Thomas Livezey Pennsylvania Merchant Miller Part 4

By Herb Lapp

Introduction

This series on Philadelphia merchant flour miller, Thomas Livezey (1723-1790), so far has comprehensively detailed his life covering such topics as his early education, Quaker faith, the site for his mill, seminal development of central-eastern Pennsylvania's transportation infrastructure for raw materials and goods that influenced his civic and political activities. His relationship with Benjamin Franklin and many other influential Pennsylvania political, religious and business leaders joined him among the ranks of those notables. His Quaker beliefs and personal philosophy dominated his personal vision that he was a North American British citizen that restrained him from taking a supportive role in the American Revolution. Even though this prevented him membership among the nation's founding fathers, his accomplishments in these critical arenas profoundly contributed to building the foundation for our nation lead me to see Livezey as a second tier founder.

Several influences contributed significantly to Livezey's success among which included increases in the Western world's population. The growing population struggled to feed itself compounded by several global wars and frequent catastrophic weather events experienced on both sides of the Atlantic making flour the eighteenth century's "oil." We saw William Penn's influential role at the turn of the eighteenth century creating the political province of Pennsylvania blessed by a temperate climate, abundant rainfall and excellent soil for growing wheat. This established Pennsylvania as a haven for immigrants with the promise they would enjoy religious freedom while being encouraged to economically prosper. Highly skilled farmers came in great numbers, representing Quaker and German Mennonite sectarian religious sects, added the final ingredient to this potent recipe.[1] In affect Livezey was a man at the right place at the right time. However his intense personality and milling skills differentiated him from his peers were the final attributes he needed to succeed.

The focus of the first three articles in this series was on Livezey 'the man.' In the next three articles I will explore early eighteenth-century flour milling technology, detailed specifics of the

[1] Candace L. Withers, the Evolution of a Regional Flour Milling Tradition: A Material Culture Study of Three Lancaster County, PA Flour Mills. (Harrisburg, PA: Master's Dissertation, Penn State University, 1982), 28. Withers mentioned Scotch-Irish immigrants were also part of this mix but were not known for possessing skills as highly developed those from other two sects.

internals of his mill at a level of detail beyond anything ever before seen, the tradesmen who designed and built it though the notes Livezey left to us, and his cooper shop through a set of its original tools and documents. This research found that very little is documented about these topics eventually turned up three sources worthy of note. The first finding was the discovery of the Livezey family papers with many mill account (or day) and receipt books covering the first 50 years of his mill's existence.[2] Second in 2010 the International Molinological Society published a translation of this important old report providing important information to my research.[3] In 1830 two young, recently schooled Prussian millwrights, Carl Friedrich Ganzel and Friedrich Wulff documented their findings from a two-year visit begun in 1827 of merchant mills in America. The purpose of the trip was to uncover milling information to infuse American flour milling know how so the Prussian milling industry could compete with American flour. Their Prussian benefactors sent them to do industrial espionage so they might compete against our milling industry. [4] The original report was named Contribution to the Understanding of American Mills and Flour Production. Translation project team members Derek Ogden and Gerald Bost renamed that report Ganzel & Wulff the Quest for American Milling Secrets to better reflect the actual purpose of the report. The project team lamented, "It is disappointing to find very little or no remains of the mills Ganzel and Wulff visited.but if [they] had not been sent to America it is certain we would not know as much about the large merchant mills in the United States and the precise details of how they were constructed or operated."[5] Nearly 200 years later the situation on surviving mills has gotten even worse.

By 1830 merchant mills had changed considerably in size and used much "modern" internal machinery compared to that found in Livezey's original mill. However, the core grinding processes with primary milling machinery and techniques described in the report were still applicable to those done in the early Livezey's Mill. With this report the original Livezey data made much more sense to me explaining and amplifying what Livezey cryptically noted. What is interesting and relevant here is the fact the Prussian report was written more than fifty years

[2] These materials extended beyond Livezey's lifetime with many written by his partners who were two of his four surviving sons, John [5-44] and his youngest brother Joseph [5-50]. His oldest son, Thomas [5-42] (1750-1830) worked with him (about 25 years old) before his father set him up as majority partner at the Spring Mill which the elder Livezey purchased in the 1770s near modern day Plymouth-Whitemarsh Townships. John and Joseph continued following the book keeping system their father after his death in 1790 that he had created. These materials will become the subject of future research examining the mill's operation during the very successful flour market between 1790 and John's death in 1826.

[3] David Metz, retired engineer who has been working on the restoration of the Pine Mill nineteenth century mill in Muscatine, Iowa, near the Mississippi River made the author aware of the existence of this new publication. I am grateful to him for his interest in my research as well as his frequent sharing of his rich technical knowledge and experience.

[4] Derek Ogden and Gerald Bost, Ganzel & Wulff the Quest for American Milling Secrets. (14 Falmouth Road, Congleton, Cheshire, CW12 3BH, England: The International Molinological Society, 2010), ii.

[5] Ibid. i.

after Livezey last entry in his Buildings book (1776).[6] This work affirmed - amplifying what Oliver Evans wrote in his 1795 publication of The Young Mill-Wright & Miller's Guide that will be referred to shortly. Readers will recognize this important notebook after being introduced in the first article of the series, provides us with even more important historical information.[7] That value cannot be overstated since it comes to us directly from Livezey himself. Chronicled over this twenty-five year period he detailed each of the mill's routine and emergency repairs that required stopping the mill, hence taking it out of service as we say today managing modern process facilities. Along with this information he named the millwrights, along with noting the major tasks they completed during their visits, the time needed to complete them; and the fees Livezey paid to have that work done. [8]

The importance of Livezey's unique notebook can be more clearly seen when we look at what was known about flour milling before the industrial revolution experienced in America.[9] This information became more clear upon discovering the third old source of information about eighteenth century milling surprisingly found in Thomas Ellicott's introduction to his section of Evans treatise just mentioned, published in 1795. For several years I worked studying the

[6] Later I will draw on millwright material published in Oliver Evans' The Young Mill-Wright & Miller's Guide published in 1795 and frequently republished up until the Civil War. Not being a milling expert had one advantage as reading Evans' work I was not always able to exactly differentiate between what he wrote describing existing, older mill processes and those offered as his brilliant innovations providing new labor-saving devices to the milling community. I saw Evans' material handling improvements as different but was uncertain when he described other milling processes. The addition of the Ganzel and Wulff recent translation significantly aided me not only in understanding Livezey's Building book removing these uncertainties with collaborating documentation but also Evans' book. Reynolds in his Stronger Than A Hundred Men cited in an earlier article in the series inferred some of this interpreting very old diagrams found in rare book libraries produced as early as 1400.

[7] Herb Lapp, "Thomas Livezey: Pennsylvania Merchant Miller, Part 1," *The Chronicles,* (Early American Industries Association, v. 63, no. 1, March 2010, 7.

[8] Before beginning to write this article the author transcribed all the information Livezey documented in the Buildings book into a spreadsheet. Before inputting data time was spent carefully developing the architecture of the categories so data could be sorted using any one of the many categories I created. I ultimately decided on using a spreadsheet over a database program since the data cells are more readily available to see and use than typical database programs allow. The hours spent inputting all this data which was a significant number, was an investment that has paid for itself many times and promises to continue yielding more information in the future.

[9] This period in American industrial history accelerated metal-working technology during our Civil War was shortly enhanced by two other innovations: the first in machinery and the second a revolution in manufacturing processes. First was the European invention of the metal roller milling machine in the 1870s that dramatically replaced the old stone grinding process making it obsolete in less than twenty years. This invention precipitated a seismic-paradigm shift that almost overnight moved the most complex technical tasks in flour milling, millstone-related work, from the local milling site to a factory where machinery could be mass produced built by a smaller number of highly trained mechanics (where the best became the precursors to modern professional engineers), the remaining millwrights then evolved into our modern day machinists. What this produced was a radical reduction in costs, improved quality and an ability allowing rapid observations leading to continuous improvements not easily done when the major activity is field installation work. All this was slow by comparison to modern experience but I believe we are seeing here the seminal beginnings to what is normal manufacturing today in the post Dr. Deming world. This is a very interesting story in itself but must be left to others to explore. For more information on this process see Alan I. Marcus and Howard P. Segal, Technology in America: a Brief History (Boston: Harcourt Brace College Publishers, 1999).

Evans text attempting to reconcile the older physical theories with what I knew studying physics as an undergraduate. To that point I had ignored the last section, the most practical one entitled *The Practical Millwright: containing instructions for building mills, with all their proportions, suitable to all falls from 3 to 36 feet.* He documented millwright techniques, independent done from Evan's new material handling equipment, such as building water wheels, water wheel shafts, gudgeons and cogging gears. Ellicott, a highly respected-experienced millwright lived in Bucks County, Pennsylvania. This introduction provided important and a fascinating brief first-hand historical summary of his observations about the state of mid-18th century milling practice. His introduction described how he came to write this small section, essentially a chapter in an ordinary technical book. Even though he had a long career he wrote that he decided to write it and began systematic research10 years earlier that included frequent visits to other mills, often distant. That decade was one fourth of his millwright career that I believe narrated what millwrights had been doing for more than two centuries. While visiting other mills he searched Philadelphia book stores (the best in the Colonies) for published mill-related materials. There he was deeply disappointed finding numerous technical inaccuracies while being devoid of practical content. Two of his observations critically impact my study:

- Few mills employed buhr-stones, rolling screens and only the best merchant mills used fans.
- Almost all work was completed using backbreaking manual labor including having bolting done at other locations and [most] "bolted by hand."[10]

The findings drawn beyond his own experience incorporated the experience and observations from "several millwright brothers" for material on rolling screens, fans, and their power sources in both merchant and grist mills. He added that his personal experience included developing fan machinery for farmers to improve their ability to clean grain before shipping it to the mill. On these he boasted: "I believe being the first, that made these things in America."[11] This insight allows us to differentiate his historical knowledge from what he had contributed to the millwright trade. Ellicott's career began about 1752 coincided with the building of Livezey's original mill making this valid what was done when Livezey's Mill was built making Livezey's Building Book entries more meaningful. I will use this and other of his historical observations as objective criteria to evaluate Livezey's operations and flour compared with his milling peers, especially merchant mills.

Some readers may think too much emphasis is being made of all this, perhaps even appearing superfluous. From my studying I found these sources seminal in understanding eighteenth century milling better than any other references I accessed. Why is there so little documentation about these mills beyond what I found? For one Livezey's Mill no longer stands

[10] Ibid., v.
[11] Evans, Ellicott's Chapter 5, v.

but some built during this era in the mid-Atlantic region still stand providing study opportunities. Unfortunately most are privately owned and not open to the public. Researching and writing my earlier Livezey articles aided the author obtaining access to several in the region. Soon I learned several around Philadelphia-Southeastern Pennsylvania continued operating well into the twentieth century supported in large part by the region's well known conservative culture. Even though these early mills appeared original viewed from their external eighteenth century architecture; their interiors were technologically based in the late nineteenth century. Living in this region I have the opportunity to interact with some "old order" people. On several occasions they demonstrated that being conservative does not mean them were not practical men, to include nineteenth century millers. The older millers likely made the decision to reuse their old mill buildings. But the competitive marketplace drove them to internally upgrade flour making equipment while upgrading milling process to enable their flour to complete in their regional marketplace. This is consistent with the conclusions reached by mill expert and consultant, Ted Hazen, "…as the old mill machinery wore out or competitive economic pressures grew to some breaking point, millers were forced to make new capital investments, to remove and discard the old machinery and install the new requiring them to adopt newer milling processes.[12] Millers being practical saw no need to preserve remnants of their old equipment, as if in a museum. So that equipment was discarded after mill upgrades (see Figures ___, ___ and ___).[13] In cases where the old wooden parts were not burned some were left outside the mill to the ravages of the elements and bacteria as seen in a late nineteenth century hybrid bevel gear made of iron with wooden teeth and the rotting spindle shaft shown in Figures ___-___. Here the wooden teeth held in their iron frames have almost completely decayed after 50 years exposure. Mill interiors often reveal little about the original equipment. Internal space was often radically modified to best suit the new machinery and the newer milling processes often left little or any signs (footprints) of the older technology. Once and a while a piece of equipment was moved to some out of way place in the mill, abandoned far from where it originally provided its service that only confused us more.[14] Even when retired in place vandals frequently ruined what remained making it difficult to visually reconstruct as seen in Figure ___.[15] All this makes it very

[12] Email and telephone conversations with the author over the course of this research.

[13] Almost all of the eighteenth century mill equipment was made using wood. The removed parts could either be easily burned for heat or being wood allowed to sit outside unprotected from the elements. After 150 years this old wood would have decayed returning to mulch.

[14] In person and telephone discussions with Bill Foshag, owner of the Dillar-Heishman Mill and David Metz, member of the Friends of the Pine Creek Mill who has been working for nearly a decade restoring that old mill, shared their experiences dealing with "orphaned" relocated mill equipment found in out of the way places within their mills and the difficulty doing industrial archeology within their mills to uncover what was originally done.

[15] Withers, 33-39 and 187-193. From 2009 I have attempted to study one local mill the Geiger's Mill in Geigertown, Berks County, PA built in 1783. This mill, privately owned by the elderly spouse of the late Frank A. Stephens allowed me a brief look inside the mill explaining that I was the only person permitted to see inside since her husband's death in December 1990. After Mrs. Betty Stephens' death in September 2010 it took nearly another year to make contact with her daughter who inherited the mill to access it again this time so I could photographically document the mill which was now in serious decay. Hardly any mill-related equipment existed.

difficult to use traditional industrial archeology principles and techniques to infer anything about their earliest years of operation. The modern industrial revolution caused radical changes in how mills were designed and built; no longer being built as unique, one of a kind facility as had been the case for centuries.[16]

Figure __. Discarded pair of hybrid nineteenth century bevel gears from the Dillar-Heishman Mill near Carlisle, Cumberland County, PA owned by Bill Foshag. This mill was originally built about 1800 but likely had an earlier 18th century structure on the site. These bevel gears were part of the mill's turbine water drive which had replaced an earlier conventional wooden water wheel. (Photographed by the author and used with permission from the owner).

What was found was a single French buhr millstone (not the set) retrieved by Mr. Stevens many years ago from the turbine pit where it likely feel into (perhaps as the result of the electric generation project mentioned below), the millstone crane, a single section of elevator shut as if it were built right out of Evans' book and rusted parts of the nineteenth century turbine. At this point it looks like all other evidence of flour milling had been removed. Recently I was completely surprised when Ted Hazen, mill expert living near Atlanta, GA informed me that he learned Geiger's Mill had been used to make electricity before it ceased animal feed milling in the early 1930s. This new revelation makes it impossible to know if the very rusted turbine was used exclusively to produce electricity or had been used earlier to grind grain, see http://books.google.com/books?id=d6gvAAAAYAAJ&dq=geiger+mill&source=gbs_navlinks_s. This experience was similar to ones I observed visiting the few other mid-eighteenth century mills I gained access to. Mills were factories not mill museums we find today whose purpose is to function as romantic educational demonstrations for school children.

[16] By 1900 the millwright's role in millwork was limited to being a factory representative installing and maintaining mill equipment usually built by his firm. What he did that was a carryover from the earlier traditional millwright work was mainly limited to building and installing elevators and conveyors that interconnected the factory built equipment. See L. L. Houseknect, A Millwright's Journal, transcribed & complied by William L. Denton (Westminster, MD: SPOOM Bookstore C/O Union Mills Homestead, 3311 Littlestown Pike, Westminster, MD 21158, 2006).

Figure __. A mill spindle shaft seen decaying out in the elements near the mill where it once proudly turned.

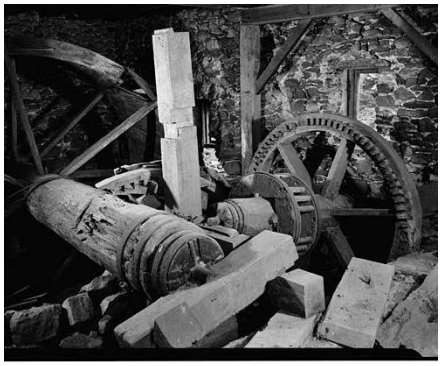


Figure ___ A 1930s photographs from the national Historic American Buildings Survey of an abandoned mill left in disarray only later to be destroyed by vandals according to an internet source, leaving only this image as a record of its existence. (Thomas **Mill**, Crum Creek (Willistown Township), Chester County, PA, HABS PA,15-WHIHO.V,2-).

Mills could now be built more generically assembling the mill using an assortment of commercially milling equipment built in centralized factories. Overnight this radically changed the millwright's role from being the designer - builder to that of installer - mechanic to insure that it operated as advertised. While at the same time nineteenth century milling equipment manufacturers started marketing and advertising functions that created literature helping to sell their products.[17] Soon some written marketing information began looking like primitive technical manuals, something that never have existed in the former era of apprentice-trained

[17] Many examples of this exist but "*The United States Miller*," Volume 7, 1879 is a nineteenth century example of this, see http://digital.library.wisc.edu/1711.dl/WI.USMillv07 will show this change.

millwrights who used oral communication to vigilantly protect their trade secrets.[18] These changes, a true revolution, quickly eradicated the existence of the early milling technology processes and equipment much of which disappeared in as little as a quarter century. Another less obvious reason exists why so little is conclusively known about early eighteenth century mills. Most were frequently sold at the retirement or death of the miller. Previous owners must have kept their own records of the grain purchased, flour ground and shipped with their expenses. New owners likely did not see these records as being important. With so few now existing leads to the assumption that the new owners saw any need to preserve their mill's documents as having any historical significance. Most were likely thrown into the trail race since that was the common method used to discard unwanted milling byproducts.[19] This makes the Livezey's efforts to preserve their ancestors' mill documents found after starting this study when so little exists elsewhere so important.[20]

Before closing this introduction let me review the schedule for these articles. The present article will explain the basics of mid eighteenth century flour milling along with an introduction to mechanical gearing found in early mills allowing me to translate the ancient gear names Livezey used encountered in the next. The next will focus on what Livezey specifically documented about his mill's technology and operations using his ledger entries. A large part of that ledger was Livezey listing by name nearly 18 millwrights who worked for him listing the tasks they performed. The millwrights will be the subject for the next. Genealogical research was made into each finding about half left traces of their lives beyond Livezey's notes will be discussed allowing a trade composite to be made on who and what an eighteenth century millwright was.

[18] Many early tradesmen were quite illiterate with some believing this extended that to include millwrights. This author believes that most, if not all millwrights were literate and received educations not dissimilar to what Livezey received covered in the first article of the series (Volume 63, Number 1, January 2010). The topic of millwright education will be treated later.

[19] My research indicated the Livezey's as being very different from other millers (such as the Gorgas brothers who owned and operated the mill immediately south of the Livezey Mill on the Wissahickon) since so many of Livezey's notebooks were saved. First they were devout Quakers. Quakers had a penchant for detailed record keeping as exhibited by each monthly meeting's copious minutes that still exist at Swarthmore College's Friends Historic Library where the Livezey Family Papers now reside and another similar library at Haverford College. They adopted this trait of saving family documents many for more than two centuries. Second the family owned and operated the mill continuously till it was purchased by Philadelphia in the formation of the city's Fairmount Park in the late 1860s that may have also influenced them to see historical value in their family's business books.

[20] With all the time I spent studying the Livezey family papers I was able to confidently trace the stewardship of these papers. After Livezey's [4-11] grandson, Thomas [6-107]'s death in 1884, his unmarried son John [7-173] became the keeper when he returned to his Germantown home Fairview at 911 Allens Lane, to care for his widowed mother. His youngest sister, Sarah Marshall [7-177] husband died in 1899 at an early age facilitating her move back to Fairview along with her only son Thomas Thompson Firth [8-163]. All three men were life-long, birth- right members of the Society of Friends who continued the tradition of documenting and protecting these legacy documents written by our miller, Thomas Livezey [4-11]. Upon the death of Firth's wife, Caryl Rogers Firth in 1988, the papers became the responsibility of their youngest son, Rogers (Mike) Firth [9-166] till they were donated to Swarthmore's Friends Historic Library.

The final article will examine Livezey's cooper shop and tools since I found many of the actual cooper tools.[21]

The Phases of Livezey's Mill

The history of his mill can be divided into three phases. The first lasts for forty three years beginning with the mill's purchase and ending in 1790 shortly before his death. Livezey family biographer and genealogist, Charles Harper Smith was not entirely correct when he reported that due to Livezey's difficulties with his pre-Revolution political activities and events he experienced around the Battle of Germantown, that he retired to a quiet life involving poetry writing and his grandchildren. The current research supports that he did these activities but was surprised to find that on May 17, 1790, six months before he died he concluded a license agreement with Oliver Evans allowing him and his descendents legal right to use Evans' new milling processing equipment that revolutionized flour milling (Figures 1 & 2). The discovery of that signed contract was important as few exist today. It showed that Livezey was still actively involved in the milling business even though most of the labor-intensive work was being done by his two sons (John [5-44] and Joseph [5-50]).

Figure 1 Oliver Evans (1755-1819) American engineering genius who revolutionized flour milling and later invented the first high pressure boiler or steam engine. His genius reviled that of Thomas A. Edison a later famous American inventor.

(Patty: Note these two images might look good sitting side by side on the same level. I'm leaving them large for resolution so you can manage best. I hope the license

[21] During the study of his papers the author found these cooper tools from the eighteenth century among the many Livezey artifacts that survive.

document will be large enough for readers to be able to read the content as very few of these license agreements exist)

To all to whom these Presents Shall Come, Oliver Evans of New Castle County Delaware State, Sendeth Greeting — Know Ye, That Thomas Livezey of Roxbury Township, Philadelphia County, Pensylvania hath paid unto the Said Oliver Evans, the Sum of Forty Spanish Milled Dollars, in Consideration whereof, the Said Thos Livezey his Heirs, Executors, Administrators, and Asigns, are hereby Permited to Construct, make, use, and enjoy, all the Machines Necessary to produce his the Said Olivers improvement on the art of Manufacturing Wheat into flour, Viz For Elevating of Wheat and Meal from the lower to the upe Stories, and Conveying it from one part of the Mill to another, and for cooling the Meal, and attending the Boulting Hopper, without the aid of Manual labour — for the use of his Double Mill Consisting of two Waterwheels, Situate on Wissahickon, in Said Township — For and During all the Term of Years unexpired for which the exclusive Privilidge of making, Constructing, and using and Vending to others to be used, the Said Machines, was Granted to the Said Oliver Evans his Executors Administrators & Asigns, by an Act of the General Asembly of the Commonwealth of Pensylvania, and for Such Term of Years as the Same Shall or may be Granted to him, by or under the Auphity of the United States, or by or under the Authority of the State of Pensylvania — In Witness whereof the Said Oliver Evans hath hereunto Set his hand and Seal this Seventeenth Day of May in the Year of Our Lord One Thousand Seven Hundred and Ninety —

Sealed and Delivered
in the Presence of us

Alexander M. Donald

William Wain

Oliver Evans

Figure 2. Signed license agreement between Oliver Evans and Thomas Livezey to use Evans flour mill inventions purchased for forty Spanish milled dollars in 1790. (LFP-private collection, photographed by the author).

The mill's second phase was short and I consider it as a transition defined by signing the license agreement to build and install Evans material handling machinery (inventions) and the tragic fire that brought the business to a halt in 1793. Surviving Livezey papers are completely silent about these upgrades or even mention anything about the fire.[22] By 1790 John Livezey, nearly 40, would not have procrastinated installing many of the material handling devices covered by the agreement to reduce his (and his brother Joseph's) backbreaking work manually moving grain and flour up and down the mill's floors as Ellicott told us. Several account and receipt books exist from John's tenure as miller beginning in the later years of his father's life up to the time of his death in 1826. John's image as he saw himself was "Miller from Roxborough" which was supported by the significant volume of flour he produced.[23] So even in the absence of documentation in the Livezey family papers it was inevitable that the upgrades were made.

The two brothers oversaw the mill's reconstruction that included being enlarged by raising its height adding another level for discussion later (see Figures __ - __) .[24] The third and final phase of the mill's 125 year history, all owned by the same family began just after it was rebuilt starting operation in early 1794 till being purchased by the City of Philadelphia for Fairmount Park. It is quite possible some Evans machinery might have been installed during phase 2 while

[22] We know of the fire via two sources. The first mentioned in an eighteenth century journal kept by Elizabeth Drinker, a friend of the family (cited in a previous article in the series) and in an edition of the Philadelphia Gazette, the fore runner of today's Philadelphia Inquirer.

[23] One of John Livezey's [5-44] 14 credit-debit-receipt account books that he used to document debits and credits covered the period September 14, 1792 to December 26, 1794 is interesting. He did not note that there was a fire at the mill dated by a diary entry in Elizabeth Drinker's famous diary as October 23, 1793. This Livezey book is primarily organized around specific accounts listing the transaction events over time. The majority of entries covered the first eight months of 1793 but occasionally did document ones from the date of the fire into the early part of the following year. I did not find any mention of the fire; however, the number of transactions after the fire was noticeably fewer with most being about the sale or purchase of hickory wood. The surviving 14 Credit-Debit-Receipt books cover from 1781 to 1824. Books for the year's 1787-1790 and 1806-1817 do not exist in this collection. Joseph left a few debit-credit books mostly after his brother's (John) death. But none were labeled like John's with the banner "Miller from Roxborough." (FHL private collection).

[24] For more information about field work the author did assessing the differences between the early mill in phase 1 and the rebuilt mill see "Thomas Livezey: Pennsylvania Merchant Miller, Part II, *Chronicles*, V63, no. 2, 47-69. You can see other photographs of the mill taken in the late nineteenth and early twentieth century's in this previous article. The mill was purchased in 1868-9 but was allowed to grind wheat for a short period in the 1870s due to the inability of the Flourtown (near Germantown) mill that had become the areas primary source of flour after the Livezey's ceased to grind it. Harper Smith reports that the mill was leased by the family and used to make oils in its final years after the death of the youngest brother and partner, Joseph about 1840. The notebooks mentioned above in fn 20, show Joseph's nephew, Thomas [6-107] and son of his partner John worked with him to operate the mill and maintain the facility and its properties beginning before John's death when his heath began to seriously decline likely due to mill-related health issues.

working around flour production schedules.[25] With the mill not being able to operate, it had to be simultaneously rebuilt while at the same time adding all of the Evan's material handling improvements that made sense for this mill. I can easily conclude that 1875 was the logical end to phase 3. Readers need to know that Philadelphia's prominence as the leading exporter of flour was replaced by Wilmington and Baltimore after 1830. John Livezey died in 1826 leaving Joseph, now 66. Joseph's nephews, John's sons, John [6-106] and Thomas [6-107], helped him. Joseph died in 1841 but likely like his father and older brother suffered in his later years from pulmonary illnesses making it nearly impossible for him to continue milling. Both nephews were college educated and based on their later life's work showed they had no desire to pursue careers as a miller. So the practical end of phase 3 is actually in the late 1830s. Nephew Thomas leases the mill to others but it works only as a local custom mill.

In previous articles we saw several pre-1900 photographs of the mill's final phase taken before being demolished. Additional early photographs were found shown in figures __ - ___, were taken during demolition show aspects of the mill not clearly seen in the earlier article. These clearly show the later stage of the mill with five levels and an attic under a gable roof. What do we know about the original mill? Unfortunately no illustrations survive of it but Smith described its external structure in some detail.

> Nothing is known of the capacity of the mill in 1747 except that it contained two pairs of stones, but a pen and ink draught of the property made in 1760 [which was not found among the LFP] contains a drawing of the mill building which gives a general idea of its dimensions. It was then a tall narrow building located on the site of the present ruin [Smith wrote this in 1934, almost 50 yrs after the mill was demolished], apparently three stories in height and only wide enough on the creek side to accommodate two windows on each floor….the present ruin was four stories high and filled the entire space between the hill and the stream, the rear wall being sunk into the hill-side so that only the gable projected. [Smith further commented] Since the building which Thomas built was destroyed by fire in 1793, its similarity to the present ruin cannot be determined.[26]

Unfortunately the 1760 draught Smith examined in the early 1930s was not found among the LFP that were discovered and studied. Since I disagree with Smith proposing a radically different view without written documentation, it is important to explain my different conclusions. I studied other draughts among the old LFP, one of which was shown in the

[25] Mill expert Hazen in telephone and emails with the author suspects that the Livezey's like other millers would have started adding some of Evan's inventions to the mill as soon as they heard enough about them to instruct their millwrights to begin installing. Being devout Quakers it was a requirement for them to legally license them from him which we saw was done in 1793 two years before Evans published his book. His book was not published for sale in the traditional manner. The only way a miller acquired a copy for him and his millwrights was to pay Evans his license fee.

[26] Smith, 41.

second article in the series that initiated my discomfort with his narrative based on his study of the sketch.[27] The mill structure Livezey drew on the draught seen by Smith was likely not drawn to scale as was the case on the one shown in Part II. It appears he drew a simplified rendition of the mill (an icon) lacking architectural shape, detail or accuracy. The building's sketch on the draught was likely not part of the drawing's purpose (establishing property lines) making it likely that this situation applies to the missing draught. Inferences like this can be risky and troublesome for historians, so additional support will be offered. In the Buildings Book Livezey adds a second compound gearing system (we will cover what that means in more detail in the next article) on the downstream side of the mill in 1771.[28] Suffice it to say compound gearing takes considerable amount of footprint to install to accommodate these large gears and their immense shafts. This required more floor space indicating the original structure had to have a larger footprint than Smith described above. The mill's fire suggests and supports the new conclusion. Mill structures were built using burnout beams with fire-notches cut at 45° angles on each end that was inserted into a stone wall as shown in Figure ___. This general practice in mill construction has been well known and commonly used when Livezey's original mill was built since builders knew mills often experienced bad fires. During such an event support timbers resting in the external and internal stone walls would quickly burn. Since they supported heavy equipment (a pair of millstones easily weight more than a ton) caused them to fall to the floor below without tearing down the stone walls. A real example demonstrated this. Chapman Mill built ca. 1859 located near Manassas, Virginia, was one such very high-walled structure, (see Figure ___-___). This mill was completely burned not once but twice and its walls survived both times. It was first burned by Union forces during the Civil War's second Battle of Manassas (or Bull Run as referred by the Confederate Army) and again recently in October 1998. Why then would the Livezey brothers, being very practical men, go to the expense and effort to rebuild new walls with new foundations if the existing walls were still left standing? Very unlikely. John Livezey's credit-debit notebook over a period of three months before and after the 1793 fire adds further support for this conclusion. The three months following the fire showed decreased milling activity compared with the same period before the fire. I conclude that reconstruction was quickly completed implying they reused all original stone structure's footing and only added height to the stone walls where new floors were added especially above the original water house on the mill's creek side (see Figures ___-___).[29]

[27] Herb Lapp, "Thomas Livezey: Pennsylvania Merchant Miller, Part II," *The Chronicles*, (Early American Industries Association, V. 2, no. 2, June 2010), 56.

[28] Livezey Book of Buildings, April 23, 1771 entry, 34. (pages in this book were hand numbered by the author).

[29] I use the term "milling activities" since John still purchased grain and conducted some other business. However no reference was found to actual milling during this period.

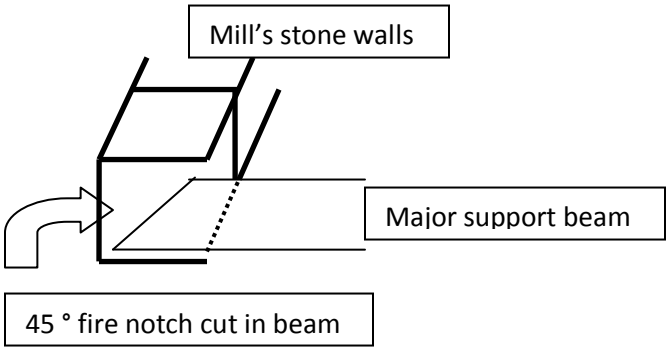
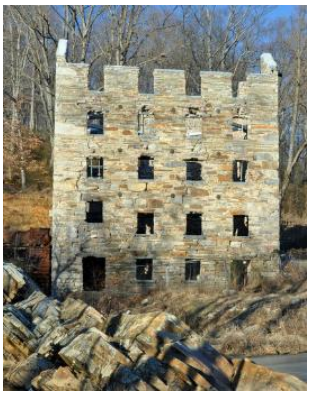


Figure cross section of a burnout beam showing the 45 degree notch cut that allows them to fall in the event of a fire without tearing the stone walls down in the process.

(a)

(b)



(c) (d)

Figure ___ image (a) shows the post Civil War Chapman Mill as it appeared before the October 1998 fire shown in (b) and (c). You can see the tall mill structure walls still stand after the fire was extinguished left standing as a result that the millwrights used burnout beams to support the mill floors. Photographs (a) and (d) from the Civil War Trust and used with permission.

Lastly archeological fieldwork at the site provides to support my claim the new mill existed using the same footprint as the original. The amount of buildable land along the creek and the wall is a small area with the surviving rear wall common to both the original phase 1 mill and the reconstructed structure. 2009 winter floods were unusually bad, so in spring significant bank erosion was discovered revealing details not seen in more than a century. This erosion uncovered neatly laid, hand cut stones one to two feet below the former stream bank (Figure ___). I believe these stones are what remain from the mill's original 1747 outer wall. Livezey's water wheel was originally located outside this wall exposed to the elements (with its shaft entering the building through an opening in the outer wall). In 1751 Livezey documented building a water house, a building that enclosed the water wheel protecting it from winter freezing that would have prevented milling during winter's coldest months that I will consider to be part of the original mill of phase 1 (see Figure ___ for a typical water house, most were simply made of wood).[30] His new addition would have been made of stone. All indications of water house outer wall foundation artifacts have long been destroyed by all the ensuing creek floods over the last century leaving only the valley's bedrock seen in the deepest part of the present streambed. The outer wall of the mill seen in Figure __ would now be several feet out into where the present creek bed where the creek's channel is now deepest.[31]

Having said this the mill's third phase enlargement is significant as it added considerable floor space above the original water house area along with an additional floor with a full attic under a gable roof (see Figure __ for a view of the Phase 1 mill looking east and Figure __ looking north at the mill structure).

[30] Ibid., June 24, 1751, 4.

[31] The Wissahickon Creek's streambed has changed significantly over the past century when its present course is compared to that shown in a ca. 1900 photograph, Part II, 47.

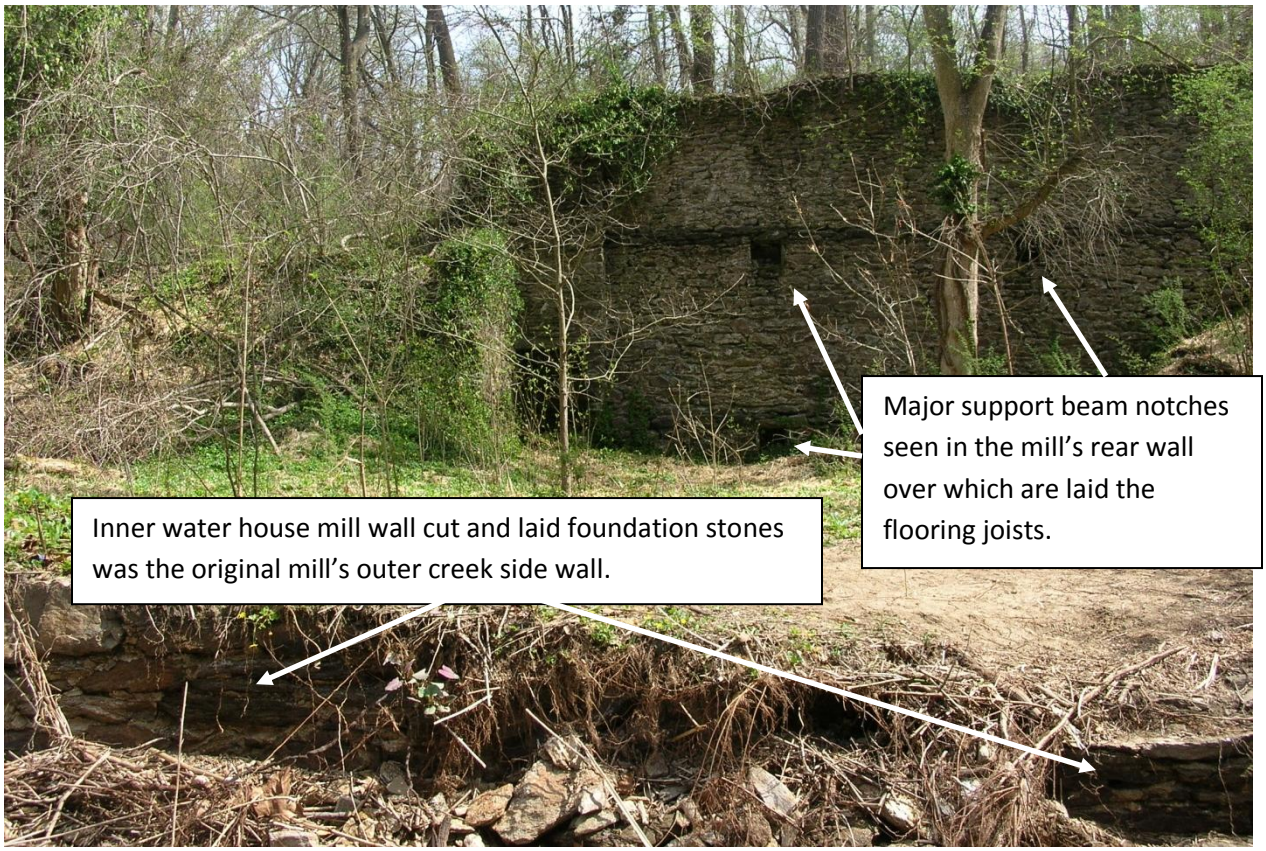
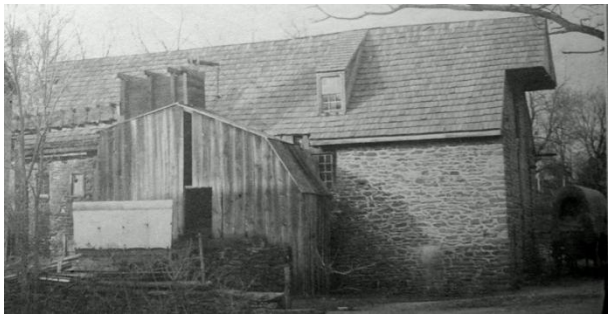


Figure __ rear wall of the mill ruin looking east. In the foreground we see the mill's outer wall remaining foundation which coincides with the water house's inner wall built in 1751 as revealed by winter 2008serious floods that removed sediment deposits from this area. This illustration also shows the rear wall's mortise beam notches mentioned earlier. (Photograph by the author).



(a) (b)

Figure ___ image (a) is ca. 1855 photograph of another Wissahickon Creek mill originally named Townsend Mill and later Roberts Mill's wooden "water house." It was the oldest Philadelphia mill purported to have been built in the 1690s. Image (b) on the right shows the mill's overshot water wheel after its water house was removed as part of the mill's demolition in the early 1870s as part of Fairmount Park's formation in time for the nation's Centennial celebration.. (Both are nineteenth century photographs taken by well-known Philadelphia photographer Robert Newell)

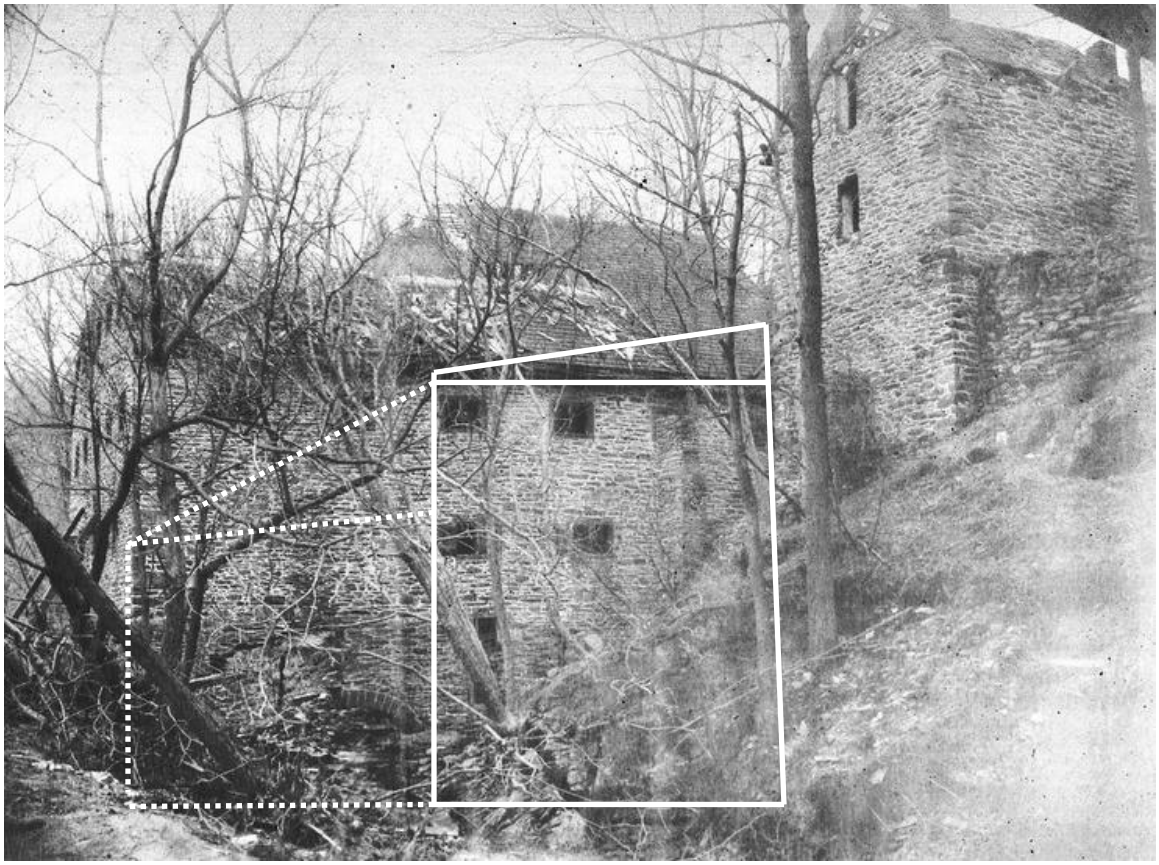
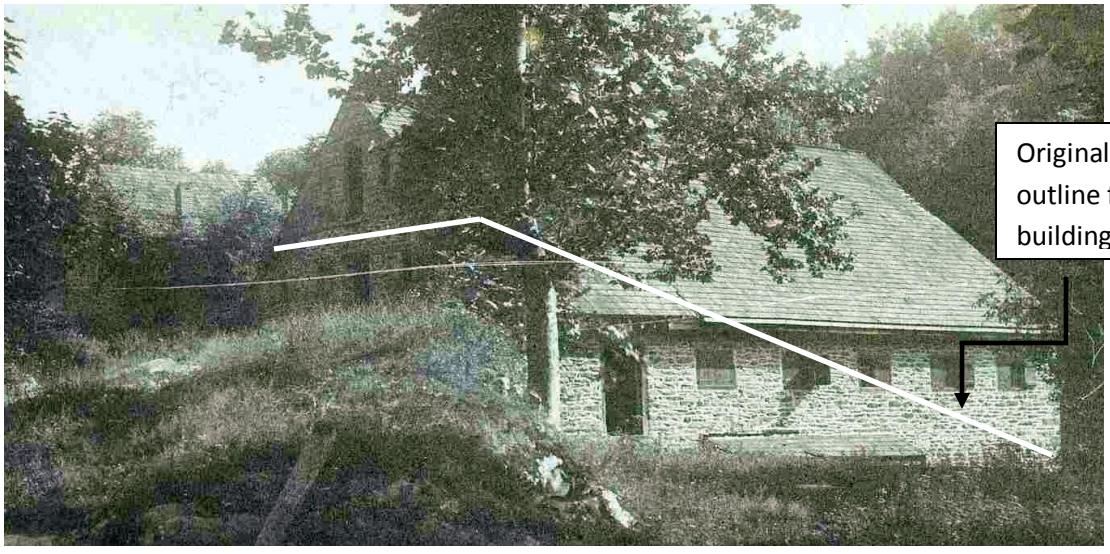


Figure __ Late nineteenth century photographs of the upper level of Livezey's post 1793 mill. Figure __ shows the mill taken from the top of the tailrace's outer or creek side-west wall looking north. The photographer, Thomas Shoemaker, captured the mill during early stages of its demolition by the Fairmount Park Commission. Both photographs show the cedar shingle roof being removed. The corn kiln mentioned in the series second part. Notice the archway to the tailrace seen on the mill's lower left western end. The thick dark lines show the outline of the mill's first phase and dotted lines show approximate outline of Livezey's 1751 water house addition that likely would have had a shed roof. Photographed by John D. Bullock, about 1900. The corn kiln building stands to the right of the mill structure.

Figures __ & __ These photographs were taken at the top of the hill the mill was originally built into looking southwest provides a better view of what I believe is the enlargement done by the brothers after the 1793 fire. This path up the hill was the one Livezey took on his many to and fro trips between his house and the mill. Harper Smith family history-genealogy described the early mill as having a single-pitched roof sloping to the creek. The upper door significantly improved unloading materials and general supplies to the mill even considering advantages gained by installing Oliver Evans wheat and flour handling machinery to more easily move these materials around the mill. The roadway before the mill and corn kiln seen on the left runs off Livezey Lane about halfway down to the creek where former materials had to



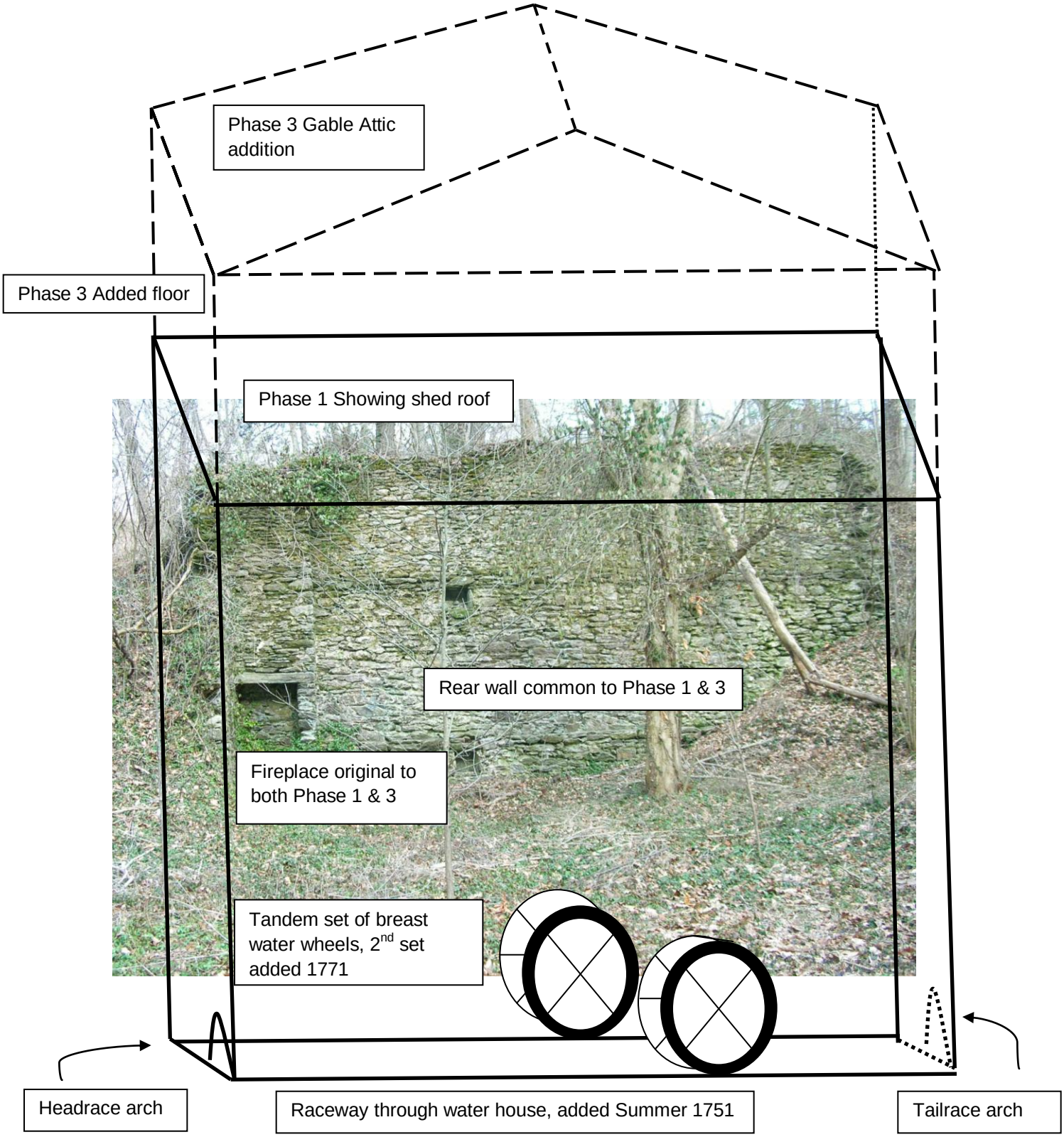

Phase 3 Gable Attic addition
Phase 3 Added floor
Phase 1 Showing shed roof
Rear wall common to Phase 1 & 3
Fireplace original to both Phase 1 & 3
Tandem set of breast water wheels, 2nd set added 1771
Headrace arch
Raceway through water house, added Summer 1751
Tailrace arch

Figure ___ Photograph of surviving mill rear wall that I believe is original to both the phase 1 and the enlarged rebuilt 1793 Phase 3 mill. I have superimposed outlines of the building showing its Phase 1 and Phase 3 structures which I also believe shared the same foundation footprint. Livezey added a water house, covering the water wheel in 1751 not long after purchasing the mill. I have not attempted to show the water house in this illustration to keep it from becoming too complex. His notes did not articulate all the work building it involved. (Photograph and drawing by the author)

Mid-eighteenth Century Flour Mills

Before becoming very specific about the details of his mill in the next article, a discussion of the workings of a pre-Evan's, mid-eighteenth century merchant mill will be helpful.

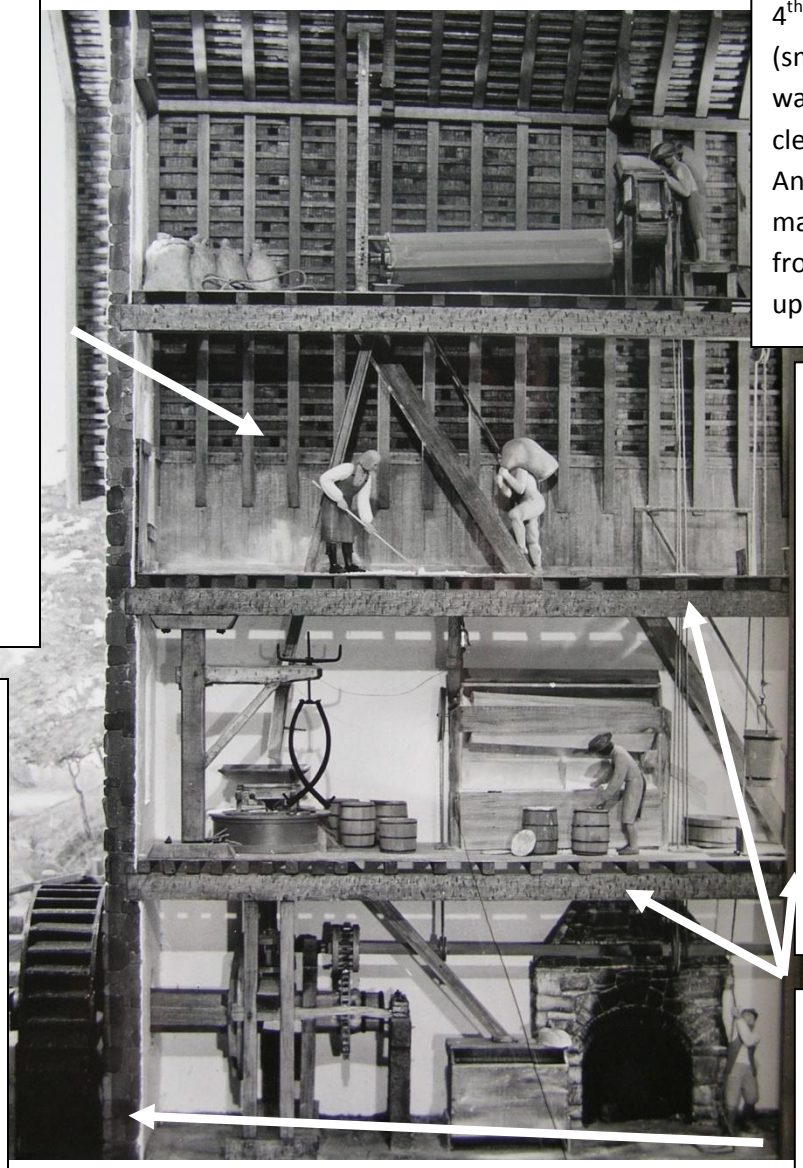
The Hagley Library and Museum near Wilmington, Delaware displays a three-dimensional model of a very advanced working custom or grist mill.[32] Even though it represents a grist or custom mill, much smaller than Livezey's, it provides an excellent overview of a pre-Oliver Evans type mid-eighteenth century mill (Figure __).[33]

[32] This conclusion is made using one of Ellicott's findings from his ten-year study of eighteenth century mills previously noted in fn 21.

[33] I will describe parts of the mill that Livezey specifically mentioned in his Buildings Book. I am ignoring other pieces of equipment like the millstone crane since he did not do any maintenance on his cranes. If interested the reader may refer to any general reference concerning flour milling cited earlier. Milling elements written into this overview are included since they specifically link to what was learned about eighteenth century milling studying Livezey's papers and using Ganzel and Wulff's recently published translation.

3rd level: Ladder between floors, hoist opening & railings, miller spreads out freshly ground flour on the floor to dry before sorting with the grain cleaner. Once dry the miller would sweep it into a shut located above the bolter for sorting.

4th level: grain cleaner (smutter), bags at left waiting to be dumped into cleaner by another laborer. Another laborer is seen manually carrying sacks from the 3rd to the 4th level up the stairs or ladder.



2nd level - Milling floor: millstone station at left side of floor. Miller is filling flour casks with the appropriate grade of flour, bags at left waiting to be dumped into cleaner by the miller. Notice the bucket or tub of wet freshly ground flour being lifted by hoist at right up to the 3rd floor by a laborer standing to the right of the fireplace.

1st level: Left to right… external water wheel, gear train that transmits power to turn millstones and auxiliary equipment, box with chute from millstones to capture and store wet-freshly ground flour and stored till manually shoveled into the bucket or tub seen hoisted by the miller on the right.

Very robust husk or hurst frame independently supports the mill's heavy rotating machinery to prevent vibrations from destroying the building's stone structure. The stone walls do not touch these timbers.

Figure __ A full scale model of a pre-Oliver Evans mid-eighteenth century custom or grist mill. Notice the backbreaking work millers had to endure moving grain and flour up and down between the mill floors as well as introducing material into each of the simple processing machines they used in the milling process. First bags of grain were also manually hoisted to the upper floor and manually dumped into the grain cleaner to crudely remove dirt before grinding. Once cleaned, it traveled by shut flowing into the hopper above the millstone for grinding. Additional grain bags can be seen sitting at the left waiting to be put into the cleaner. Once ground fresh-wet crushed grain (included flour) flowed to the lower level into a cabinet

or hopper in preparation to be hoisted up from the milling floor to the 3rd level. It was spread across the floor to dry and then swept into another chute in the floor so it could flow into a machine called the bolter seen on the 2nd level to sift the ground components to separate it into flour, middlings and bran.[34] From there the casks or barrels of flour were taken from the mill using a handcart trolley for loading into wagons for shipment. (Courtesy of the Hagley Museum & Library)

Beginning with the water wheel that powered the mill we will follow the flow of grain, then flour though this model. Water wheels drove mills using one of three designs to take maximum advantage of the available water power: undershot, breast and overshot water wheels (tub mills will be ignored since only a few existed in the area only to power small custom or grist mills).[35] Livezey's Building book mentioned the water wheel numerous times but he never specifically indicated the type installed at his mill. Of course Livezey never intended his notes to be read 250 years later since it was perfectly obvious to him what type of water wheel he had. Early hunches suggested that the most probable wheel he used was a breast wheel since it was the most commonly used in the region. (That was later confirmed studying Livezey's maintenance entries when he made entries for raceway maintenance).[36]

Energy captured by the water wheel (seen on the lower left side of the model) was transmitted to the millstones using wooden gears which increased the water wheel's slow speed (typically 10 to 12 RPM) to efficiently grind grain (1:10 ratio). This technology had little changed in over two thousand years. The most common gearing systems used were simple two-gear systems seen in the Hagley model (see Figure ___).[37] Figure ___ is an enlargement of the model's primary gearing system allowing us to briefly discuss its power train for this overview (mill gearing will be treated briefly in this article). This mill used this simpler gear system to turn a single pair of millstones using one large cog wheel engaging a smaller gear (called a trundle gear or stone nut).

[34] Middlings is the name given to the larger-course particles of wheat that sometimes were used to make break for sailors and slaves in the Caribbean. It was also referred as sharps or shorts. In most cases it was either sold for animal feed or discarded being dumped into the mills trail race. The bran and resulting light dirt left over from milling was discarded using a crude fan, as was the case at Livezey's Mill. This fan was typically called a "Dutch fan." See http://www.angelfire.com/journal/pondlilymill/glossary.html#anchor280001 for Ted Hazen's dictionary of the most common milling terms, used with permission.

[35] These water wheel designs were introduced in "Thomas Livezey: Pennsylvania Merchant Miller, Part I, 15, see Figure 14. Some mills were wind powered like several in New England and the very old Wye Mill north of Easton, MD, a town on Maryland's eastern shore. The author does not know of any wind powered mills built and operated in Pennsylvania.

[36] I cannot definitively determine if the Hagley model water wheel was abreast or undershot water wheel. The model's photographic view makes it difficult to authoritatively infer but I assume it is likely a breast since these were most common types found in the region.

[37] The narrative requires me to discuss simple gearing in this overview that will be covered in greater detail in the next section where the principles as well as the translation of the old-archaic gear names Livezey and his contemporaries used (and no longer used today) with their modern equivalents.

This set of gears transmitted the water wheel's energy to the millstones to grind the grain. Understanding the simple energy transmission, how does the flour get produced?

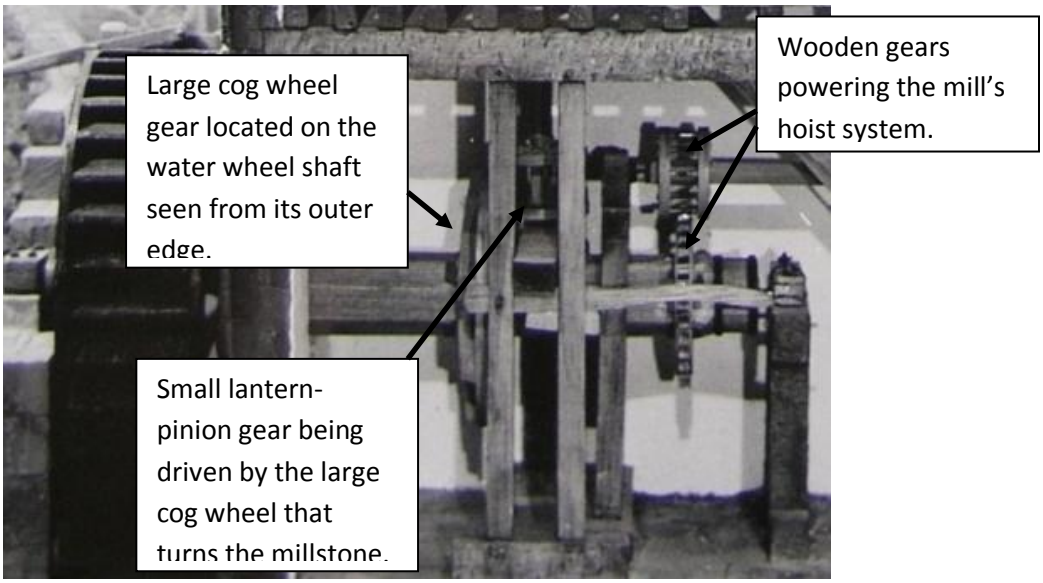


Figure __ Enlargement of the Hagley Mill photograph showing its frontend power train. The large cog wheel, seen viewed from its outer edge, making it difficult to make out. The smaller lantern-pinion gear the cogwheel drives is also hard to see since it is in the shadows between the two floor support beams. (The gearing basics with definitions of old vs. modern gear names will be covered in the next section.)

The story begins back at the Pennsylvania farm discussed in a previous article with the farmer growing, harvesting the mature wheat threshing the wheat harvest.[38] Threshing is the mechanical process used to separate the wheat seed or kernel from the plant's stalk commonly called the chaff or straw. Many used a tool called a fail made up of one long pole for holding and rotating with a short pole or rod loosely attached at its end for "thrashing" or flailing. The smaller rod struck the dried wheat stalks lying commonly on the ground outside the barn freeing the wheat kernels from the stalk. The loose kernels then had to be shoveled into bags before being delivered to the mill that included lots of dirt. Other methods have been used by various cultures over the ages. At Livezey's merchant mill prior to grinding the newly arrived bags of wheat, they had first to be cleaned removing as much dirt as possible before grinding since he had a cleaner or smutter as it was later called.[39] Using Ellicott's observations cited earlier this is an indication that Livezey's Mill and milling practices well above that of his peer millers. Once at the mill the miller would use an external hoist to lift each bag up into the mill for storage on an upper floor putting it into bins or garners as they were called back then (the model's builder did

[38] Herb Lapp, "Thomas Livezey: Pennsylvania Merchant Miller, Part II," *The Chronicles,* (Early American Industries Association, v. 63, no. 2, June 2010, 47-9.
[39] Occasionally some farmers would have their wheat threshed and cleaned by someone else at another location.

not model these bins but from the Buildings Book they were an important part of Livezey's Mill). In the model we see the bags of wheat on the model's upper 4th floor sitting on the left side of the floor (see Figure __). The model shows a 4th level laborer emptying a bag of grain into a hopper attached to the cleaner or smutter machine in the old vernacular located on the right end of the floor (The following is a brief description, a fuller one will be provided in the next article).

Inside is a fan, frequently called a Dutch fan (a term Livezey used with fan blades made of leather). The fan created a draft though the cleaner which blew away most remaining pieces of shaft and the lighter inorganic earthen dirt. Before getting too far ahead, why was there a need for another machine to process the wheat prior to milling it into flour? Threshing was often done by the farmer's wife and children on the lower floor of his barn where the freed kernels were sweep up putting it into sacks that included not only the wheat kernels, but the many bad wheat kernels that had been harvested and lots of floor's dirt into the sack as well. In many cases farmers used horses or cattle to assist in the threshing operation where they were walked around over the cut wheat to reduce the human effort to separate the wheat kernels.[40] Using animal threshing means additional organic contaminants found their way into the wheat kernels. The animals would naturally defecate and urinate while threshing meaning this excrement was added to the mix. When the thrashed kernels were shoveled into the bags, most likely the larger pieces of excrement were removed before shoveling which then only included the inorganic dirt already mentioned but remaining small pieces of animal excrement the workers missed or ignored. Not a pretty thought but using a cleaning or smutter machine like this was a big improvement compared with what had been happening for the previous two thousand years prior to the invention of a smutter. And as Ellicott pointed out was uncommon then even among merchant mills.

Most flour made before that time was actually very brown in color largely caused by all this inorganic and organic dirt.[41] Using a smutter was part of the reason why I believe that Livezey's flour was so desirable since he mastered the ability like a few other millers of his time to produce a super fine flour very white flour (though still not nearly as white by our modern standards since we bleach the flour typically using chlorine gas). When coupled with his ability to dry out the freshly ground flour which prevented it from spoiling when shipped long distances (sometimes taking months by ship) made his product very desirable and profitable. The operation of the cleaner or smutter will be covered in greater detail in the next article.

[40] Typically the farmer would put the freshly cut wheat plant (stalks and kernels) up in his barn to allow it to dry. Threshing was usually a winter-time task done to take advantage of the reduced cold weather farm workload while making it easier for the kernels to be removed from the plant's dry stalks.

[41] Modern flour is bleached typically using chlorine as the bleaching agent to make it white. The natural color of flour is a creamy white to yellow product. The brown skin of the kernel called bran, was mostly but not completely removed furthering the dark brown color of colonial flour. See John Storck and Walter D. Teague's A History of Milling: Flour for Man's Bread. (Minneapolis: University of Minnesota, 1952). 167, 189-192.

At this point the grain can be introduced into the millstones where it enters the stone's eye and is ground as it passes from the inner part of the stone to where it falls out of the outer edge into a trough. A paddle is attached to the runner stone spindle that acts like a rake to push the flower around this trough where it moves over a hole in the floor entering another chute guiding it to a flour bin seen to the left of the fireplace on the lowest level.[42] The chute is seen coming down from the millstones running diagonally to the right. The flour is not yet ready to be packaged into the barrels or casts since two more operations must be accomplished. First the freshly ground flour's consistency is not homogeneous while at the same time being too warm and wet containing from grinding to package. In larger mills the miller usually shoveled the newly ground product into a large wooden bucket called a tun where it is hoisted up to the bolter machine located on the 3rd level in the model (see Figure___ for examples of tuns) which was another use of the mill's internal hoist system that was part of the larger mid eighteenth century mills. Moving flour casks and heavy wheel-less tuns around the mill required other simple machines like hand trucks (see Figures __-___, found among Livezey artifacts owned by one of his descendents when I studied his papers). The tun and hand truck would have been made by the mill's cooper in the cooper shop made entirely of wood to avoid using expensive iron and preventing sparks which could cause dust fires. A special observation the tun seen to the right of Figure __ is likely older than that on the left since the bands holding the staves were made from wood, rived thin-flexible sapling wood (coopering will be covered in the last article of this series: Livezey's cooper shop).

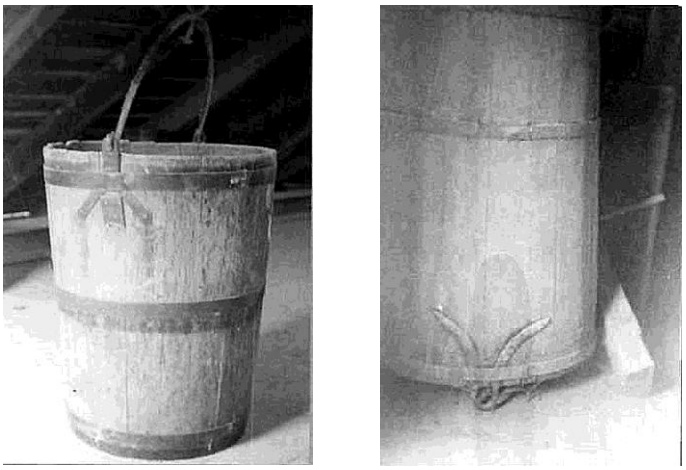


Figure ___ Two different example of large flour buckets called tuns used to transport the moisture-wet unbolted flour stored in a bin under the milling floor to the area on that floor where the hoist is to be lifted

[42] Livezey did not make any notations about millstone preparation or sharpening in the Buildings Book. Ganzel and Wulff describe what they learned about these millstone tasks in great detail, 53-60. I have decided to keep the overview of milling to support the new information Livezey's entries provide us, I have decided not to treat the topic of how millstones work. Interested readers should consult Hazen's excellent web site on the topic: http://www.angelfire.com/journal/pondlilymill/indexpage.html especially under millstones.

up to an upper level for drying and bolting. The bucket on the left is traditional having only a carrying handle. Notice the small wheels on the tun seen on the right enabling the a worker to move it across the floor to the hoist area. The bucket on the left without wheels could be moved using a hand truck. (Photographs of the tuns from Ted Hazen's photographic archives and used with permission) See Figure ___ for a hand truck that came from Livezey's Mill and is in the possession of his descendents.

Figure ___ The only surviving hand truck used at Livezey's Mill. It's construction suggests being handmade in the sometime in the eighteenth century. It is all wood construction including the use of wooden dowel pins shown to the right, to secure mortises in their tenons to insure that it cannot create a spark to ignite a dust explosion in the mill's dusty environment. This construction was well known at that time. It is in the possession of descendents of Thomas Livezey who gave permission to the author to photograph and use it.

The grain's passage continues through the mill, after being ground it went into a bin or chest till the tun was filled so this product could be hoisted to the second level (in the model) to be put through the bolting machine or bolter. To best separate the ground wheat's components millers knew long ago that it had to be cooled and dried. Wheat kernels contain considerable moisture content which is only partially released when ground between the millstones. Friction from grinding added considerable heat, warming the newly ground unfiltered flour with its moisture makes it rather sticky. In ancient times millers sifted this mixture separating the components found in this mixture by hand using sieves (screens held by wooden rims). But later began using finely meshed cloth in machines called bolters, named after the fact that the cloth for this machine came to the mill as bolts of cloth. (Even though drying happened prior to bolting, the

bolter and bolting process will be discussed first.) Freshly ground wheat kernels comprised a mixture of fine flour particles, larger crumbs called middlings and the kernel's outer skin called bran. The heart of the bolter shown in the model is a sifting reel invented by Scotsman John Mine ca. 1720. Before having a reel sifting or bolting was down using a pair of slanted flat mesh screens made of fine wire that were mechanically shaken. The earliest reel bolters were usually hand-cranked or rotated by hand. Milne's invention was a significant improvement making bolting more efficient.

> The Dutch weavers in Haarlem began using a stronger cloth silk during the 1700's. Bolting cloth came in two weaves. Regular weave for interior cloth and very fine mesh, and twisted weave which prevented the mesh from spreading. The twisted weave could be made by the Dutch weavers at 88 openings per inch, and the regular weave could be made to 125 or more openings per inch. Bolting cloth was made from wool, linen, cotton, horsehair, and even silk cloth.[43]

The finest meshes sorted out the finest flour called superfine. The largest components were caught and shaken down to courser meshes to separate out the middlings (middle product). This middle component from grinding was mainly used at Livezey's time as animal feed or a product called "shipstuf". (Bran, the outer brown skin on the kernel was also another milling product). Livezey documented shipping shipstuf to various customers. Here I found another archaic term that caused confusion. The meaning became clearer when I later studied the backgrounds of several flour account book customers. Several were found to be ship captains. Shipstuf was middlings used to feed sailors on long voyages like to the Caribbean purchased as a very inexpensive food for human consumption. Others who were local Germantown residents purchased smaller quantities likely for use as animal feed. Middling's baking qualities were poor but at that time sailors had no say in the quality of their food. When it could not be sold as either shipstuf or animal feed the miller just disposed it by dumping it into his tailrace making for good downstream fishing. As a part of Evans milling revolution middlings were later re-captured and ground a second time, remixed with unground wheat producing more useable flour. To close this topic bolting is just the mechanical separation of wheat's ground components by allowing it to pass though cloth or wire screening of various meshes to sort it by size. The construction and operation of Livezey's bolter will be covered in more detail in the next article.

Returning to the flour's path through the model the first two flour components just described can be seen (simulated) falling into a flour bin or chest. The laborer is in the process of adding this finely bolted flour to a cask (possibly using large shallow wooden bowl as a shovel).[44] In this

[43] Theodore Hazen, web page: http://www.angelfire.com/journal/millbuilder/boulting.html

[44] The modeler shows two casks sitting on the floor to the laborer's left, the nearest is the one he is filling. The other is likely one just completed and filled. Notice the white circular object sitting on the floor leaning against the full barrel, even though small is an actual milling artifact being modeled. It is a handheld sieve used by the miller to manually examine the components while deciding what to do in making adjustments to the bolter.

situation the laborer would use a hand truck shown previously from the surviving Livezey artifacts to move the filled flour barrels out of the way in preparation for shipping to customers. Mentioned previously Livezey's flour had a well-earned high reputation (reported by Smith as part of the family's oral tradition) for avoiding spoilage allowing it to be shipped long distances. Why was his flour so special and how was that accomplished?

Prior to discussing the pre-bolting process we saw a laborer working up on the third level holding a stick in his hand apparently trying to move something on the floor. The photographic detail does not allow seeing that he is holding is a rake. The floor in this area was built with a shallow bowl like shape or "hopper" where the freshly ground floor was manually poured. This made him the mill's "hopper boy" a task usually done by a very young lad. Raking out the moist flour promoted faster drying by re-exposing the granules to air rather than being loaded into the flour casks.[45] Even though Livezey in his papers is silent on what he did at this level of production, I believe we can infer what milling techniques he understood that differentiated him from his milling peers. To achieve the value of his flour's shipping stability he had to insure his hopper boy spend considerable time raking the moist flour to dry it completely. He learned the benefits outweighed the added cost adding to production time. Consistent results like this would not have happened if he did not religiously supervise the "simple" raking operation. Ellicott's observations about such practices at many other regional mills at that time, made Livezey's methods world class.[46] Earlier articles in the series showed Livezey's ability to details and this is manifested but not simply because he is detail oriented or picky. This personal characteristic and behavior added significantly to his competitive advantage not seen by others, that not only making his flour better for shipping long distances; it also made it whiter, a very desirable quality that people were happy to pay extra for. Once again Livezey's business acumen as well as being a good miller speak-out to us.[47] Later in the last mill era he would have his millwrights build an automated raking machine, called a "hopper boy" using Evans design thus making the human hopper boy redundant. This new machine was a simply wide rake held by a vertical shaft affixed to the middle of the rake head turned by gears powered by energy from the water wheel.[48]

[45] According to Hazen, allowing the flour time to dry exposed it to air. Air is nearly 20% oxygen which is an oxidizer or mild bleach. Oxidizing the flour whitens it since most oxide compounds of other elements are also white. Adding bleach (chlorine) to the wash does not remove dirt from the clothing. It just turns it white making it almost invisible!

[46] This was supported 50 years later when the Prussians sent Ganzel and Wulff to America to learn the best milling secrets that made America's flour the best in the world.

[47] It should be mentioned that Livezey no doubt knew the raking time had to vary through the year compensating for changing the mill's ambient relative humidity. Philadelphia's relative humidity varies significantly throughout the year since and if he didn't vary the raking time such a reputation would not have been possible.

[48] A personal note, all during this research I knew of the Evans' hopper boy invention and re-reading Evan's book. This point was made to the author in a telephone discussion with mill expert, David Metz, did I come to realize that Evans' name for that machine originated from the actual man seen illustrated in the Hagley model. This was one

Once the flour is dried, it is then scooped or shoveled into barrels or casks that were made by hand in Livezey's cooper shop that will be covered in this series last article.

This completes the cycle of wheat arriving at the mill in bags, cleaned, milled, dried and packed into flour casks for shipping. Before detailing Livezey's equipment and milling processes as he shared in his Buildings Book, we need first discuss gearing terminology. This simple gearing overview needs to be done for two reasons: first, some readers may not be familiar with gears and their use; and second, Livezey writes about his mill's gearing and its maintenance using ancient-archaic terms, so using them in the next article I want readers to understand what he is telling us. Several terms took me considerable effort to translate into their modern equivalents just as Ogden and Bost experienced in their work mentioned earlier.[49]

Mill Gearing Overview

The most simple gear pair is the common pinion gear used with another often called a bull or drive gear. These are actually simple machines which all millwrights were well versed in and are found is nearly every mechanical device we use today. What is a pinion gear?

of several laborer positions his machinery inventions made redundant in flour milling. See Evans, part 3, 74-7 and figure 12 in Plate VII.

[49] The project team of Derek Ogden and Gerald Bost who supervised the translation of Ganzel and Wulff's report written in 'Old German' ca. 1830 from their espionage trip to America encountered the same challenge,. In the forward to this publication they wrote, "Translation of the book was not easy as it was written in 'Old German' and difficult to understand, particularly many of the early milling terms and descriptions…not only were there many off German terms but many of the old American milling terms were somewhat obsolete and difficult to comprehend." Livezey and his millwrights lived at the time that country was an integral part of British North America and there was no disconnect between the two lands separated by an ocean as happened after our split later in the century. Over time colonial millers and millwrights began to slowly change some of these labels perhaps since a substantial number did not come to America from England. Living languages always change slowly over time; however, everyone alive then knew and understood the terms; hence, no need for a dictionary. However, 250 years later, all of these men are gone as is the milling technology they practiced. It took considerable time for the author to analyze several of these terms allowing me to understand what Livezey was specifically describing. Mill expert Ted Hazen was invaluable in assisting deciphering them, several of which he had no idea what Livezey was referring to.

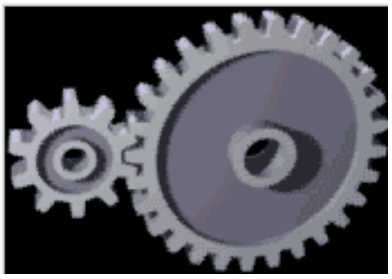


Figure __. Modern pair of meshed gears. The smaller gear on the left is called a pinion gear. I will refer to the larger on the right as the driver or driving gear (some refer to it as a spur gear). Whichever gear is driven can be referred to as the master gear while the other seen as a slave. In most mill applications the larger gear is the one to which power is applied starting with the water wheel turning at from10 to 15 rpm needs to drive other machinery like the millstones at much higher speeds on the order of 100 to 125 rpm. The loss of torque or turning force to achieve additional speed is acceptable when water power drives a large water wheel. In the eighteenth century the smaller pinion gear was often called a wallower, lantern, nut or trundle gear depending on its application.

Pinion gear –shown in its modern configuration (see Figure __) is typically the smaller of a set of two gears whose teeth mesh forcing the smaller pinion to turn when the other, seen on the right, is rotated by some kind of rotational energy source. The pinion serves two purposes: from its geometry compared to the bull gear, must turn much faster than the bull gear meaning it is used to speed up the number of revolutions on a second shaft (if the pinion is driven the opposite happens causing the second shaft to rotate slower than the pinion's shaft). In flour mill applications other machines require being operated at higher rotational speeds than what is available from the larger gear alone (the water wheel is the prime source of rotational energy and for a breast wheel turns at about 10 RPM). The second purpose is to change the direction of rotation from that of the primary gear. This is sometimes required for a specific application but other times happens simply from the interaction of the two and serves no other specific purpose which is the case of what happens in an eighteenth century flour mill. What the millwright knew there is a controlled – predicable interplay between the speed each turns and the torque or twisting force they possess. Ratio of the diameters of the two gears controls or governs the relationship between the individual speeds and their torques which work in opposite (or inverse) ways, meaning the faster the smaller gear turns compared to the larger, the smaller the torque the smaller gear (the pinion) has compared to the bull gear. This mathematically described as an inverse proportion. The formula even eighteenth century millwrights used is

$$\frac{D_{\text{larger or driver gear}}}{D_{\text{pinion}}} = \frac{\text{Speed}_{\text{pinion}}}{\text{Speed}_{\text{driver}}} = \frac{\text{Torque}_{\text{driver}}}{\text{Torque}_{\text{pinion}}}$$

Where D represents the gear's diameter.[50]

A simple example will illustrate this relationship. For a 12" diameter driving gear meshing with a 2" pinion, the relationship is a ration of 12:2 which is the same as 6:1. For any given speed the driver turns at, the pinion will turn 6 times faster keeping the 6:1 ratio. For their torques, the relationship stays the same: the larger gear even turning slower generates 6 times the torque the pinion is able to generate. We experience this relationship each time we drive a car. When we need the car to begin moving the transmission (the gears between the engine and car's wheels), selects the smallest gear available (the pinion) to drive the largest. Hence the engine must be rev'ed up to turn very fast giving the larger gear, attached to the wheels the great torque to get the heavy car moving. (The trade-off is low speed in the lower gears to get hi torque to overcome the car's inertia due to its weight as shown in the formula above.)

Analogous old mill gears – Due to sheer size of the largest of mill gears I will begin discussing the drive gear (Livezey referred to his large and small drive gears as wheels, or wheals as he spelled it). In the mill it took a couple of forms, one with the gear teeth, called cogs by Livezey, which stood perpendicular to the wheel's major circumference seen in Figure __. The cogs on the spur gear (or cog wheel) were also made to radiate out from the gear's circumference having the appearance of the modern gears shown in Figure ___. Only a small pinion gear survives from Livezey's mill shown in Figure ___. It would have been turned by the more common form that Livezey called a cog wheel in Figure ___ as the old painted image with an old man sitting on the large shaft working on the cog teeth. Below this image is a photograph of these gears from an old mill photographed during the Depression as part of the HABS project. This illustration provides both a visual overview to typical early eighteenth century mill gearing along with the old gear names Livezey and his peers used at that time that are no longer heard today. The trundle gear was most challenging taking months before I finally knew exactly what Livezey meant when he used the term in his building's book.

[50] Reynolds discussed mathematical skills a typical eighteenth century millwright possessed. He felt most did not know algebra which then was a relatively new mathematical tool for our western culture. But they did possess intuitive ways to use this concept, perhaps using comparative thinking even though plugging numbers into a formula or solving an equation as we can easily do today was not a common knowledge technique.

Figure __ The only surviving component from Livezey's Mill, a lantern gear that was being used as a lamp table in Mike Firth's home. The rectangular central hole accepted a shaft with those dimensions so the gear would securely turn the shaft. This gear was about 18" high and nearly 2' across. The rounds show a step-notch indicating wear caused by the cogs driving them on the larger cog wheel. (Photographed by the author).

Figure ___ Overview of simple gearing that connects modern gear terms with their archaic, no longer used, eighteenth century counterparts that I found Livezey using in his Book of Buildings.

Modern Pinion Gear (slave)

Modern drive gear

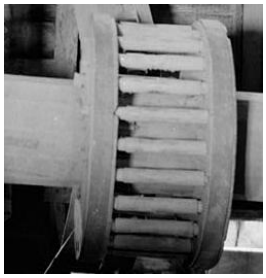
18th century equivalent

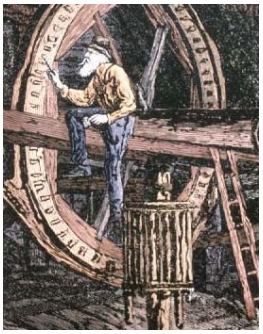
18th century equivalent

Lantern gear From Livezey's Mill

Large spur gear driving a lantern pinion gear

Other old names: lantern gear, trundle, nut

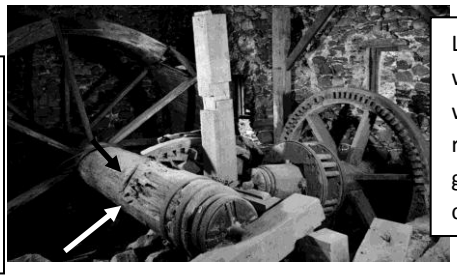




Great cogwheel or large wheel on right sometimes called a crown gear as seen when viewed laying on its side.

Two old large lanterns- 1 horizontal & 1 vertical

Top part of the great cogwheel seen between the water wheel and the vertical post…its broken arms are missing see arrows pointing to the mortises in water wheel shaft where it was once held onto the water wheel near bands on shaft.



Little cogwheel with wallower on shaft with some broken rounds. Stone nut gear running off little cog is missing.

Lantern, trundle, wallower gears or stone nuts are different archaic names for old mill pinion gears. The lantern gear likely got its name since it looks somewhat like an old lantern. It is made using two thick circular disks held apart by round rods or thick dowels called "rounds." These were typically made using hickory or hard maple for strength and grain tightness that reduced the friction and wear as the cog tooth entered and drove the round forward as it pulled out of the trundle housing. The upper disks could have been made using any other conveniently found hardwood like oak. To keep the disks together millwrights made iron bands to secure the wooden disks made just smaller than the disk diameter. The bands were heated directly in a fire allowing the metal to expand. Once heated the band was moved from the fire by tongs and placed over the disk. Being very hot its diameter was slightly larger than the disk's and then was quickly quenched using buckets of water to get the bands to shrink while putting out any fires started on the disk circumference. This process was likewise done around the ends of all large shafts to hold in bearing sleeves using Ellicott's instructions in the next article. Before the lantern gear was ready for use the millwright split the ends of each round (on both ends) and drove in hand-made wooden wedges to securely hold the round to the disk body since it typically turned at speeds greater than 100 RPM experiencing considerable vibration. The lantern or wallower gear used to drive the millstone spindle was typically called the "stone nut" or "nut." Examples of actual installed lantern gears can be seen in Figure ___ on the lower left side that show both horizontal and vertical orientations. The lantern from Livezey's Mill shows a rectangular central hole for a rectangular shaft which the gear securely forced to turn (Figure ___). On the other installed lantern gears seen below the Livezey gear, wedges (not easily seen) were hammered into a gap between the inner hole of the gear and the large round shaft which went through the gear's central hole. These wedges would be added around the entire circumference so the lantern gear would not slip while the larger shaft turned making them turn as a single unit.

Conclusion

In this article we have discussed the technical documents containing information important to understanding mid eighteenth century flour milling. It also overviewed the milling process using an excellent three-dimensional model of an eighteenth century mill found at the Hagley Museum and Library near Wilmington, Delaware. We attempted to re-create Livezey's original Mill using available photographs and other related historical information comparing the original mill structure with the one rebuilt and enlarged after the 1793 fire. This discussion was aided by present day field photography of milling components that Livezey said existed in his mill contained in notes made when he maintained, repaired or replaced them during the first 26 years of the mill's life. Finally the article concluded with a discussion of gearing basics that will serve as a transition to the next article where we will go deeper into Livezey's gearing systems from his own words.

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