose for woolen machinery in Pennsylvania, Mr. Jenks answered it, and at once commenced its manufacture, and furnished the first woolen mill started in the State, by Bethuel Moore, at Conshohocken, with all the machinery necessary for this manufacture.

> In 1830, he invented a power-loom for weaving checks, and introduced it into the Kempton Mill at Manayunk, where its success produced such excitement among hand-weavers and others opposed to labor-saving machinery as to cause a large number of them to go to the mill with the avowed purpose of destroying it, from doing which they were only prevented by the presence of an armed force. This and other improved machinery made by Mr. Jenks soon acquired an extended reputation, and induced the erection of larger buildings; and now the establishment is one of the most extensive and important in this country. Since the decease of Mr. Alfred Jenks and for several years previously, the business has been conducted by his son, Mr. Barton H. Jenks, to whom, if eulogy were admissible, we might refer as the type of model manufacturer fertile in invention, skillful in mechanism, liberal, just and public spirited, - one, indeed who throws around the pursuit of manufacturing something of the lustre and glory which the mercantile profession borrowed from the genius of Giovanni de Medici.
>
> To attempt a recital of the various inventions and improvements which this firm have made for the benefit of cotton and woolen manufacturers would carry us to far beyond our limits. Of looms they manufacture a large number of different styles, ranging from the single shuttle or ordinary loom, through the more intricate forms of two-shuttle looms for weaving checks, three and four shuttle looms for weaving ginghams and other fabrics requiring a corresponding number of colors in the weft, to the more enlarged carpet loom; and all of these embrace in a greater or less degree improvements and advantages not possessed by looms manufactured elsewhere. The several improvements in the looms are covered by seven distinct patents; and the main features accomplished by these inventions, so far as they relate to the two, three and four shuttle looms, may be said to consist in the expeditious manner of moving the shuttle boxes to change the picks of weft, and by certain new constructions, combinations, and arrangement of parts essential to this operation, and to others of an important character, by which almost as many picks of weft can be made by these two, three, and four shuttle looms as by the single shuttle loom. As an exemplification of this it may be stated that so perfect is the arrangement of the various parts of these latter description of looms, and the principle upon which they work, that they make 130 picks of weft per minute where the same class of ordinary looms only make 110.[43]

The Jenks firm prospered through the mid-century period, first as Alfred Jenks Inc., then A. Jenks and Son, and finally, after 1867, as Bridesburg Manufacturing Company. Watkins Mill contained equipment bearing each of these names. By 1872

Jenks employed over 500 men and was known not only for the quality of its textile machines but also, in the tradition of David Wilkinson, for innovation in its production machines as well.[44]

Watkins' other principal supplier, Furbush and Gage, Inc., displayed similar origins. Merrill A. Furbush (1817-1887) trained at the Gay, Silver Company in North Chelmsford near Lowell, Massachusetts. Ira Gay, who had also worked in Pawtucket, was known as an inventive machinist and his shop produced a number of machine-builders of note. Furbush next appeared in 1851 in partnership with George Crompton in a Worcester, Massachusetts, firm established to manufacture looms based on the patents of George's father, William. Furbush contributed his machine shop, training and some cash.[45]

The firm Furbush and Crompton continued until 1859; under the terms of its dissolution, the market was divided so that for several years Crompton had exclusive rights to New England, New York, and Canada, and Furbush to the rest of the United States. Moving to Philadelphia, he joined with D. T. Gage, in the firm of Furbush and Gage, which lasted until 1869. Gage, also a machinist, had apprenticed and worked at the Davis and Furber Machine Company, a noted manufacturer of woolen machinery in North Andover, Massachusetts, in which he was a partner before leaving for Philadelphia.

Furbush continued to improve on his looms through original and purchased inventions. After his death in 1887, the company operated under his sons' management until, full-circle, it was merged into the Crompton and Knowles Loom Works "about 1903".[46]

The sources chosen by Watkins indicate he was in touch with some of the prominent suppliers of textile machinery of the time, trained in the leading centers of the trade. The sources of their knowledge reveal his distance from the origins of the textile industry, but their availability indicates the accessibility of state-of-the-art machinery to Westerners. Therefore, when the mill did not utilize advanced equipment, an explanation other than availability must be sought.

WATKINS MILL BUILDING

The Watkins Mill Building (Photos #75-#77, store, #78), erected for textile production in 1861, must have presented a handsome and imposing facade to the residents of this rural area at the time. Restored, it offers a partial impression of the industrial site located in the midst of an attractive agricultural and domestic setting. Only the absence of various associated structures such as workers' cabins, the blacksmith shop, and a wool storehouse limits the integrity of the scene.

The building reveals limited planning or foresight regarding the requirements of production, however. For example, the four spinning jacks on the third floor filled the space so completely as to have presented serious problems to operatives bringing jackspools of roving and taking away quantities of bobbins filled with yarn. Since the machines represented equipment of a type and size available when Waltus Watkins built the mill, he could have planned for the jacks originally installed and allowed for efficient increase in capacity.

If the present-day layout of machinery accurately represents the situation during production (and in large measure it must), movement of materials within the plant would have been awkward. Wool carried into the first floor for scouring may have gone to the picker room through a trapdoor located near the gigmill; without knowing where it was dried, one cannot be certain. Picked wool had to be carried through the weave room and up the stairs to the carding room, it seems. The difficulty of moving stock to and from the jacks has already been noted. Yarn and cloth would both have moved up and down the stairs to the second and first floors before going to the attic for tentering. Substitution of travel on the hoist at the west end of the building for stairway trips was possible, but scarcely represented a convenience.

Perhaps the most surprising aspect of the mill's construction, however, was the absence of slow-burn construction design and techniques which had been developed in the East beginning in the 1820s. Watkins' ignorance of or willingness to ignore these features, despite the high fire danger in textile mills, must indicate an effect of his relative isolation.

Fire insurance companies in the East would have objected to the dark and dangerous workspace under the peaked roof, the location of the picker and steam engine within or attached to the main structure, the excessive flammability of flooring laid on joists (rather than planking on timbers), the absence of a watertight barrier between floors, the lack of a sprinkler system with a cistern to operate it until pumps could be turned on, the omission of a stair-tower, and the use of tied-in floors. Flooring systems bolted through the walls provided strength and rigidity, but in case of fire the collapsing floors pulled the walls in on top of them; floors which could fall free from the rest of the structure create the possibility of rebuilding within standing walls.

Locating the staircases within the building, rather than in a stair-tower on the end or side, not only added to fire dangers but also meant that moving machines and materials in and out of the buildings or through it impeded production. In a fire, employees could exit through such a tower with fireproof doors open only as necessary, thus shutting off the draft which otherwise fed the flames. Wool, yarn, and cloth could travel vertically without interfering with other operations. A cistern could have been placed in the tower above the top floor of the mill.

Adding a flour mill (Photos #79-#82) to the operation introduced still another source of fire danger. No fire-preventive measures seem to have been taken, however.

Eastern millowners began developing slow-burn construction in the 1820s and their discoveries were rapidly adopted. For a mill to be built in the East in 1860 with none of these features would have been amazing, to have done so in Missouri was only slightly less so.

CONCLUSION

Waltus Watkins' decision to enter woolen manufacturing came at the start of a thirty-year period of striking growth in the American woolen industry.[47] Although Missouri in 1845 had just three carding mills,[48] in 1860 15 woolen mills operated 86 sets of cards, and by 1870, one hundred fifty six mills ran 256 sets in the state.[49] In 1864, however, 10 mills reported processing 16,650 pounds of wool per week (793 lbs. per set of cards) to produce $75,344-worth of cloth per year,[50] suggesting a rather small pie was being divided among those seeking profits from these operations there. Compared to the country's 1868 production of $175,000,000-worth of woolens,[51] Missouri's share (.0004%) indicated dramatically its relationship to the industry nationally. Watkins Mill matched the 2-set Mississippi Valley average size of this period (not counting the cards used for custom or domestic, rather than production, use), compared to a five to six-set average in New England.[52]

An account written at the end of the decade described the condition of this industry: "Since the tariff acts of 1862, 1864, and 1867, the woolen manufacture has been greatly extended. There is no branch of it, except that of fine broadcloths, in which entire success has not been attained, and the immense supply required in the country is now almost wholly provided at home."[53] Given the expansion and prosperity of the industry overall, what, from a basically technological point of view, might have caused Watkins Mill not to flourish?

Wool, for one thing, represented a technically more difficult type of production than cotton, the other primary fiber of the time. As has been noted, each department within the mill offered difficult matters of judgment and skill, most of which require expert attention to this day. General problems, such as the factory plan, the lay-out of machinery, maintaining the proper temperature and humidity must also have plagued the new enterprise.

Indications of one aspect of the obstacles facing Watkins were contained in the response of Lyman Wilder, a Hoosick Falls, New York, manufacturer of shears, to a June 1874 enquiry from the mill:

> I do not understand what you mean by "Guide bar which guides the cloth in the shears" unless it is the rest or cushion (as some call it) which lies just back of the ledger blade and is made to move endwise by a small rack and pinion to regulate the width of the cloth. If this is the piece referred to, and it is not broken, I do not see why it cannot be plained [sic] off true again and be as good as ever. This is a good deal of work about this [unclear] and whether a new one would fit into boxes in which it is made to move I do not know, neither do I understand what you mean by the two friction extension pulleys with axes even belt grinders, I sell all parts of the machines at what is a fair cash price, but cannot give prices of small parts till I know what they are.

Two months later Wilder apologized for the time elapsed before repairs were completed (starting time unknown): "I should have had your shear done one week sooner had not the parties owning the largest share in the water power been obliged to shut the water out of the canal which feeds our works.... I have made a memorando [sic] of your shear so that I can supply new ones [brushes] any time." Both manufacturers had their problems, but at least the difficulties in obtaining repairs for this important machine (indispensable for many fabrics) could be avoided in the future; or so it must have seemed.

In 1881 Wilder was writing again: "I am not in a condition just at this time to repair shears," because his men were sick. Furthermore, "If I knew what kind of machine yours was... I would tell you what they would cost."[54] Either the Watkins had bought another machine or Wilder had lost his "memorando". The exchange suggests that Watkins was buying secondhand machinery, since otherwise Wilder would have known what his machines were. Had Watkins bought a different make of shear there would be little reason for him to contact Wilder, especially given the difficulties attending that firm's operations. Maintaining intricate equipment through the mail obviously presented a major obstacle to success.

Whether or not a general announcement of a Bridesburg Manufacturing Company service offered in 1885 came to Lawson in response to that firm's knowledge of conditions there cannot be ascertained:

> We call your attention to a special department at our Works--that of Mill engineering. We are prepared to furnish plans for the best arrangements of new plants, or the re-arrangement of old. As many changes would, perhaps, be made in locating machines to get better results, if competent men could be secured at reasonable cost, we could respectfully offer our services. No charge will be made for first consultation. Having able and experienced engineers in our employ, we can, perhaps, offer suggestions and furnish plans that would be valuable to you, should you design making alterations.[55]

The company did have extensive experience dealing with Watkins Mill. For the offer to have been effective, however, it would have to have come 25 years earlier.

The Watkins did spend substantial amounts of money on machinery. During the period 1861-1886 they spent in the vicinity of $10,000 (and perhaps considerably more - records are sketchy). They dealt with reputable manufacturers, and it is difficult to assess whether, in Jenks' case, his reputation as a loom-builder should be discounted because of the number of techniques he used which lay outside the mainstream of power weaving technology at the time. When they bought new jacks, they purchased models representing an improvement over earlier acquisitions, apparently demonstrating some attentiveness to the subject.

On the other hand, they at times bought items already outmoded, such as the crude 5-roll rub on one finisher card, which could not have offered the quality of the significantly improved 7-roll rub operating beside it. Scouring, dyeing, and fulling equipment were primitive. There is no warp dressing equipment, but perhaps it was junked and all warps purchased after some date.

To some degree, Watkins Mill could have suffered because of the very quality of the equipment purchased, its longevity: "Excellent authorities estimate the average life of the entire mechanical equipment of a woolen mill as being twenty years," but cards often lasted 40-50 years, and looms up to 50 years, though on average about 20.[56] At a time of rapid advancement in the sophistication of woolen machinery, such endurance could have represented a serious obstacle to advancement, particularly in an operation of marginal profitability. Since the mill did not run year round, or even for long days in winter, the equipment would last still longer.

Watkins did not take advantage of improvements available, however. Not only did he not buy or convert to self-acting mules, he also did not acquire the inexpensive intermediate card feeds, such as the Apperly, which were becoming available and which improved quality while eliminating all labor associated with moving the wool from the first to second breakers and then to the finisher. Nor did he acquire the more expensive Bramwell feed which provided the important even feed to the first breaker with only slight (and unskilled) attention. Even in areas where machinery in place could easily have been improved, as in replacing sheet card clothing on the cards' main cylinders with more efficient filet clothing (which covers the entire cylinder, unlike sheet clothing), the Watkins did not act. In each of these and other areas changes could have been made in one area of machinery which would have increased production and improved quality, often with a savings in labor costs, without requiring wholesale replacements.

The failure of the Watkins to take steps widely seen as desirable by other manufacturers leads to interesting speculation as to their reasons. It has long been seen as axiomatic in textile production that labor costs represent one of the few cost factors over which the manufacturer has control; reducing labor costs increases profit. Reducing these costs can be done by running machines faster (the speed-up) or assigning more machines to an operator (the stretch-out), and/or by reducing the skill required for operation of a process. This latter was seen to have the added advantage of reducing the workers' control of the speed or manner of production.

Highly skilled mulespinners were a source of difficulty in the eyes of many owners. Independent, organized, well-paid, and indispensable, they met none of management's criteria for labor. Skilled workers elsewhere in the process presented similar problems. Since Watkins did not adopt available technology to eliminate such skill where possible, he seems to have enjoyed a more acceptable relationship with these employees than did other owners. Since his work was part-time, he may have employed them in other capacities at times. Why his relationship was unusual, whether it related to combinations of industrial and agricultural labor, to the rural environment (and how), or to other factors, cannot be determined at this time.

Watkins difficulties, his distance from the industry's centers, his at times outmoded equipment, were compounded by the wool process' requirements for skilled labor. While the mill's worn floorboards attest to the monotony of many jobs, the skill and training of the operatives cannot be determined. The manufacture of woolens retained much of the reliance on individual skill associated with craft processes. The workers' eye, feel, and experience could produce good material on less than ideal machinery, but lacking skills in sorting, dyeing, carding, spinning, weaving, or finishing, no amount of machinery could make good cloth.

Even power looms, which more than most of the equipment replaced skill with technology, required the services of a skilled mechanic and able and attentive weavers. A loom's picking motion, for example, was responsible for 7/10 of its required power; improperly adjusted, it required an extra 1/4 horsepower.[57] The overall difficulties confronting a loom-fixer at Watkins Mill have already been described; this fact simply emphasizes the remaining significance of worker skill even in one of the most completely mechanized areas of production. By availing himself of little of the labor-saving technology available, Watkins increased his dependence of the skills of his employees.

However, since operating for the 60-66 hours a week considered standard at the time required artificial light from October 1st to April 1st, and since there is no evidence of artificial lighting, Watkins would have been hard pressed to offer sufficient work at the adequate wages to attract the most skilled workers. In fact, a dyer wrote to him stating that no competent help would be available at the salaries offered.[58]

Operating at great distance from the centers of the machinery manufacture and labor he required, producing a wide range of goods on a wide variety of machines, the Watkins Mill experience appears more remarkable for the degree of success achieved rather than for its ultimate failure.

Coming into existence at a time of rapidly increasing sophistication in production machinery, the mill operated according to the standards of a frontier mill of an earlier, suddenly foreshortened, era where comparatively simple machinery could produce goods sufficient to the requirement of an isolated market. The rapid increase in woolen production in the East, where larger establishments, permitting bigger investments in modern machinery, possessing the finest talent available, combined with steadily improving transportation facilities to make the Watkins' position untenable. In an era when the Midwest became part of the Eastern market in an industry with booming production, the time required for an approach based on learning by doing (the alternative to skilled labor) was not available.

The Watkins never seemed to aim at extracting the "last dollar" from their operation, either while operating, when they did not invest heavily in upgrading production or even run their machinery year round, or in halting operations, when they did not look to scrap or salvage to provide a final bit of income. The results were a business failure and the creation of the finest collection of historic textile machinery in situ in North America.

NOTES

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ADDENDUM TO
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