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CHANGES IN PRINT PAPER DURING THE 19TH CENTURY

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When the first paper mill in America, the Rittenhouse Mill, was built, Western European nations and city-states had been making paper from linen rags for nearly five hundred years. In a poem written about the Rittenhouse Mill in 1696 by John Holme it is said, “Kind friend, when they old shift is rent, Let it to the paper mill be sent.”

Today we look back and can’t remember a time when paper wasn’t made from wood-pulp. Seems that somewhere along the way everything changed, and in that respect the 19th Century holds a unique place in history. The basic kinds of paper made during the 1800s were rag, straw, manila, and wood pulp. With regard to preservation, we need to know exactly when changes in print paper occurred, and how to identify the various types. Of course, many of these problems must be solved in the lab, but understanding their history puts us on track to making the right choices.

At the start of the 19th century there was just one kind of paper, rag paper. Industrialization, it seems, had already begun in the 18th century, so while all paper mills made paper by hand using a mould and vat, they may otherwise be classified in terms of industrial or pre-industrial. Beginning with the invention of paper-making in 1st century China, rags were beaten to pulp using mortar and pestle. This tradition continued up through the 18th century, for example the lease on the Willcox Ivy mill near Philadelphia in 1730 carries an inventory of tools and implements, and included among these were “mortise and hammers.” This confirms the pre-industrial state of the mill, which by the way, was typical of most mills at the dawn of the 19th century.

To expedite the pulping process the rag engine was invented in Holland in the late 17th century. This device emerged as an alternative to mechanical stampers or hammers that had been previously developed in the German States. The beater, also known as a "hollander," consisted of a tub filled with rags and water, which were beaten to pulp by a set of rotating blades powered by a windmill, or later a waterwheel. It is difficult to determine in many cases when a paper mill turned industrial, generally one must look for references to waterwheels as there was no need for a water power in pre-industrial mills. The first reference to the hollander in America was at the Rittenhouse mill in 1755.

By the start of the 19th century most mills in the U.S. had a single vat, and made about two reams a day. A few mills, such as the Burbank Mill outside Boston, installed a hollender, which allowed them to start-up a second vat. Two-vat mills now became the primary source of book and printing paper, and one has only to look to the major sites of the early publishing industry to find two-vat mills, namely, Boston, Philadelphia, Hartford, and New York.

The wove mould was an important 18th century advancement, emanating from England around 1755. This new mould was designed specifically for the manufacture of book paper. Laid paper, the staple of the times, had been used in books, but when folded twice to make quarto folio the laid lines cut across the grain making it difficult to reliably print upon using letter-press. Wove paper, on the other hand, had no such distinction as the wires ran equally in both directions. Benjamin Franklin greatly admired his 1757 copy of John Baskerville’s Virgle, the first book printed on wove paper. Years later when he went to Paris as the U.S. Plenipotentiary he introduced the wove mould to Louis XVIII, gaining immediate recognition for the papier velin brand, and cementing his reputation as a friend of the court. The first reference in America to the wove mould was at the Gilpin Mill near Wilmington, DE in 1789, although it is said this was not the first time it had been used in this country.

So, the wove mould and the two-vat mill were staples of the book printing industry at the start of the 19th century. It was also about this time that things began to change, and change rapidly. Since time and memorial fine clothing was made of linen cloth, but now a new fabric was to emerge, this made of cotton. In those days the common folk owned two suits of clothes, one for everyday use, and one for social events. Following the Revolutionary War the British came back to trade, bringing with them the new cotton clothing. Cotton's lower cost meant the average person could afford more than two outfits, and so began the trend that took hold in polite society in major towns along coast.

Within a decade or so paper-makers were lumping rags into two piles, linen and cotton. The market price for linen began to advance due to demand and scarcity, while cotton rags were mostly forlorn and sold at a discount. The short and skinny cotton fibers made a rather flimsy article of paper, and were difficult to manage using the laid mould. Paper-makers soon found that a composite linen-cotton pulp worked very well, and so for the first time in living memory the price of paper actually fell. With the wove mould, paper-makers could use an entirely cotton-based pulp since the mould captured cotton fibers much more readily, thus the cost of book paper also fell significantly. Still, the production of book and writing paper remained limited by the number of working vats in the country, and in 1800 that number was around one hundred.

The paper machine was invented in France at the end of the 18th century, and made its way to England shortly thereafter where it was re-invented with the aid of advanced British engineering. This was dubbed the moving-wire machine, so called as the primary wire traveled along in a continuous circuit while the frame was shaken to imitate the movement of the vatman. Also at this time a second type of paper machine emerged, this called the cylinder-wire. The cylinder-wire worked on the principal of vacuum, the primary wire sucking up pulp from a vat, and turning in a rotary motion allowing a web of wet paper to exit through a special set of press rollers.

The British Parliament recognized the importance of the paper machine(s), and so forbid it's export to its colonies, and former colonies as it were. Only nations with most favored trading status such as France, Germany, and Russia, were permitted to acquire the device, while America was forced to sit on the sidelines and watch.

American paper-maker Joshua Gilpin of Wilmington, DE was the first to successfully start-up a paper machine in this country. Using a certain amount of guile and deceit, he was able to obtain the plans of the cylinder-machine from the London patent office. He then hired a master papermaker who had supervised the building of one of the first machine mills in Great Britain. When the new mill on the Brandywine River in Delaware was completed in 1817, Gilpin presented a thousand foot long roll of paper at a meeting of the American Philosophical Society in Philadelphia.

Unfortunately, it would still be another five years before the second paper machine was built in America, though there were nearly sixty in operation around the country by 1830. The cylinder-machine made excellent print paper, and marked a rare time when such articles became more widely available and at a lower price. The benefits to the book trade were immediate. Where previously a publisher had to place an order a month in advance with a two-vat mill, which made only enough for 500 books, the same could now have enough paper for 5,000 books in a weeks' time.

With the paper machine it seems anything was possible. In 1827 a farmer in Meadville, PA was making potash and taken to lining the hopper with long straw that became crushed in the process.

He noticed the macerated pulp may have applications in paper-making, and so carted a small load over to the nearby paper mill owned by John Shyrock where it showed great promise. Straw has only 35 percent cellulose content, but when mixed with rags the paper gained a durability enough for use as wrapping or sack paper. It could easily be processed by the cylinder-wire machine using a fine mesh screen of 30-34 wires per inch. The straw process now made the rounds in the industry and began to pay big dividends in the form of royalties to the Shyrock family. Shyrock experimented with other field crops such as wheat, rye, barley, oats, buckwheat, and corn, but in the final analysis rye, wheat, and straw made the best paper, while oats were the least desirable. Straw paper possessed a hardness and rattle equal to fine rag paper, and so Shyrock set his sights on the manufacture of newsprint. Imperial stock was then selling for $2 a ream, and Shyrock's mill was capable of 300 reams a day. The tipping point seems to have been forty percent rag content, and in 1829, both the *Niles Weekly Register* and the *Philadelphia Bulletin* were successfully printed on straw newsprint. Unfortunately, with the rising cost of rags the papermaker faced diminishing returns, so the experimental straw newsprint was abandoned for the time being.

During the 1830s the paper industry worked in perfect harmony as hand mills turned out superior articles of laid writing papers, while the new machine mills made all the inexpensive stock as book, news, wrapping, and wall paper. But, there was trouble brewing on the horizon as the number of paper machines fairly doubled while the quantity of rags diminished ever faster than the population could replenish it. Things finally came to a head during the Panic of 1837 when over 600 banks failed overnight. Many paper mills who had loans for building or expanding found they could not make their margin calls due to the ensuing slump in the paper market, and so went into receivership.

The Panic of 1837 did have one unintended consequence, the invention of manila paper. Lyman Hollingsworth and James Whitney of South Braintree had established a machine mill in West Groton Conn. in 1835. In the aftermath of the Panic the firm found itself short of cash and unable to buy rags, so they sought raw material in the refuse of the New England fishing fleet. They gathered up old manila rope, rag-bale ropes, hemp sails, canvas sheets, and the like, then Lyman Hollingsworth cut up some rope bolts and tossed them into the rag engine. Things such as rope, yarn, and burlap made of bast fibers of jute, flax, and hemp had higher tensile strength, so beating time must have been considerable. But, in the end the cylinder-wire machine lapped up the pulp and made a smooth manila-colored paper. The fiber content of hemp and jute is similar to flax, about 80 percent cellulose, the only problem being it could not be bleached white. Even so, the manila-colored paper had immediate applications as sack or wrapping paper, and from this point forward the West Groton Mill made manila paper. Other mills soon took up the trend, and the number of such mills in the country grew to thirty by mid-century thus helping relieve the strain on the rag market.

The demise of handmade paper finally came in the late 1830s with the invention of the tandem dryer. The tandem dryer combined drying and pressing of the paper emanating from the paper machine, and it produced a sheet of great smoothness that was superior to that made by hand. The market soon became flooded with machine-made writing paper, and all the remaining hand mills were now forced to switch to the machine or go out of business.

During the 1840s the Hollingsworth brothers patented a process for whitening manila stock using a rag boiler. The rag boiler was a spherical container filled with rags and water to which was admitted steam. After rotating for about four hours the rags came out free of impurities and fairly tenderized. What the brothers found was the addition of caustic soda or soda ash significantly whitened the fibers. During the 1850s a mill in Chatham Four Corners, NY diverged from the

conventional straw-rag mix, and using the Hollingsworth whitening process, they began making a new variety of straw-manila papers called “bogus manila.” Bogus manila was made of 20% straw and 80% hemp or burlap, with a bit of cotton thrown in for texture. The popularity of bogus manila rapidly caught on, and the bleach boiler, as it was now called, soon became a standard in the industry. Bogus manila now became a favored form of print paper. At a nearby mill in Rock City Falls the manufacturer began using an improved bleaching liquor from France that proved even more effective. The mill began making newsprint from three-quarters straw and one-quarter manila, the first use of which was for the Saratoga Flag.

The most ignoble quality of straw papers are the impurities found within. Straw, being a field crop, invariably contained a mixture of dirt and weeds that could not be economically filtered out. Finally, in 1860 a firm at Fort Edwards, NY patented the “stable fiber” method that employed a line of machinery to first winnow out any impurities, then crush the fibers between heavy metal rollers. The combination of winnowing and bleach boiling eventually produced a line of paper called “whisky rye” that became a popular low-cost alternative used by the New York dailies during the Civil War, a time when paper prices reached record highs.

About this time came certain improvements to print paper in the form of sizing. External sizing had long been used on writing paper, and now a new form of internal sizing was developed for print paper. The goal of internal sizing was to produce a smoother sheet. In 1806 a German papermaker found that rosin soap added to the hollander coated the fibers and allowed them to slide more freely against one another, enabling them to form a more stable structure. Another material considered at the time as a sizing agent was alum, a colorless and non-magnetic metal powder that added volume but very little weight. Modern chemistry, however, has proven that rosin was the only true sizing agent.

The other paper machine referred to as the moving-wire, more popularly known as the Fourdriner after the original patent-holders, was slow to develop. But, during the 1830s, much to the delight of newspaper printers, the firm of Phelps & Spafford of East Hartford, CT began manufacturing the moving-wire machine in this country. This high-speed machine was capable of ten times the volume of the cylinder-wire, the only drawback being it could only process cotton rags. Still, it soon became the mainstay of the industry as during the 1840s, nearly every advance made previously to the cylinder-wire was adapted to the moving-wire.

The machine-makers, Phelps & Spafford, went bust following the Panic of 1837, but Mr. Phelps went on to bring another significant innovation to the industry, this called the rag washer. The rag washer was an attachment to the hollander which strained the fibers using fresh water. This device enabled the removal of excess bleach that was e added to the hollander to whiten the fibers. White paper, as we know it today, was largely unknown to this point in history. Papers of the early 19th century were generally tan, or smoke colored, due to processing the rags using water with high iron content, what we call “hard water.” During the late 1820s paper manufacturers in the U.S. began using ground lime, the active ingredient being calcium carbonate, to cleanse the fibers during the beating process. As the use of lime had no effect on the vatman, hand mills were finally able to regularly produce a grade of off-white papers. In the machine age, lime went in the bleach boiler where it was even more effective, but still the papers came out less than pure white. So, here is where the chlorine bleaching process enabled by the rag washer attachment came to the fore. As an aside, it is something of a misnomer that the bleach boiler was used for washing rags, while the rag washer was used in bleaching them.

During the 1830s publishers were faced with unlikely scenario of the availability of cheap paper while the majority of the population was still largely illiterate! So began a proliferation of spelling

books, the first inexpensive version on machine-made paper being the ever popular United States Spelling-Book. By the 1840s spellers become so common that not only was there one in every schoolhouse, but virtually every student had their own copy. The result became an explosion of demand during the 1850s for books and newspapers. Books had long been a scarce resource, being largely the property of the privileged class for centuries on end. The 1860s saw the emergence of the first dime novels, and soon small town libraries began to appear all across the country. As the renowned paper historian Dard Hunter once wrote, “Paper precedes printing.” Indeed, during the Civil War, when the price of paper skyrocketed, the invention of the cylinder press finally allowed newsprint to be fed and printed in one continuous operation. In 1862 the Niagara Falls Paper Company was the first to contract with a New York daily to deliver paper in reels equaling 2000 sheets.

Rag paper had emerged fairly unchanged through most of the century, however, the proliferation of the high-speed machine created a tightening of the rag market that caused paper prices to rise nearly fifty percent by 1850. The penny daily soon became two cents, and later a nickel. The public reaction was fairly negative, and instead of absorbing the higher costs, they cut back on consumption. Efficiency became the watchword of the industry, and mills that previously had been operating without a clue as to cost of goods sold, soon went bankrupt. Banks and lenders simply turned to a new set of investors to buy the mill, thus creating a revolving-door of owners that failed in succession, that is, until the mill came into the capable hands of a master papermaker. The situation became even more exasperated during the Civil War, which is when the Smith Paper Co. first invented engineering accounting. The new accounting process allowed them to implement cost controls at every stage of manufacturing. Soon thereafter, no mill could do without it as competition was a cruel taskmaster.

Necessity being the mother of invention, it wasn’t until the late 1850s that a device came along to relieve the rag market. This new invention was called the rag refiner, also known as the Jordan. The refiner worked like a meat grinder, where pulp from the rag engine was piped through it. A funnel holding filler materials such as white starch or china clay was attached to the top of the refiner allowing the materials to gradually enter the stream before being piped back to the hollander. The result was a paper made with fifty percent less rag, thus relieving the rag market and sending the price of paper back down for the first time in nearly ten years. The drop-off in price sent shock-waves through the industry, and so for the first time about a dozen mills formed the Writing Paper Manufacturers of America with the intent of holding the line on price. Newspaper manufacturers soon followed suit, starting up their own trade association in New York.

The search for alternate fibers was renewed during the Civil War when demand sent paper prices skyrocketing. Theodore Steinway, of piano manufacturing fame, noticed sheet music imported from Germany was printed on paper made from wood-pulp. He then helped form a company to import the wood grinder from Germany, and set-up the first wood pulp mill in 1867 at Curtisville, MA. The first load of wood-pulp was delivered to none other than the Smith Paper Co., who were in a position to pass judgment having themselves invented the industry’s accounting practices. When it subsequently became learned that wood-pulp drained rapidly on the high-speed moving-wire machine, Smith immediately contracted the Curtisville Mill for all their output for the next year. Still, despite all its promise, Smith Paper was not wedded to the process, and instead began experimenting with the use of esparto grass, which had come into popularity among British papermakers as an alternative to rag stock. Once the year was up Smith Paper did not renew, and the Curtisville Mill began working with other clients. The first New York daily to carry an edition on wood-pulp paper was the January 1868 edition of the *New Yorker Staats-Zeitung*, a German language newspaper.

American publishers largely dismissed wood-pulp paper as inferior stock because it contained lignin, which acted as an epoxy covering the wood fibers. The paper came out stiff and brittle, not only that but within a day it yellowed and faded, and easily broke apart after just a few foldings and unfoldings. The fate of wood-pulp hung in the balance, and only by a matter of chance did it ultimately succeed.

During the late 1850s, Henry Lowe of Baltimore imported a process of boiling fibers in highly caustic soda inside an iron digester which was essentially a double boiler; the outer boiler holding water and steam, while pulpwood chips cooked in an alkali solution within the inner boiler. Lowe made tests with the bark of spruce, fir, and hemlock at a mill in Maylandville, PA, with much success. Still, insufficient quantities of bark were available to make it a commercial success, so Lowe continued experimenting using flax, straw, hemp, corn, bamboo, pineapple leaf, and even coconuts. In 1861 Lowe traveled to North Carolina and began experimenting with southern cain in the swamps around Wilmington, whether he remained after the war broke. Then, in 1868 a papermaker at Herkimer NY finally put it all together, ordering a wood grinder from Steinway & Co., and a digester from Lowe. Fibers came out softer and easier to process, and so the Herkimer Mill became the first to make book paper from wood-pulp.

Howe's soda process soon took the wood-pulp industry by storm. In 1870 the *N.Y. World* became the first English-language publication printed on wood-pulp paper. The *Providence Journal* and *Brooklyn Eagle* began using wood-pulp newsprint in 1871, the *N.Y. Evening Express* in 1872, and the *N.Y. Times* and *Albany Argus* followed the next year. A host of publications made the switch over 1874-1875 including the: *N.Y. Weekly Times*, *Vebote* [Chicago], *N.Y. Sun, N.Y. Tribune, N.Y. Herald, N.Y. Journal of Commerce, N.Y. Evening Post,* and *Cincinnati Daily Gazette.* In fact the rush to wood-pulp rapidly depleted all available stocks, so the above could not entirely avoid the use of rag paper until around 1881.

The soda process became just the first of several chemical cocktails developed during the 19th century. Each of these were similar in that pulp had to be boiled in a digester. The sulphite-pulp process was an outgrowth of straw processing, and Benjamin Tilghman of Philadelphia was the first to try it with wood fibers in 1866. Tilghman cooked wood bark in a solution of sulfuric acid, but dealing with strong acids was no minor undertaking. He lined the interior of the digester with lead to withstand the attack, but then found the acid so strong it damaged the wood fibers. Tilghman then traveled to Germany to obtain help from the burgeoning chemical industry there, finally returning in 1882 to set-up a sulphite-pulp plant at a struggling paper mill in Maine. The advantage of sulphite was it could strip the lignin from any wood source, unlike soda-pulp that was limited to soft woods. In 1889 President Grover Cleveland led a team of investors to build a new sulphite-pulp mill in central Maine called the Madison Mill. The state was already host to thirteen ground wood mills rated at 157 tons per day, and twelve chemical-pulp mills producing 182 tons of pulp per day. Sulphite-pulp was highly competitive with soda-pulp, and between the two the price of wood-pulp dropped down to less than four cents a pound. As the price of wood-pulp hit an all time low in 1890 the remaining rag mills were no longer competitive, and either converted to wood-pulp or went out of business.

Remarkably, manila and straw paper continued for the time being. Many paper mills had both moving-wire and cylinder-wire machines, making newsprint on the high-speed equipment, and wrapping paper on the other. Straw was used in season, switching to manila when stocks became scarce. Manila paper was highly valued for its high strength and durability, and became used in innovative new ways for such products as tissue paper, collars, paper plates, and boxes. Manila was also highly adaptable for use with aniline inks, used to make colored and glazed papers for writing, lithograph, and wrapping paper.