WESTERN STYLE SPRING FOUNTAINS, PLAYS OF WATER AND HYDRAULIC CONSTRUCTION IN THE YUANMINGYUAN IN BEIJING AND THEIR EUROPEAN MODELS

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Keywords

Beijing, Yuanmingyuan, hydraulic construction, spring fountains, Bernard Forest de Bélidor, Edme Mariotte

Abstract

Theme of the paper are the Western style spring fountains and plays of water in the Old Summer Palace Yuanmingyuan in Beijing, which were built on request of Emperor Qianlong in 1747-1759 together with the Western Buildings. In contrast to the latter, the fountains and the hydraulic constructions, all designed by the Beijing-based French Jesuit, mathematician and astronomer Michel Benoist (1715-1774), are less studied. Neither Benoist nor the Chinese craftsmen had practical experience with the artistic and technical design and the execution of this kind of fountains. In this specific epistemic situation Benoist had to dwell almost exclusively on European book publications on the topic. Concentrating on the first group of fountains around the Palace of Harmony, Wonder and Delight (Xieqiqu) the paper investigates the design processes and the role of the treatises of Morland, Mariotte and Bélidor, which offer concrete design and calculation methods and machine technology, and which were available in the Jesuit libraries in Beijing.

Acknowledgements

The present paper presents some research results achieved by the present writer within the ongoing, larger collaborative research project between the Beijing Tsinghua Heritage Institute for Digitization THID (Tsinghua University Beijing; project head Yin Lina) and the Bibliotheca Hertziana (Max Planck Institute for Art History, Rome; project head Hermann Schlimme). The project is devoted to the now ruinous Western Buildings that are part of the Old Summer Palace Yuanmingyuan in Beijing, and which were planned and erected around 1750 by Italian and French Jesuits and Chinese architects and craftsmen. The aim of the project is to comprehensively investigate and understand the Western Buildings and to analytically visualize them in virtual 3D-models. The project examines the Sino-Western experience in the planning and construction processes with the mutual exchange of techniques and methods, concepts and models, and explores the interaction between Chinese and Western conceptions of architecture, gardens, fountains, construction and hydraulic technologies.

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INTRODUCTION

The wish of Emperor Qianlong to have European-kind spring fountains and plays of water was the main motivation for the construction of the today ruinous Western Buildings (Xi-yanglou) in the Old Summer Palace Yuanmingyuan in Beijing in 1747-1783. The architecture was designed by the Beijing-based Italian Jesuit Giuseppe Castiglione and executed by Chinese architects and craftsmen. The architecture of the Western Buildings has been studied extensively (to mention some of the titles: Adam 1936, Schulz 1966, Pirazzoli-t'Serstevens 1987, Droguet 1994, Thiriez 1998, Chiu 2000, *Disturbed dreams* 2010, Guo/He 2010, Zou 2011). The artistic and technical design process of fountains and hydraulic constructions and the hydraulic technology itself, however, have not been studied so far. The present paper aims to make a contribution in this sense. All fountains were designed by the Beijing-based French Jesuit, mathematician and astronomer Michel Benoist (1715-1774), decided by the Emperor and executed by Chinese craftsmen. We know about Benoist through the letters he and his Jesuit fellows wrote from Beijing to Europe (*Lettres édifiantes* 1843, Cordier 1882-1887, T'oung pao 1917-1918-1921). In 1860, at the end of the Second Opium War the Yuanmingyuan was destroyed by Western troops. Sources for the systematic study of the Western Buildings are among many others the written sources (the aforementioned letters and more), the photographs of the ruins and a series of engravings from 1783. Furthermore we have drawings and other materials from the archive of the architect's family Lei in the National Library in Beijing (Guo/He 2010) and the archeological remains on site.

Figure 1: Bélidor 1737-1753, frontispiece (Bibliotheca Hertziana, Rome); Figure 2: Versailles, garden and castle, etching by Adam Perelle, ca. 1680

The fountains and plays of water were not the first ones in China. There had been dragon-fountains and spring fountains in the palaces of Yuan Dynasty Emperors, but they were destroyed in Early Ming Dynasty (14^{th} century; Needham 1971, pp. 133-135). Qianlong's predecessor Emperor Yongzheng had the idea to erect a continously playing European style fountain in the Yuanmingyuan, but it was not realized and not even planned (Zou 2011, p. 122; Ripa 1861, pp. 127-128). Thus at the moment of the Western Buildings there was no current craftsmanship available in China for the realization of European fountains and also Benoist had no experience with the artistic and technical design and the execution of fountains and hydraulic technology. Benoist had to dwell on European book publications on the topic – the sources explicitly say that he worked on the fountains "avec le secours des livres" ("with the help of the books")(*Lettres édifiantes* 1843, p. 226). The paper concentrates on the first group of fountains around the Palace of Harmony, Wonder and Delight (Xieqiqu), completed in no more than half a year in autumn of 1747 (*Lettres édifiantes* 1843, pp. 162-180). The paper analyses the interaction of art and technology in fountains and investigates the Western Building's fountains design process on the basis of up to now unconsidered sources. In the focus is the role of the treatises of Samuel Morland (1685), Edme Mariotte (1693) and Bernard Forest de Bélidor (1739, fig. 1), which were available in the Jesuit libraries in Beijing. Through these investigations the paper aims to shed new light on this paradigmatic chapter of Sino-Western knowledge transfer concerning fountain design and hydraulic construction.

THE EMPEROR AND THE EUROPEAN FOUNTAINS

As is well known from letters the Jesuits wrote from Beijing to Europe the Emperor Qianlong in 1747 had seen a painting of European spring fountains and decided to have similar ones in his Summer Palace (*Lettres édifiantes* 1843, p. 226). He may have seen those of Versailles, as the French King Louis XIV. in 1688 had sent *Vues, plans etc du Château des Versailles* as a present to Emperor Kangxi, the grandfather of Emperor Qianlong (fig. 2 and Pirazzoli-t'Serstevens 1987, p. 18). The Emperor's wish to have explicitly European fountains enhanced the contrast between on the one hand Chinese use of water in parks with natural flowing water and naturally formed water edges and, on the other hand the concept of water in European (Italian and French) gardens, where water does not appear "in its natural form but rather through artificial contrivances", based on mechanical, power-driven, hydraulic systems (Zou 2011, pp. 122).

The first group of spring fountains and plays of water around the Palace of Harmony, Wonder and Delight (Xieqiqu, figg. 3-5) include the water reservoir building to the northwest of the Xieqiqu (Xushuilou; figg. 8, 9), the single spring fountain on the north side of the Xieqiqu (figg. 3, 4) and, taking advantage of the sloping ground, the complex curvilinear-shaped water basin situated about 1,35 m lower and attached to the south side of Xieqiqu with varied spring fountains and plays of water (fig. 5). The front edge of the intermediate stair landing is linked to the surface of the water basin through a series of little water spouts (fig. 5). In front of that we see a row of eight water spouting wild geese. In front of them we recognize two crabs creeping up smalls rocks and spouting water to the sides. Two dogs, two sheep and two further birds, which are sitting on the balustrade of the water basin, are spouting back. In between these intercrossing water spouts we find high vertically springing fountains coming out of two lotus flowers and out of a big fish. The overall aesthetics of the fountain with its richness and the sheer number of water spouts can be compared with European examples like Versailles (fig. 2) or the Villa Lante in Bagnaia in Italy.

Like in Europe itself, the Chinese saw European fountain art and hydraulic technology as a whole. In fact the choreography and the shapes and copiousness of the springing and spouting water is an ephemeral but integral part of the architecture of fountains, which relies on and at the same time is "engineered" by the hydraulic construction. Bernard Forest de Bélidor in his treatise in fact not only describes how to design, calculate and dimension basins, spring heights, water quantities, tubes and nozzles, but he also describes all types of plays of water and water spouting forms from the artist's point of view, represents them in images and deals with the aesthetics of the water jet of a spring fountain and describes how the ideal of a compact, transparent and uniform jet can be obtained through precise engineering (Bélidor 1739, pp. 392-397 and p. 412). These artistic aspects can, however, just be mentioned here, but this much can be added: It is this art-engineering-interaction through which the Western Fountains were integrated into Chinese culture. Hui Zou puts it like this in his 2011 book publication: “The water method of a fountain was a transformation of a Western fountain and it held its own meanings through its ‘view’ in the Chinese context” (Hui Zou 2011, p. 123). This was mostly done through poems, which describe the feelings of the spectator (in this case the Emperor). The water jet, which shows stability in movement, became a metaphor for the harmony in a society and watching water features in the garden became part of symbolic actions of the Emperor, which reminded him that it was his goal to care for the happiness of the population (Hui Zou 2011).

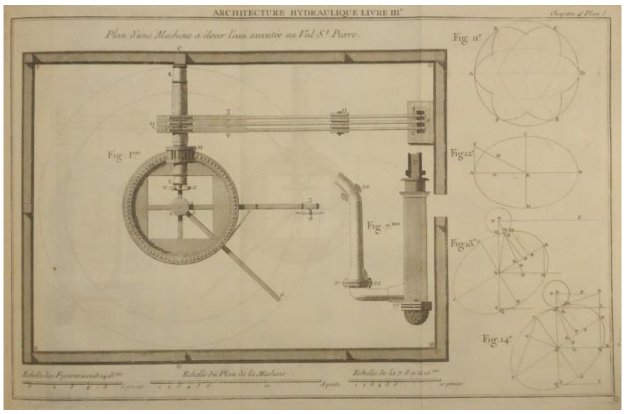
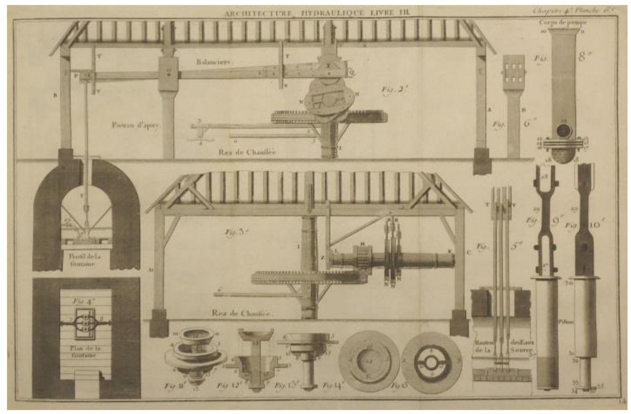

Figure 3: The north side of the Xieqiqu with the rests of the spring fountain, photograph E. Ohlmer, 1873 (from: Beijing World Art Museum, Qin Feng Studio 2010, p. 51); Figure 4: the same view today (Creative Commons License BY-SA; foto by 颐园新居, 2013)

Figure 5: Xieqiqu, south side with spring fountains and plays of water; etching, 1783, detail

MACHINES FOR LIFTING THE WATER

Water technology was not only the tubes which conduct the water to the spring fountains and the water spouting animals, but the important and expensive aspect was to lift huge amounts of water up into a water reservoir that had to be at least as high as the artists wanted the water to spring up. In the Villa d’Este in Tivoli near Rome, where we have very early spring fountains, a 1000 m long tunnel was dug through the mountain to deviate 600 to 800 liters of water per second from the Aniene river into a high water reservoir, which feeds the fountains. Thanks to the steep topography and the river coming down from the mountains it was not necessary to mechanically lift the water into a reservoir. Similar were the cases of Villa Aldobrandini in Frascati and Palazzo Farnese in Caprarola.

Providing water for spring fountains and plays of water was much more difficult when the topography was almost flat as in Versailles and in Beijing. In Versailles it was necessary to lift the water from the Seine no less than 160 m uphill. Therefore huge machinery, the famous Machine de Marly, was constructed from 1680 onwards, which lifted about 2.000 to 2.500 cubic meters of water a day being powered by the flowing water of the Seine itself. That was the amount of water which in Tivoli arrives without machine in about an hour. The Machine de Marly was integral part of the King's self-representation and symbol of his power and the well functioning of the French State. Visits to the machine were part of gentlemen tours to France (Brandstetter 2008). Bélidor's frontispiece (fig. 1) shows a similar situation. We see a lifting machine, which pumps the water in the reservoir on the left. The machinery is hidden in architecture but finds the interest of the people. The water from the reservoir then serves for the plays of water and the high spring fountain in the background.

Figures 6 and 7: Water lifting machine as built in the Chartreuse en Tiérache, val Saint-Pierre, near Vervins, France, plan, sections and details; from: Bélidor 1739, 3rd book, 4th chapter, plans 5 and 6 (Bibliotheca Hertziana)

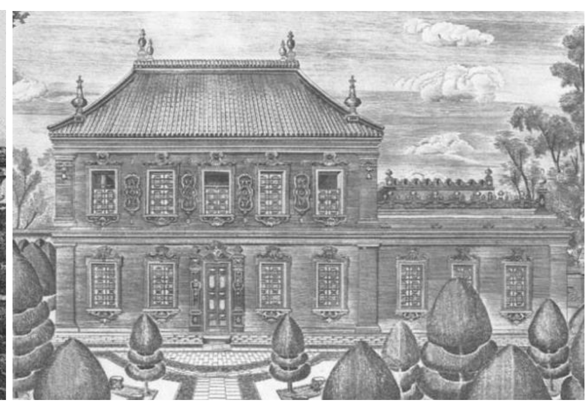



Figure 8: The Xieqiqu (left) and the Xushuilou water reservoir, photograph S. Black, c. 1915 (from: Thiriez 1998, p. 40); Figure 9: The Xushuilou water reservoir, etching, 1783, detail

The water reservoir was situated in the lower part of the reservoir building (Xushuilou) as drawings published by Maurice Adam confirm (Adam 1936). Unfortunately these drawings are lost today (Rujivacharakul 2012). In order to pump water up into the reservoir, Benoist built a machine, which the Jesuits in Beijing named "machine du val de Saint-Pierre". Source for this is a letter, which the Jesuit Amiot wrote to De la Tour the 17. October 1754 (*Lettres édifiantes* 1843), where he affirms: "père Benoit exécuta, il y a quelques années, la célèbre machine du val de Saint-Pierre, pour fournir aux plus variés et aux plus agréables jets d'eau, qui embellissent les environs de la maison européenne, bâtie sur le dessin et sous la direction du frère Castiglione".

And this can refer only to the Xieqiqu, as the construction of the second group of fountains (Haiyantang) was achieved later.

Bélidor's *Architecture Hydraulique* deals with the machine du val de Saint-Pierre and makes a „Description & analyse d'une machine exécutée au Val Saint-Pierre" in the Chartreuse en Tiérache, near Vervins in France (Bélidor 1739, pp. 142-157). As this is (as far as the present writer knows) the only description of the machine de val Saint-Pierre available at the time, the book of Bélidor was evidently available in the Jesuit libraries in Beijing, though it is not in the Verhaeren book list of those libraries (Verhaeren 1949/1969, see Koenig 2014 for a shortlist of books on hydraulics from Verhaeren). Verhaeren's list is, however, not at all complete as lots of books were lost for different reasons before Verhaeren made his list (Golvers 2012/13). After the present writer had found this link on his own he saw that Schulz in 1966 already mentions this link Benoist-Bélidor, but Schulz does not at all elaborate it. He does not mention the length of Bélidor's detailed description (25 pages!) and does not reproduce or even mention two engravings showing the machine. The present author is thus the first to link these images (figg. 6, 7) to the Yuanmingyuan. This was already presented by the present author on 25 March 2014 during an international workshop in Rome (Schlimme 2014).

That the horse-driven machine de val Saint-Pierre, which moved the poles for the pistons up and down through elliptical wheels, was executed in Beijing finds two further confirmations. First, the inside space available in the upper story of the Xushuilou measured 16,30 x 10,10 m (survey of the remaining building foot print) and was sufficient for hosting exactly the machine published in Bélidor (fig. 6, 7), which requires 13,85 x 9,85 m of space. Second, one can see the machine through the windows of the building in the engraving (fig. 9). Benoist chose to execute the machine de val Saint-Pierre in Beijing most probably because Bélidor recommended this horse-driven water-living machine explicitly for places situated in plains with just a brook or a source (thus without a big river) as was precisely the case in Beijing (Bélidor 1739, pp. 414-415). Furthermore, Bélidor offered a precise technical description. Bélidor acknowledges Samuel Morland as inventor of the elliptical machine and cites Morland's treatise (Morland 1685), which was available in Beijing.

CALCULATION FOLLOWING MARIOTTE AND BÉLIDOR

As already said, Benoist had no experience with water lifting machines and with the design of spring fountains and plays of water and re-invented the technology from the treatises at hand. When talking about Benoist's work on the fountains of Xieqiqu, the Jesuit letters confirm furthermore that Benoist did his job based on calculations, drawings and experiments: "Souvent encore il étoit obligé de se retirer dans sa chambre au sortir de table pour vérifier ses calculs, préparer des dessins et faire des essais sans lesquels il n'osoit rien risquer" ("Often he was constrained to go back to his room after dinner in order to verify calculations, prepare drawings and make experiments without which he did not dare any risk")(*Lettres édifiantes* 1843, p. 228).

Morland, however, offers no specific design and calculation methods for spring fountains (Morland 1685). The only treatises available in Beijing to do so, were Mariotte (1686, 1693 and 1717) and Bélidor (1737-1753, especially 1739). Mariotte's "Règles pour les jets d'eau" (Mariotte 1693) were extracted and augmented from the more general 3rd and 4th part of his *Traité du mouvement des eaux* (Mariotte 1686). The *règles* were republished several times. In Beijing also the 1717 edition was available (Mariotte 1717), but the present paper refers to the first version of 1693. Bélidor's "De la manière de distribuer & de diriger les eaux jaillissantes pour la décoration des jardins" is chapter V of the fourth book in the second volume of his treatise *Architecture*

Hydraulique (Bélidor 1739). Both authors offer calculation methods and tables with values for spring heights of fountains, necessary water volumes, tube and nozzle diameters and therefore were surely crucial for Benoist. The paper now shows how Benoist could manage to design and calculate the spring fountains on the basis of both treatises.

As prescribed by Bélidor, Benoist collocated the machine de val Saint-Pierre above the level to which the water had to be lifted. Benoist probably put it on top of the reservoir in the upper floor of the reservoir building with its floor-level slightly above the parapets of the mostly fake windows (fig. 9). The water level in the reservoir would thus be at the level of the cornice between ground and upper floor, which is the level which the spring fountains south and north of the Xieqiqu reach (fig. 5). The height above ground of the water basin, in case the assumptions are correct, would be ca. 4,40 m (in respect to the north side of the Xieqiqu) and ca. 5,75 m (in respect to the south side of the Xieqiqu, due to the difference in the level of the terrain). This was estimated on the basis of archeological surveys and historic photos. On the north side of the main volume of the reservoir-building there is the canal, which is 1,95 m deep from terrain level and which brings the water to the bottom of the lifting machine. The machine needs to have a minimum of 30 cm of water depth in order to work (see fig. 7). The machine has to lift the water 6,05 m (4,40 + 1,65 m) high (= 18,6 *pieds du roi*). Following Bélidor's instructions (1739, p. 147-148) one can recalculate the possible water quantity for any lifting height. A smaller lifting height results in larger piston-diameters and thus in a bigger amount of water lifted, and *vice versa*. The result for 18,6 *pieds* lifting height is 405 liters per minute. This was the amount of water available for the fountains.

Now, Benoist could spend this water. Main "consumers" are the one fountain on the north side (figg. 3, 4) and the three fountains on the south side of Xieqiqu (fig. 5). Following Mariotte (1693), it is possible to determine the necessary water quantities and the diameters of tubes and jets. For the north side fountain, which springs 4,40 m (13,5 *pieds*), Mariotte (1693, table on p. 513) recommends 5 *lignes* (1,13 cm) of jet diameter and 2 *pouces* + 1 *ligne* or 2 *pouces* + 3 *lignes* of tube diameter (5,6 or 6,1 cm). For the south side fountains, which spring 5,75 m (17,75 *pieds*), he recommends 6 *lignes* (1,13 cm) of jet diameter for each fountain and 2 *pouces* + 3 *lignes* or 2 *pouces* + 6 *lignes* of tube diameter (6,1 or 6,8 cm). The consumption of water can be calculated by merging the information from two tables in Mariotte; on the one hand the table where Mariotte gives the water consumption in relation to the jet diameter assuming the fixed basin height of 12 *pieds* (3,90 m; Mariotte 1693, table on pp. 509-510) and on the other hand the table, where Mariotte gives the water consumption in relation to the basin height assuming the fixed jet diameter of 3 *lignes* (0,68 cm; Mariotte 1693, table on p. 510 bottom). By graphic and linear interpolation one can determine that each south side fountain consumes 68,3 *pintes*/min (65 l/min) and the north side fountain 41,4 *pintes*/min (39 l/min). The four fountains consume 234 l/min, thus of the 405 l/min remain 171 l/min for the rest of the plays of water (water spouting animals, water curtain), which seems plausible. Bélidor, who is dwelling much on Mariotte in his treatise, however, simplifies the calculation of the water consumption of spring fountains by merging the information, which was offered by Mariotte in the two cited tables into one table (Bélidor 1739, pp. 406-408). Bélidor refuses interpolation and uses the closest values in the table, as values were anyway approximations. The north fountain due to Bélidor consumes 40 *pintes*/min (38 l/min) and each south fountain 68 *pintes*/min (65 l/min). These numbers are almost identical with those of Mariotte. Interpolation, however, would result in slightly smaller values.

CONCLUSIONS

The paper has shown that on the basis of Bélidor (1739) it is possible – and thus it was possible for Benoist – to precalculate the amount of water lifted with the machine de val Saint-Pierre in its adaption to the Beijing context. Furthermore it is and was possible on the basis of both Mariotte (1693) and Bélidor (1739) to foresee the water consumption of the single spring fountains (and also of the smaller plays of water). This paper re-enacted Mariotte's and Bélidor's calculation methods for the Xieqiqu fountains, and obtained water production and water consumption values, that fit well together. Sources confirm that Benoist used specific book publications and did calculations when he designed the fountains of Xieqiqu. Therefore it is more than probable that he planned and calculated on the basis of the treatises of Mariotte and Bélidor, which were available in Beijing. Their treatises enabled him to plan the number of fountains and water spouting animals and also to determine tube and nozzle diameters and thus to design the complete water features. This evidently worked well as the Emperor ordered Benoist to realize a second, bigger group of fountains (Haiyantang) in 1756. That spring fountains in Beijing were most probably designed on the basis of Mariotte and Bélidor is a further example for how the ever more intense interaction of emerging natural sciences and technology enabled the latter to move away from trail-and-error approaches towards precalculation and precise planning. Nevertheless, ad-hoc solutions kept (and keep) to be largely applied on the construction and building sites.

The paper furthermore has shown that and why the machine de val Saint-Pierre was executed in Beijing, how water art and hydraulic technology are inseparably linked and how design and official reception of spring fountains integrated both aspects. The present author will continue research on the topic within the framework of the collaboration with Tsinghua University, Beijing (see acknowledgements). Next steps will be the documentation and systematic investigation of the physical remains of the hydraulic features on site, which will bring further insights. The second group of spring fountains, plays of water and hydraulic technology in the Western Buildings (Haiyantang) will be studied. A further step will be to investigate, to what extent the experience of the craftsmen with the water lifting technology commonly used in Chinese agriculture was adapted to realize Benoist's plans for the Emperor's fountains.

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