Ornamental Hydraulics in the Arenberg Park of Enghien in the 17th Century: a possible link to Salomon de Caus

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Background

The park of Enghien [1] was acquired in 1607 by Prince Charles of Arenberg and Princess Anne de Croÿ, when they wished to retire from the court life of Archduke Albert and Isabella, governors of the Spanish Netherlands in Brussels. They were 57 and 43 years old, respectively.

Figure 1: Portraits of Charles of Arenberg and Anne de Croÿ

Charles of Arenberg was chamberlain to Archduke Albert and carried out diplomatic and military missions on his behalf from 1598 to 1606. Anne de Croÿ was a lady in waiting of the Archduchess Isabella. She was the sister of Charles de Croÿ, governor of Hainaut, well known for the "Albums de Croÿ". When her brother Charles died, without an heir, Anne de Croÿ inherited all his titles and fortune.

As soon as they settled in Enghien, the prince and princess undertook the creation of a new garden, instead of a new residence, and they gathered a fabulous botanical collection. Prince Charles died in 1616 and Princess Anne in 1635. After Charles's death, Anne ruled - Enghien alone and with an iron fist:

> 'In 1611, orange trees were brought from Brussels, grafts from Paris, firs from Spain as well as many plants and flowers. The provost from Tournai sent pheasants to populate the park, the abbot of Saint-Martin sent orange trees. Several flower gardens were created, and a gorgeous aviary filled with all kinds of singing birds [2] was built in one of them.'

> 'In 1620, the princess added new embellishments to her grotto. According to the records, this place was as interesting as it was rare and valuable since there were an organ, cuckoos, nightingales and other bird automata whistling and singing by means of water supplied to the grotto by a pump and pipes [3].'

Their eldest son, Léopold, suspected of having taken part in the *Nobles Conspiracy* against the Crown of Spain, was taken and kept in captivity in Madrid, where he died. He was posthumously pardoned and awarded the title of Duke.

The fifth son of Charles of Arenberg and Anne de Croÿ, Antoine (1593-1669), took over the office of chamberlain at the court of Brussels in 1606. When his father died in 1616, Antoine entered the Order of the Capuchin. He was also suspected of conspiracy and was sent into exile. He travelled around Europe and became friends with the Nuncio Fabio Chigi, future pope Alexandre VII (1655-1667). Antoine of Arenberg was staying in Rome at the time Alexandre VII had Bernini build Saint Peter's Square. When Antoine was cleared, he returned, became general of his order and designed the park of Enghien for his nephew (the son of Léopold) Léopold-François.

When Antoine entered religious life, he handed over all his belongings to his mother, including his library which was a witness of his knowledge of ancient philosophy, poliorcetics, mathematics, botany, astronomy and architecture. He owned, among others, The *Four Books on Architecture* by Andrea Palladio. He took the name of Father Charles of Brussels.

Hydraulic works in Enghien in the 17th and 18th centuries

We know about the "Fameux parc d'Anguien and its mouvements d'eau:" from the following sources

Written sources:

- The account of Father Charles of Brussels, designer of the Park, written around 1665 and intended for visitors [4]

- The description made by Nicolas Visscher, printer [5],to accompany a series of engravings printed in Amsterdam by Romeyn de Hooghe in 1685

- The Description du jeu des eaux des fontaines jaillissantes, bassins, réservoirs, conduits, décharges, aqueducs, écluses, written by the master of works of the city of Mons, H. Deseaublaux in 1787 [6]

- The Mouvement des eaux by the surveyor in charge H. Delulle in 1841 [7]

Illustrated sources:

- A series of supposedly anonymous engravings which should have illustrated Father Charles' account
- The series of etchings by Romeyn de Hooghe from 1685, entitled Villa Anguiana
- The plan associated with the Description by Deseaublaux in 1787
- The plan of the Mouvement des eaux by Delulle in 1841

Archaeological recording:

- Several investigations were led by architecture students from the Institut Supérieur of Architecture Saint-Luc in Brussels, supervised by the author of the project during the summers from 1993 to 1995

We consider that the topography and the geology of the park has not been altered since it was acquired by Charles of Arenberg in 1607.

The park is naturally supplied with water from a number of sources:

- From the East by the river Warelles, which has its source near the castle of Warelles at a height of 75 meters
- From the South East by the river Bourlotte, which has its source at the Champ du Cochet at a height of 77.5 meters at the top of the watershed, just before the Valley of the Senne, which flows into Steenkerque
- From the South by the stream of Maire-Bois (Tierne Farm, 85 m.) and by the stream of Balingue (Balingue Farm, 77.5 m.)

The last three join in Hoves and form the river Odru, which currently enters the park under the highway A8-E429 close to Park Farm. Collectively these sources represent a watershed of about five kilometres wide from East to West by six kilometres long from North to South.

Within the park, the valley of the Odru was landscaped with ponds which were, along the direction of flow;- the Grand Canal; the Mill Pond (adjacent to the castle farmyard); and the Dodane, the former city ditch. The lowest point of the park reaches 52.5 metres.

A small tributary from the East begins in the Duck Pond and feeds the Mirror Pond, the castle moat and the Mill Pond. Geologically, the ground consists of a five meter deep layer of silt, on a clay base fifteen meters deep, covering a sandy and permeable subsoil containing pressurized water. If a well is drilled, the water comes up nearly to the surface of the silt.

Figure 2: Plan and relief of the park of Enghien

Principles

Naturally storing water at the highest point

The Seven Stars circular basin was the first reservoir built in the park in 1661, at the highest point of elevation (72.5 metres). It has a surface area of 1018 m^2 and a water volume of 940 m^3. It is fed by a spring, which seems paradoxical because of its altitude but is possible bearing in mind the screed of clay covering the layer of sand.

Figure 3: The pavilion of the Seven Stars and its circular basin, Romeyn de Hooghe, 1685

A large pond was created in 1673 on the Eastern plateau and was named after its designer, the canon Munoz [8] of Mons. It collects springs at an altitude of 70 metres and constitutes a water reserve of 200 x 250 x 2.5 m., that is 125,000 m³, whereas the highest point of the park is the Seven Stars Pavilion at an altitude of 72.5 metres.

Figure 4: The Munoz pond in the Eastern part of the park of Enghien, dried up nowadays

Artificially raising water

However, according to the engravings and records, two statues of river gods were situated at the entrance of the Seven Stars Pavilion and were pouring water from a vase into the basin. We have recovered the inlet lead pipes of these statues. For water to be pressurized at this location, it had to be coming from somewhere higher. A brick water tower was standing on the Western edge of the heptagonal park. At the top level below the roof, a lead water tank was filled by a pump that would draw water from a ditch, still visible today, and collect the overflow from the Seven Stars basin as well as some of the water from the heptagonal wood.

A similar water tower the South of the Mirror Pond still exists there but dates from the middle of the 18th century. The façades are brick linked by a crossed structure of beams on which lies a lead tank of 3.70 x 2.50 x 2 m., holding 18.5 m³. This tank was supplied from the Munoz pond by the principle of communicating vessels, whereas the one of the Seven Stars is above any possible natural supply.

Figure 5: The water tower called "le Fruitier"

Two types of pumps have been described in the texts. The first one specifically for the water tower near to the Seven Stars Pavilion:

> 'For the water of the tank be conducted to the top of the building n°48 by means of a first lower pump, then a second upper pump, into a lead lined tank located below the roof of the said building.
>
> A lead pipe comes out of this upper tank and brings water down from n°49 to n°50. There, a manhole and three taps lead water to three other lead pipes, one of which feeds the colonnade basin up to n°51 [9].'

The second description applies to the Mail:

> 'On the bottom of the Mail building n°68 was built a machine with a big wheel or drum moved by several men walking inside it. This movement activated three pumps to raise water through a pipe made partly of lead, partly of wood up to a lead tank, called the reservoir of this machine…'

The oldest elevated tank, dating back to 1636, is still hidden behind the fragmented pediments at the top of the Slave Gate and has a capacity of 4.90 x 4.90 x 1 that is 24 m³. This tank is fed by the overflow from the Seven Stars circular basin according to the principles of the communicating vessels. It is the reserve of pressurized water for the five enclosed gardens.

Figure 6: The Slave Gate, water tower.

Delivering pressurized water

The pipes conducting water from the tanks to its release are made either of:

- Lead, in the form of 4 to 6 millimetres thick lead sheets welded longitudinally
- Wood, as trunks drilled longitudinally, shaped to fit together and secured with iron rings
- Pottery, sections of glazed terracotta of about fifty-seven centimetres long, with male/female joints, sealed with mortar

The outflow pipes are different. They are made out of either masonry covered with stone flags or out of wood in the form of long crates held together by wooden harnesses, together with wooden flanges.

Figure 7: Excavation of the foundations of the Fountains Grotto, (Wallon Region, Directorate of Archaeology, under the supervision of te archaeologist Didier Willems, 1999)

Figure 8: Stoneware pipes with the Arenberg coat of arms. (Excavation of the Walloon Region, Directorate of Archaeology, under the supervision of the archaeologist Didier Willems, 1999)

Controlling the flow

The piping goes from one inspection chamber to another, each chamber being equipped with taps and switches:

> '36. Manholes with three taps for water intake through three leaden pipes around 32, 33 and 34 [10].'

These taps are made of brass or bronze and their heads are ring-shaped. They can also be found in the walls of the water towers, evidenced by continuous grooves in the masonry intended for the pipes and recesses inexplicable if not intended for the taps.

In the enclosed gardens, water was used sparingly and reused several times according to the principle of the communicating vessels for the Slave Gate, fountains in the Garden of Florets, circular in-and-out steps stairway and niches, and fountain in the Garden of Flowers.

Creating ornaments

Once water is pressurized, its simplest ornamental form is the water jet, vertical or oblique, shaped by a nozzle: straight, oblique or fan-shaped…Some nozzles are mobile, mounted on an axle and designed to move under the pressure of water, creating a spiral shaped water jet.

A water jets are used as *giochi d'acqua,* designed to trick visitors:

> 'The star-shaped cobblestones of this triumphal arch cover countless of fountains which surprise curious visitors and spray them when they least expect it [11].'

> 'The second tap gives plenty of water by means of a lead pipe with eight little jets buried in the ground that covers the area of the theatre stalls, called the tricks, n°35 to surprise the spectators and make them wet.
>
> A third tap, in the manhole n°34, can be turned on at any time to make water gush out of a lead pipe through five other jets hidden in the ground. It has the same tricky purpose.
>
> In this manhole there is also a fourth little manual tap connected to a leather pouch which, leads to a copper nozzle that can be aimed in any direction to jet water up to seventy or even eighty feet. It was used to spray the people in the theatre, near the basin, at the tricks or anywhere nearby [12].'

Sometimes water is part of the architecture, like the small waterfalls of the circular in-and-out steps stairway linking the Garden of Florets to the Garden of Flowers:

> 'Going down the beautiful steps made equally of water and marble… Do not be trapped in the present, forget all about the past, look up behind and you will have the most varied and beautiful view you could imagine. The one of the two cabinets, the balustrade and the royal stairway with its facing gilded metal statues. You will also see sixteen niches divided by as many pilasters that support everything that lies above. The whole architecture is genuinely beautiful and its whiteness, highlighted by a background of azure mixed with green that appears to be many emeralds and turquoises, gives a very pleasant view on a large area and when the sun shines with all its brilliance, one's eyes can hardly bear its brightness.
>
> Each niche is adorned with various ornaments made of shells or other curiosities from the sea and has in it centre a lion head fountain spilling water into a marble basin. The water flows by a marble canal alongside the alley with a gentle sound, which satisfies one's ear as much as the smell and the sight were satisfied in the garden, where the four lawns (I forgot to mention) are lined with low hedges and orange trees, as there can only be in the most beautiful gardens in the world [13].'

Figure 9: The circular in-and-out steps stairway between the Garden of Florets (above) and the Garden of Flowers (below)

Water jets can also be combined with statues. As stated previously, the statues of river gods at the entrance of the Seven Stars Pavilion were pouring water from the vases they were holding. At the centre of the Orange Trees Basin stands a fountain in typical renaissance style: a small water jet fills a round basin until water overflows around its entire circumference into a second basin held by the Three Graces, which overflows in turn into the larger basin.

> 'In front of the Pavillon du Mail stands the Water Spitter fountain, a more baroque figure: In front of this pavilion, on the avenue side, there is a statue above average height, with outstretched hands and raised head, who throws a big water jet from his mouth into a large, round stone basin, from which water overflows into another basin underneath [14].'

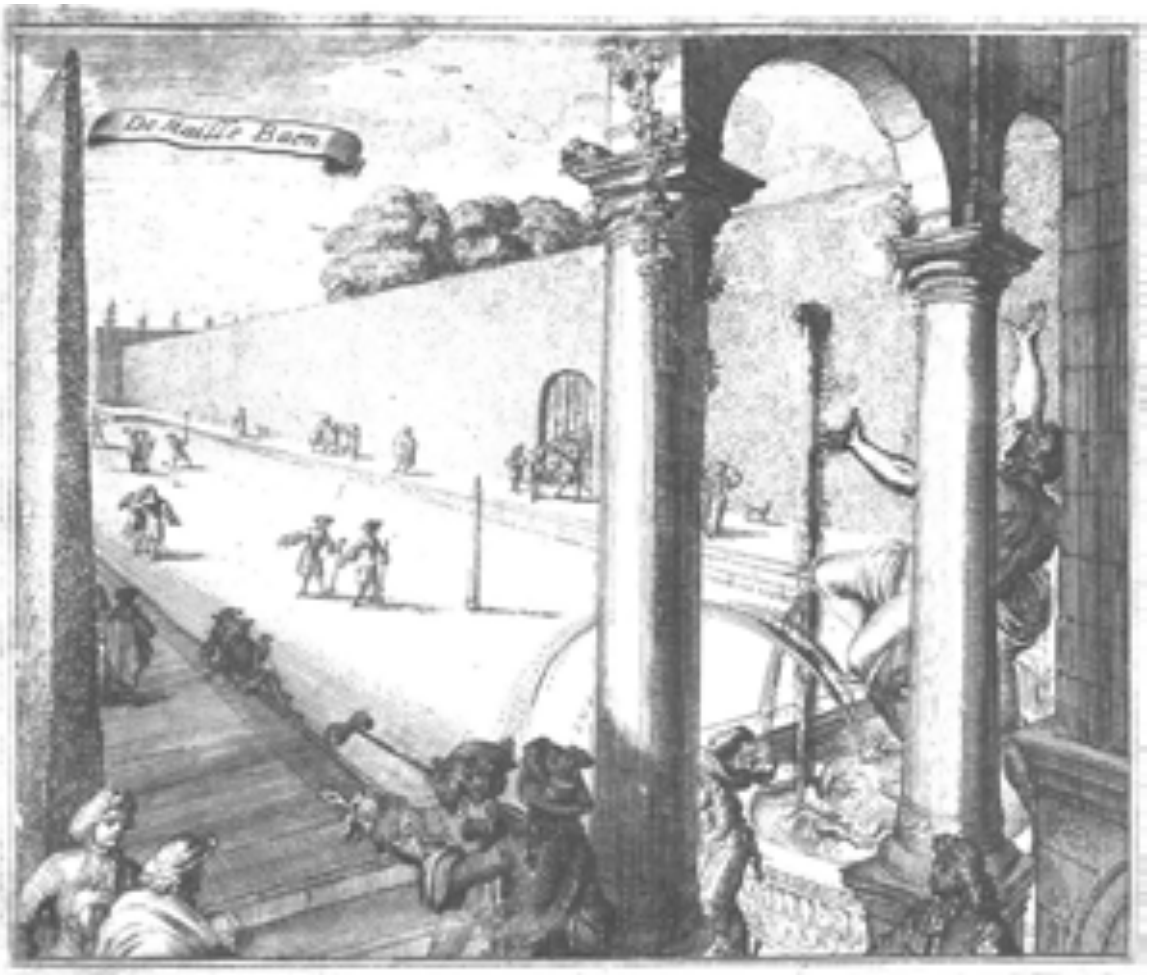

Figure 10: The Mail and the Water Spitter

Water flow can be used in a very unexpected way: a certain volume of water can only be displaced by moving an equal quantity of air. Therefore, we can compress air by filling in a closed volume with water or create a suction by allowing the water to flow out of a closed volume [15]. This principle was used at the top of Mount Parnassus, an artificial hill accessible through two helical paths (see Palladio) and topped by a hexagonal tower, topped itself by a statue of Fame:

> 'At the top of this tower and mountain stands a Fame, who invites everyone with her trumpet that can be heard at great distances to come and see the place [16]

But the most remarkable hydraulic curiosity from the 17th century is the automata cabinet, of which we have two descriptions. The first one, is the more sensible:

> 'The second cabinet compares favourably with the first one and even outshines it by its ornaments and the beauty of the rock, embellished with many water flows. There are three castles, two of them shoot artillery fire and one defends itself bravely: there is no fire in these battle scenes, but water can hit the viewers if they are not careful. There are also six villagers who spend their time trying to shoot a bird on a long pole. The less skilful fail, others make it spin until one of them hits it. There is another (villager) shooting a duck, a water spitting dolphin and some whimsies.'

> 'In the grotto is also represented the fable of Pyramus and This be [17] Pyramus is lying dead, and water gushes out of his wound up to the ceiling. Water jets also spring out of Thisbe wounds to form waterfalls, whose we mentioned before. The rock is dotted with several cupids mourning the death of the two lovers [18].'

The second description emphasizes the recreational use of water:

> 'A large garden divided in several beds of palms, whose branches and leaves interlace neatly and make many different patterns… At both ends of this garden are two lovely cabinets, even more remarkable from the inside where can be seen beautiful grottoes and fountains showing a thousand different moving scenes: uncommon statues representing Pyramus and Thisbe's death, all the technicalities of a castle siege, pole archery hunters, an aviary, etc. While curious spectators admire these rarities, fountains hidden under the cobblestones are switched on and wet them. And when they think of running out, others are ready to throw buckets of water in their faces…'

These works were popular in 1636 and the trend was introduced at the court of Brussels between 1605 and 1610 by Salomon de Caus, the hydraulics engineer invited by the archdukes Albert and Isabella. It should be noted that Charles of Arenberg and his son Antoine were chamberlains to the archduke, the first one until 1606, and the second between 1606 and 1617. It is reasonable to assume that the senior members of the court were knew and may have wished to emulate the latest innovations made in the archduke's gardens?

Searching for Precedents

Examples of hydraulic automata theatres from the 16th and 17th centuries are scarce. Only some visitors descriptions and drawings of the Italian gardens of Pratolino are known to us [19]. From the work of Alexander and Thomas Francini [20], who came from Pratolino to France, in Saint Germain-en-Laye, there only remain their descriptions and drawings to help picture spaces, which are now plain and empty. The same goes for the palatine garden of Heidelberg designed by Salomon de Caus, where architectural works are now emptied of the decor and the animated hydraulic automata, that made them famous. As for animated hydraulic mechanisms, some were restored or rebuilt by Rodney Briscoe; among others the organs in the gardens of the Villa d'Este in Tivoli (Rome) and in the Alcazar in Seville. Nowadays we can still visit the grottoes and the automata theatre in Hellbrunn (Salzburg, Austria), from 1613, and the precious pavilion of the villa Buonaccorsi in Potenza-Picena in the Marches (Italy), pre-1655. The last example, although the later, bears witness to an ancient tradition that was still alive in the second half of the 17th century, although slightly out of fashion. Nevertheless, by their size and the thaumaturgy of their movements, these works give an idea of what could have existed in Enghien. Moreover, their mechanics give valuable information on the craftsmen's skills and help us understand how manual or even pneumatic hydraulic automata work.

Salomon de Caus (Dieppe 1576- Paris 1626) travelled to Italy. Between 1597 and 1610 [21], he was invited in Brussels by the archdukes Albert and Isabella. He created several works in the Warande Park, known today as the Royal Park, below the palace of Coudenberg: basins, reservoirs, grottoes, rockery decors [22]. Between 1605 and 1610, he built a grotto animated with hydraulic automata.

> 'One goes up to this lovely place on a large square terrace with a big basin elevated on a pillar in its centre. From the basin flows clear water, which takes all kinds of shapes by means of the instruments fitted into the pipe. From there, one crosses a quite beautiful house, one room of which opens, through five monumental arched doors, onto a lawned terrace, from where is seen a gorgeous frontispiece with five porticos on a very wide platform artfully decorated with rockery and shells and adorned with twelve marble busts representing twelve Roman emperors.
>
> One reaches the place by a seven circular in-and-out steps stairway dotted with a countless number of pipes spraying water on people who do not expect it. The platform, cobbled in a rustic way, has nearly as many water jets as it has cobblestones. Each portico shows interesting rockworks, shells, water throwing figures of men, animals or fish. The one in the middle represents the Parnassus where all the figures throw water. In some of them, water is used to turn mills or to move working craftsmen as blacksmiths, sawyers, woodcutters, weavers and even cooks; at last, others present beautiful waterfalls decorated with birds, beasts and dragons throwing water. It is undoubtedly one of the most beautiful work of its kind, where water is handled with the most artistry and delicacy…[23]'

The account books also give an indication of the materials used [24]: 350 pounds of stones from England, 100 pounds of stones from India, a basket of sea plumes with eight big sea snails from Peru. The Frenchman Jean le Mesle provided beautiful stones, big orange shells, shells from Cape Verde, two hundred forty thousand mother-of-pearls and eight hundred porcelain shells. Guillaume Bernaerts delivered a wooden cyclops and three other stone figures, including a shepherd. Jérôme Duquesnoy delivered a few wooden figures, little birds. An organ was sent by the maker, Van der Elst. In 1611, Orpheus played a new music; birds moved in a new way. De Caus was paid six hundred pounds for motion generating devices [25]. All these descriptions give an idea of what could have been the decoration of the pavilion if it existed in the contemporary gardens of Enghien.

When he finished his project in Brussels, Salomon de Caus was hired between 1610 and 1612 by the Prince of Wales to work on the gardens of Greenwich, Somerset House and Richmond.

Later, he designed the Garden of Heidelberg for the Prince Palatine Frederick V, future king of Bohemia. After his employer's relocation, Salomon de Caus returned to France and benefited from the protection of the Cardinal of Richelieu.

Salomon de Caus has an impressive literary output. He published:

- la Perspective avec la raison des ombres et des miroirs (London, 1612)
- les Raisons des forces mouvantes avec diverses machines tant utilles que plaisantes ausquelles sont adjoints plusieurs desseign de grotes et fontaines (Frankfurt, 1615)
- Institution harmonique (1615), treatise on musical notation
- Hortus Palatinus (1620), in which he describes his creations and the other plans he had for the Garden of Heidelberg
- la Pratique et la démonstration des horloges solaires, avec un discours sur les proportions (1624)

In his work *Les Raisons des forces mouvantes,* Salomon De Caus, describes a pneumatic organ driven by a hydraulic system. Paddle wheels operate bellows, which produce air. They also operate a musical drum, on which was "programmed" the madrigal score given by the Norman engineer *S. De Caus* [26].

There are a number of similarities between the features in Enghien and the work of Salomon de Caus:

- The circular in-and-out steps stairway described by Father Charles as a royal stairway made of marble and that has, by a very industrious way, as many fountains as it has steps…[27] Bramante invented the model when he designed the Cortile del Belvedere in the Vatican, but without fountains. Salomon de Caus made his own version in Heidelberg, where water flows from one basin to another, on every other step

- The aviary located on the island in the Mirror Pond, which combines the model of the Parnassus with the aviary in a clearing surrounded by birds

- The Mount Parnassus in Enghien, the double helical form of which was taken from Palladio but the topping of which, Fame sounding the trumpet, uses the depression principle explained by Salomon de Caus in his work les Raisons des forces mouvantes

- The cabinet of hydraulic automata, where the theory of les Raisons des forces mouvantes applies literally

- The solar clocks in the Garden of Florets, mentioned by Father Charles: in the centre of the four others (flower beds) are new solar clocks, surpassing the most ingenious: they show the time from many different sides, representing almost all the places in the world

- The Seven Stars Pavilion, which is both a solar clock and a perpetual calendar

The question remains, did Anne de Croÿ know Salomon de Caus? There is a clear connection: Salomon de Caus married Esther Pickart on March 19, 1606 in the parish church of Saint-Géry in Brussels. Their son, Guillaume, was baptized on February 24, 1607 in the parish church of Sainte Gudule [28]. Guillaume's godfather was Bertin Oudart Spinola and his godmother was Barbara Basselier. Bertin Oudart Spinola, count of Brouay, was married to Claire of Arenberg, seventh child of Charles of Arenberg and Anne de Croÿ.

Towards a Reconstruction

The inside dimensions of the automata cabinet in Enghien were 4,80 x 4,80 x 4,70 m. That is a cube with a side length of seventeen feet and each wall had a door or a window of seven feet wide (1,92 m.). Corners were then free to host four playlets, which redefined an octagonal central space with sides of eight feet. Therefore, the niches were four feet deep, that is +/-1,15m.

> 'The second cabinet compares favourably with the first one and even outshines it by its ornaments and the beauty of the rock, embellished with a lot of water movements [29].'

According to the text from 1665 written by the author of the project, Father Charles of Brussels, the pavilion was fully decorated and gave the visitor the impression of being inside a rock. The niches in the corners were probably arched and were animated by many water movements.

In these small grottoes were exhibited the popinjay or pole archery, Pyramus and Thisbe's death, a castle siege and, as described by Father Charles, a farmer shooting a duck and dolphins throwing water. In 1685, Nicolas Visscher described

an aviary and its birds. Some unknown event might explain the change of decor in one of the niches but so could the disappearance of Anne de Croÿ's grotto, whose elements could have been recovered and reused.

The programme

The programme, through its scenes, affirmed the power of the patron: a scene illustrating the acquaintance with classical authors, a battle scene, a popular scene depicting the prince's skills with weapons and eventually a scene depicting nature. Indeed, the best way to show one's domination over things is to reproduce them. All these *intermezzi* ended with the watering of the spectators. That had two purposes: on the one hand, to break the enchantment before it was analysed and on the other hand, to exhibit a waste of water, symbol of life, as an "external sign of wealth".

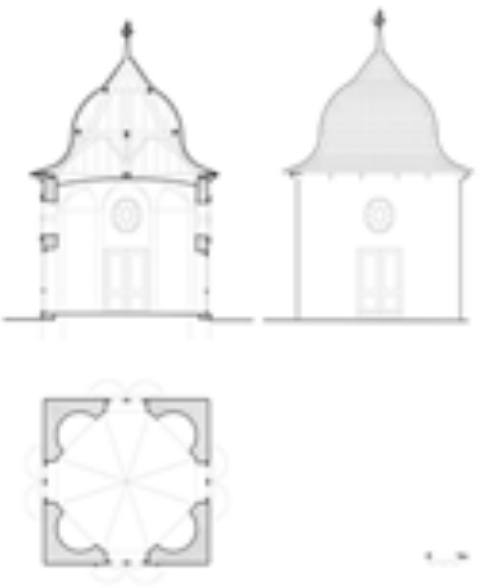

Figure 11: Plan, section and elevation of the Paintings Pavilion, one of the fourth identical pavilion on the corners of the Garden of Florets. On the plan is drawn the hypothetical layout of the niches in the Grottoes and Fountains Cabinet.

From the Pneumatics of Hero of Alexandria (1st century AD), translated in Latin by F. Commandino (1575)[30] and in Italian by B.Baldi (1589)[31] and G B. Aleotti (1647)[32], as well as from the descriptions written by Salomon de Caus in *Les Raisons des forces mouvantes* (1615)[33], we can say that two of the scenes were static and the two others were animated with automata.

Two of the grottoes were mainly animated by fountains: the castle siege and Pyramus and Thisbe's death. In contrast, in the ones showing the pole archery (popinjay) and the aviary, hydraulic automata needed a bigger space to house mechanisms, but also to allow someone to reach in and reset them.

The excavations carried out by the Walloon Region on the site of the Grottoes and Fountains cabinet revealed walls three meters high below the estimated level of the pavilion, suggesting a basement. This space was probably used to host

hydraulic mechanisms: valves, paddle wheels, gears and pulleys, as well as water and air tanks. A full resumption of the excavations may perhaps enable us to learn more about the water conveyance.

The scene of Pyramus and Thisbe's [34] death does not present any technical difficulty. It was probably a fountain statue, operated manually and occasionally by means of valves. The myth of impossible love was illustrated by fountains flowing from statues. Water gushes out of Pyramus's wound "*up to the ceiling. Water jets also spring out of Thisbe's wounds to form waterfalls, which we mentioned before. The rock is dotted with several cupids mourning the death of the two lovers* [35]*".* The author mentioned a fountain flowing up to the vault of the grotto, which corroborates the hypothesis of there being playlets.

The second grotto held: *"all the technicalities of a castle siege": "there are three castles, two of them shoot artillery fire and one defends itself bravely: there is no fire in these battle scenes, but water can hit the viewer if he is not careful*." One can easily imagine a fortified castle being attacked by water jets from two armies of figurines and them striking back with water jets aimed not only at the attacking armies but also at the spectators. The water jets were probably simply operated by means of valves, manually and occasionally as it was for the previous scene.

The third grotto put on display a scene of: *"six villagers trying to shoot a bird attached to a long pole. Some, less skilful, fail, others make it spin until one of them hits it."*

The game of the "papegau/papegai" also called the "tir du Roy" or bird shooting was particularly widespread in this period. It was a good training exercise for crossbowmen. A target, originally a parrot replaced afterwards by a copy made of wood or cardboard, was placed on the top of a pole or a mast. Archers or crossbowmen had to use their skill to hit it and make it fall. The winner of the tournament was seen as a hero and received the title of "roy". He might represent a brotherhood or guild and receive its honours for one year. He was also exempted from some taxations, notably on wine.

For the record, the archduchess Isabella became "shooting queen" on May 15, 1615 in Brussels, and so was the princess Anne de Croÿ, the same year in Enghien. This shows the popularity of this game among all classes of society.

The representation of this game in its devoted grotto evokes the second problem raised in the second book of *Les Raisons des forces mouvantes* by Salomon de Caus: *"a drawing of a grotto, in which a ball is rising under the force of water".* To this problem can be added the movement of one or several villagers, as it was suggested in the *theorem XL* proposed by G.B. Aleotti in his translation of the « *spiritali* » of Hero of Alexandria. It could also apply to the previous scene of the castle siege and explain why at one point spectators become the assailants' targets.

The descriptions of the fourth playlet or grotto of this cabinet are different from one author to another. In 1665, Father Charles of Brussels wrote the following: *"There is another (villager) shooting a duck, a water spitting dolphin and some other whimsies."*

Such a grotto is depicted in the second book of *Les Raisons des forces mouvantes* under *the problem XXVII*: *"A machine, by which will be featured Neptune, turning in circles around a rock, along with some other figures throwing water while turning".*

Figure 12: S. De Caus, Les Raisons des Forces mouvantes, Livre II, problème II

Figure 13: S. De Caus, Les Raisons des Forces mouvantes, Livre II, problème XXVII

In 1685, Nicolas Visscher describes an "*aviary, etc.*" The decor of this grotto was probably modified. The aviary presents automata moved by a hydraulic organ, as proposed by Hero of Alexandria *(theorem XLIII and XLIIII* from the translation of the "*spiritali "* by G.B. Aleotti and by Salomon de Caus' applications, livre I, *problesme X et XVIII)*

> 'To imitate a natural bird song by means of water'

and XXIII

> 'To make several birds sing when an owl turns skyward and make them quiet when the owl turns around'

It is interesting to note that the problem had already been described by Philo of Byzantium at the end of the 3rd century BC and once more three hundred years later by Hero of Alexandria. The delightful trick of singing birds is a classic that was often used in creations of the 17th century: in the grottoes of the castle of Saint -Germain-en-Laye in 1598 [36] , in the automata grotto of the castle of Outrelaize (Normandie) designed by Alexandre Francine in 1613 [37] , not forgetting in the previously mentioned examples of the palace of Coudenberg in Bruxelles in 1605, and in Enghien in 1620.

New Attempts at a reconstruction

In February 2021, the organ builder Guido Schumacher (Eupen, Belgium) created a model of a "nightingale" according to the problems X and XVIII (in reality XXII) of book I from Salomon de Caus. Since there is no indication of scale in the treatise, he relied on the upper engraving of Plate XVIII for the proportions starting from a dimension that appeared realistic to him.

Here are the main dimensions:

- Upper tank 40 x 40 cm x 10 cm high
- Lower tank 40 x 40 cm x 12 cm high
- Distance between the 2 tanks: 30 cm
- Diameter of the pipe connecting the 2 tanks: 40 mm
- Diameter of the pipe feeding the "Rossignol" pipe: 20 mm

The trick is to create a small exhaust hole (3-4 mm) in the upper tank lid to prevent large air bubbles from rising up through the 40 mm pipe and then interrupting the singing of the nightingale.The nightingale sings for about twenty seconds.

The wind pressure, which results from the compression of the air by the water that fills in the upper tank, depends on the section of the connection tube between the tanks. It was 40 mm in the model built here. By opening this tube by about 30%, a constant pressure of about of a 75 mm water column is reached for 15 seconds. This pressure is in fact common in pipe organs. By fully opening the 40 mm tube, the pressure can even rise up to a 300 mm water column. In both cases the sound emitted by the whistle is continuous at first, while the pressure is still relatively low. The sound becomes modulating when the pressure is sufficient to cause the water level to ripple at the end of the whistle. The higher the pressure, the louder the sound and the more intense the modulation. The Rossignol pipe used in this test had a diameter of 12 mm and was 80 mm long.

To make a "Cuckoo ", approximating the range of real cuckoos, one needs two pipes tuned at a minor third interval and with bodies of the following dimensions:

- Bass pipe: diameter 20 mm, length 113 mm
- Treble pipe: diameter 16 mm, length 96 mm

It could also work with narrower diameters, but in that case, the pipes should be a little longer. The organ builder does not know if real cuckoos all sing at the same pitch or if that pitch depends on the size of the birds. The recognizable characteristic of their song being the descending minor third, it can therefore be transposed.

The tap seen on the side of the downpipe was not recreated because the organ builder thought it was simply used to evacuate water. But in fact, it could/should also adjust the water flow and allow a better regulation of the water flow and pressure. The tank sides were made out of lead, which is relatively malleable. Salomon de Caus may have used a less pure alloy with some antimony or copper to harden it. These experiments show that the mechanisms hidden from the spectator were small and could be fitted under or behind the grotto.

Concluding Remarks

The need for a training course for ornamental plumbers

The Centre des Métiers du Patrimoine in la Paix-Dieu (Amay, Province of Liège, Belgium), supported by the Agence Wallonne du Patrimoine, wishes to organize a training course focused on ornamental plumbing. This discipline is sorely lacking in the restoration of hydraulic works in historic parks and gardens. Assistance was sought from hydraulic engineers of the Park of Versailles, who had themselves benefited from the teaching of André Heyen, an ornamental plumber from Liege. The Centre des Métiers asked the authors to think about the educational programme of this training course. We put forward the proposal that we should to start with the work of Salomon de Caus published in Frankfurt in 1615: *Les Raisons des forces mouvantes avec diverses machines tant utilles que plaisantes ausquelles sont adjoints plusieurs desseings de grotes et fontaines.* This treatise methodically expounds the physical principles and their implementation both mechanical and hydraulic. Starting with technically simple works, it gets more difficult as the "*problems"* get complex, ending with the creation of an organ as a final masterpiece.

The advantage of the Centre des Métiers du Patrimoine is that it can bring all the participants in a restoration project together: craftsmen (in this case the organ builder and a roofer specialized in lead roofing, a blacksmith, wood workers and a rocaille worker), art historians and archaeologists, architects and engineers, as well as the heritage administration. The training course is theoretical, practical and includes internships. It ends with the achievement of one of Salomon de Caus' problems.

There should be a place to display the masterpieces created in these training courses. Because of the significant network of hydraulic works in the Arenberg Park of Enghien dating from the beginning of the 17th century and the fact that there are still two ruined water towers, it was suggested that the city of Enghien might restore these buildings to exhibit the works made during the training courses and create a hydraulics museum in Enghien. The city of Enghien have agreed to take part in the project.

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[3] Idem, p.38
[4] F.Charles of Brussels, Brièvе description de la ville, chasteau et parc d'Enghien, Enghien, Annales du Cercle Archéologique d'Enghien, T.VIII, 1914-1922, pp.103-128.
[5] VISSCHER N., Villa Anguiana, Figure D, Amsterdam, 1685.
[6] DESEAUBLAUX H. Description du jeu des eaux des fontaines jaillissantes, bassins, réservoirs, conduits, décharges, aqueducs, écluses, AGR, Fonds d'Arenberg, Cartes et Plans n°1250.
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[10] DELULLE H., Mouvement des eaux du Parc d'Enghien, 1861, AGR, Fonds d'Arenberg, Cartes et plans, n°1251.
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[13] F.Charles of Brussels, Brièvе description de la ville, chasteau et parc d'Enghien, Enghien, Annales du Cercle Archéologique d'Enghien, T.VIII, 1914-1922, p.115.
[14] VISSCHER N., Villa Anguiana, Figure O, Amsterdam, 1685.
[15] This principle is used in Cassel, Park Wilhemshöhe, 1696. When many waters are released, two statues holding a trumpet or a horn start blowing until the water reserve is empty.
[16] F. Charles of Brussels, Brièvе description de la ville, chasteau et parc d'Enghien, Enghien, Annales du Cercle Archéologique d'Enghien, T.VIII, 1914-1922, p.127.
[17] OVIDE, Les métamorphoses, 4,43-166. Alors l'arme qu'il portait à la ceinture, il se l'enfonça dans le flanc et aussitôt, mourant, la retira de sa blessure brûlante. Il resta à même le sol, couché sur le dos et son sang jaillit bien haut. Ainsi lorsqu'un tuyau se fend, à cause d'un défaut du plomb, en sifflant il lance avec force à travers un petit trou de longs jets d'eaux qui déchirent et frappent l'air.
[18] F.Charles of Brussels, Brièvе description de la ville, chasteau et parc d'Enghien, Enghien, Annales du Cercle Archéologique d'Enghien, T.VIII, 1914-1922, p.113.
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[26] In that respect, see the reconstruction made by André Heyen, Guido Schumacher and Yves Weinand, within a study of the « Technische Hochschule » of Aachen, Germany www.orgel-Schumacher.com abbaye de Michaelstein(D) machines fantastiques de Salomon de Caus.
[27] F. Charles of Brussels, Brième description de la ville, chasteau et parc d'Enghien, Enghien, Annales du Cercle Archéologique d'Enghien, T.VIII, 1914-1922, p.111.
[28] Register of births, Parish of Sainte Gudule, from 1605 to 1608, fol.V° in : MAKS Ch. S., Salomon de Caus, 1576-1626, Doctoral thesis, University of Leiden, 1935 p.129
[29] F. Charles of Brussels, Brième description de la ville, château et parc d'Enghien, Enghien, Annales du Cercle Archéologique d'Enghien T.VIII, 1914-1922, p 115.
[30] COMMANDINO F., *Heronis Alexandrini Spiritalium Libe*r, Urbino ,1575.
[31] BALDI B., *De gli automati overo machine se moenti*, libri due, Venezia, 1589.
[32] ALEOTTI G.B., *Gli artificiosi e curiosi moti Spiritali di Herone*, Bologna 1647.
[33] DE CAUS S., Les Raisons des forces mouvantes avec diverses machines tant utilles que plaisantes ausquelles sont adjoints plusieurs desseings de grotes et fontaines. Francfort, 1615.
[34] Pyrame et Thisbé, deux jeunes babyloniens s'aiment mais, leurs parents s'opposant à leur union, ils ne peuvent se voir que secrètement par une fissure du mur qui sépare leurs maisons. Ils décident un jour de fuir ensemble et se donnent rendez-vous au pied d'un mûrier, en dehors de la ville. Thisbé arrive la première mais, effrayée par une lionne, elle s'enfuit en abandonnant son écharpe qui est mise en pièces par l'animal. A son arrivée, Pyrame croit que son amie a été dévorée par la lionne et se poignarde de désespoir. Thisbé, revenue sur le lieu de rendez-vous, trouve Pyrame mort et se poignarde à son tour. La légende affirme que c'est pour cette raison que les fruits du mûrier qui, jusqu'alors étaient blancs, devinrent rouge sombre de tant de sang versé.
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