The Significance of the Bethlehem Waterworks

From the Collections at Historic Bethlehem [PA]

Two questions can be asked about the significance of Bethlehem's waterworks. First, why did the Moravians build a mechanized water system? Second, how does this system compare with others in the history of western and American technology?

All evidence indicates that a mechanical pumping system was desperately needed. The geography of colonial Bethlehem, with the steep lull separating the Monocacy Creek flood plain where the copious spring was located from the town above, made hauling water difficult and laborious. One visitor to Bethlehem in 1754, Israel Acrelius, a Swedish minister, wrote after seeing arrangements made for Christensen's initial test:

In the same house [oil mill] they were now arranging water-works, which were to drive the water up the steep hill, and then through pipes distribute it to every house, which work a Jutlander had undertaken to accomplish. The Brethren were now working at this very actively and industriously. This will be a very useful work for the cloister, for hitherto it has kept a man busy from morning till night to carry the water up the hill to the houses.

There were other water sources near the choir houses, a map dated c.1765 shows a spring near the Sisters' House, and Thomas Pownal's 1754 (drawing of the community shows a series of wells located behind the Brethren's House, For a growing town, however, these sources were evidently not enough to supply everyone's drinking and cooking needs. By the mid-1750s, Bethlehem's population had increased to over 1,000.

Fire protection was certainly another important aspect of Bethlehem's concern for water. Constantly-filled reservoirs would give the citizens places to fill buckets and lay hoses in case of conflagration. The need for continuing fire protection was expressed in a meeting of the Aufseher Collegium on January 30, 1793. The Overseers voiced concern that when the waterwheel did not run constantly, the lowered water level of the reservoirs would be dangerous if fire started. The record continued: "Bethlehem simply did not have enough inhabitants to form rows to the Monocacy if fire broke out."

Albert Jordan states that town officials had asked Henry Antes, an earlier mill-builder for Bethlehem, to look into the water problem but there is no evidence that he ever did anything about it. Christensen's arrival in 1751, however, brought another man with great mechanical skill to the community. It is not known if he was specifically asked to develop a system, or if he took matters into his own hands when he saw the problem, but his success filled the "hearts of Bethlehem with great joy." The Bethlehem Diarist recorded on May 21, 1755, when water first flowed to the Brethren's House, that the congregation rejoiced and gave thanks in the hope that an "indescribable need in Bethlehem would be filled in a permanent way." It was also recorded that a special service of thanksgiving was held to commemorate the occasion.

Proud Moravian guides also showed the waterworks to the numerous visitors to colonial Bethlehem. In turn, many visitors who left written accounts of their sojourn in the town mentioned the water system. On April 12, 1774, the Single Brethren's Diarist recorded that Baron von Repsdorf, Governor of St. Croix, toured Bethlehem and enjoyed his visit very much. Brother Christensen presented him with a plan and description of the waterworks.

John Adams, lodging in the Sun Inn during the Revolutionary War, mentioned the waterworks in a letter to his wife Abigail, dated February 7, 1777:

They have carried the mechanical Arts to greater Perfection here than in any Place which I have seen. They have a set of Pumps which go by Water, up through leaden Pipes from the River to the Top of the Hill, near a hundred feet, and to the Top of a little Building, in the shape of a Pyramid, or Obelisk, which stands upon the Top of the Hill and is Twenty or thirty feet high. From this Fountain Water is conveyed in Pipes to every Part of the Town.

Visitors to Bethlehem in later years were equally impressed by the system. John David Schoepf, who came to Bethlehem in 1783 on his travels through the states, remarked:

Since Bethlehem stands on a height composed of limestone, a single spring, but a strong and beautiful one, must supply the whole place and all the houses with water. This spring lies far below at the foot of the hill and near to the river. An excellently contrived water-works, (suction and pressure), raises the water through copper pipes to a watertower, standing some distance away on the hill near the larger buildings. . .

The water system with its "rich spring" was also mentioned by Theophile Cazenove in 1794, and by Jolm C. Ogden in 1799:

The spring which furnished the town, is at the foot of this hill, and enclosed within a small stone vault or cellar. It affords a redundancy of water, which is raised to the height of one hundred and twenty-five feet by forcing pumps which are in constant movement, by means of a small water-wheel supplied from the Manakasy.

If colonial visitors were excited by the state of the "mechanical Arts" in Bethlehem, the question must then be asked as to where the waterworks stood in the development of technology in western civilization as a whole and in American technology in particular.

Machines to raise water had been used for centuries in Europe and, therefore, were not new in the mid-1700s, when Bethlehem began to develop its water system. Thomas Ewbank, in his study of hydraulic machinery, states that German cities used forcing pumps to raise water for public use by the end of the 15th-century although few details remain about these systems. He cites Augsburg as having a pumping system, which raised water 130 feet, mentioned in accounts of 17th-century visitors to that city. Bremen in the same period had a waterwheel, mounted on a bridge, which raised water to a reservoir. Charles Singer, a noted historian of technology, records that by 1770, about 140 German towns and cities possessed central waterworks systems. It is, therefore, logical to assume that Christensen and Arbo, the two mechanical geniuses of the Moravian waterworks, had seen some of these systems operating in Germany. In addition, John Arbo probably owned a copy of the *Theatri Machinarium Hydraulicarum*, printed in Leipzig in 1724, which illustrated forcing pumps used in various combinations and explained how they were employed in waterworks systems and mining operations.

France and England installed pumped water systems later, often using the expertise of German engineers. London developed its first water pumping system in 1582. It included a series of forcing pumps, built under an arch of the London Bridge, operated by a waterwheel turned by the Thames River. This system pumped four million gallons daily and the water reached a height of 120 feet. Over the years the number of pumps and wheels was increased. The system was removed in 1822, when that London Bridge was torn down.

In 1603, Henry IV of France approved a system of pumps and log pipes that raised and carried water from the Seine to the Louvre and Tuilleries. By 1782, the Marli waterworks near Paris pumped water from the Seine to the public gardens at Versailles.
What was becoming commonplace in Europe, however, was relatively unheard of in the American colonies. Most towns and cities relied on public and private wells, cisterns, and fountains, or obtained their water from creeks and rivers. Therefore, it is no surprise that the prospect of a mechanized central water pumping system in a small frontier community excited visitors to early Bethlehem.

The earliest American water systems merely transported drinking and cooking water in pipes from its source to a reservoir. In 1652, the Boston Waterworks Company was incorporated to construct a conduit which carried water to a reservoir where it was stored for use. Useful in case of fire, the system was eventually abandoned. A similar system was organized in 1772, when the Providence Water Company and Rawson's Fountain Society were incorporated to bring water to Providence, Rhode Island from a spring one mile away.

In July, 1774, the Common Council of New York City asked engineer Christopher Colles to develop a plan to bring water to the city's 22,000 residents. Colles devised a scheme employing a steam engine and pumps to raise water from the Bronx river to a reservoir. In 1775, the cylinder was cast for the steam engine and the engine became operational one year later. The water system was abandoned shortly thereafter because the supply of water produced was inadequate and because of the confusion of the Revolutionary War.

Americans in general did not develop an interest in public water systems until the 1790s. Yellow fever epidemics were rampant during this decade and all major American cities were affected. In Philadelphia, the 1798 outbreak killed 3,500 while 40,000 citizens fled the city.

The yellow fever brought on heated discussions concerning the reasons for it. Doctors and other concerned individuals, linking the disease with water sources polluted by garbage and sewage, began to demand clean sources for public drinking and cooking water. By this time, as well, American technology had advanced enough to make sophisticated water systems possible.

In 1792, Pennsylvania Governor Thomas Mifflin approved the incorporation of the Delaware and Schuykill Canal Company to supply Philadelphia with piped water. Part of a grandiose scheme to join the city with Lake Erie and the Ohio river, a canal was started but soon abandoned because of financial difficulties.

The 1798 yellow fever epidemic again initiated a search for a more adequate water system and Philadelphia's city officials approached engineer Benjamin Latrohe to supply the citizens with "wholesome water for culinary purposes" and to "cool the air." In his View of the Practicability and Means of Supplying the City of Philadelphia with Wholesome Water (1798), Latrobe suggested that a steam engine raise water from the Schuylkill river to a reservoir, a height of 50 feet, from where it would be conducted to another reservoir. In 1811, the Fairmount Waterworks with two steam engines and pumps began operation. Interestingly, the great expense of the steam engines caused city officials to revert to three waterwheels in 1822.

New York City consulted William Weston in 1799 for a system to bring water for drinking, cooking and cooling the streets to its residents. In his reply, the Report of William Weston, Esquire, on the Practicability of Introducing the Water of the River Bronx into the City of New York, Weston also suggested a steam engine to raise water to a reservoir.

The following conclusions then can be made about Bethlehem's water system.

- First, the machinery of the waterworks was not unusual when western technology is studied as a whole. Public water systems in Europe had employed forcing pumps in various combinations driven by waterwheel since the 1500s.
- Second, in the study of American technology, it can safely be stated that the Bethlehem waterworks was the first pumped municipal water system in the colonies. The Bethlehem waterworks came thirty years before the larger American cities like New York and Philadelphia put effective systems into operation.
- Third, the height to which the spring water was pumped appears unusual. Most other American and European systems pumped water 50 feet on the average and some of these systems employed steam power. The Bethlehem waterworks forced the spring water 320 diagonal feet or 94 vertical feet when it began operating in 1762 and without trouble was able to pump 28 additional feet during the 1798 test.
- Fourth, the Bethlehem waterworks was supported by a community totally committed to its use. Its need was recognized and it saved laborious and time-

consuming work. Unlike other systems, when repairs and problems became apparent, the system was improved, not merely abandoned.

Archaeology, Restoration, and Reconstruction

Bethlehem's waterworks was the subject of two extensive summer archaeological excavations conducted by Historic Bethlehem Inc. in 1964 and 1972. In June, 1975, an intensive salvage project to prepare the first floor machinery room for the reconstructed waterwheel and pumps was conducted. Restoration of the exterior of the 1762 waterworks took place in 1972-1973. The reconstructed machinery was installed in 1976 and then a more accurate reconstruction of the machinery was installed in 1991.

In recent years, the waterworks has been recognized as an Historic Civil Engineering Landmark by both the local and national chapters of the American Society of Civil Engineers and an American Water Landmark by the American Waterworks Association. It is also listed on the National register of Historic Places.

1991 Machinery Reconstruction

An exact reconstruction of Hans Christensen's 1762 machinery is impossible, because the 1766 drawings omit several critical details of the waterwheel and gears. This omission is not surprising, since waterwheels and gears were standard 18th-century machinery components and every millwright learned how to build them during his apprenticeship. Each master millwright had his own trade secrets that he did not want revealed. So, while we can argue about the accuracy of certain details, the truly amazing thing is that the machinery can be reconstructed all! The current (1991) reconstruction of the waterworks is a combination of details from the original 1766 machinery drawings and a 10-year study of typical late 18th-century practices in northern Germany and Denmark.

Main Machinery Framing: Designed and built by Eisenhart Mills, Easton, Pa as part of the 1976 machinery reconstruction, these main framing members are the only parts remaining from the 1975 machinery reconstruction. Everything else was scrapped or extensively altered. The framing is white oak timbers, 12' x 12', weighting approximately 3 tons.

Waterwheel and Gearing: The waterwheel and crankshaft gear are "clasp arm" design, where the arms are wedged to the outside of a square shaft, rather than being mortised through it. This was a very typical design for 18th-century Danish waterwheels and gears, so it is the one that Hans Christensen probably would have used.

The clasp-arm design was, and still is, popular in northern Europe. However, it was never widely used in the American colonies. The compass-arm wheel design, described in detail by Oliver Evans, was much more popular here. The waterworks wheel may be the only example of a clasp-arm waterwheel existing in the United States, and there may be only one other clasp-arm gear in the country--all other mills have compass-arm wheels and gears.

The shaft is one piece of white oak, 2 feet square by 9 feet long, weighing about 1 ton. It was dressed down from a log more than 4 feet in diameter at one end--this tree probably began growing soon after Christensen built his original waterworks in 1762. Look closely at the arm joints--they are not the simple lap joints that they appear to be, but are very complicated partial dovetails. Also note the dovetails near the outer ends of the arms where they bolt together and clamp onto the waterwheel "cants" (rim sections). These are 18th-century details that almost no one includes in reproduction waterwheels today.