Far Eastern Vacuum and Electricity: Augustin Hallerstein and Experimental Correspondence between Beijing and Europe

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Abstract

Hallerstein's astronomical excellence was widely recognized recently. As one of the prominent scientist attached to the Chinese Imperial Court, he was involved in other types of research besides astronomy, but his authorship was not always obvious amidst the Jesuits' collective work. Besides astronomical observations the Beijing Jesuits also provided early electricity experiment, which enabled Volta's inventions of the electrophorus and battery. The development of such devices paved the way for electrical observations that were longer in duration than the quick ones conducted with the Leyden jar. The scientists urgently needed a new approach because they wanted to know the process responsible for an interesting electrical spark. Electric experiments became fashionable in European high society meetings, as vacuum pumps had somewhat earlier. Both innovations were introduced to the Chinese court in Hallerstein's time, but never garnered the same amount of interest as Western astronomy did. One reason for the Chinese indifference was the nonexistence of a wider technical use for vacuum or electricity during Hallerstein's lifetime. Ingenhousz and other physicians educated in Leyden eventually developed a broader use of electricity in countries considered somewhat scientifically backward, such as Hallerstein's native Habsburg monarchy and Japan.

Key words: Hallerstein, Ingenhousz, Jesuits, Electrophorus, Air Pumps

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1. Introduction

The Baron Augustin Hallerstein was born in Ljubljana where he finished philosophical studies. He joined the Jesuit order following the example of his mother's relatives. The Jesuit habit was almost unique opportunity to visit China where Hallerstein worked during the second half of his life.

After learning the scientific trade as Ignatius Kögler and André Pereira's assistant in Beijing, Hallerstein published extremely accurate astronomical observations[1] in various influential European centers.[2] He cooperated closely with both Jesuit groups in Beijing

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[1] Lu, Shi, 2003, 290. The content of the present paper is largely based on Južnič, 2003.

[2] Lu, 1997, 336.

who served under the French and Portuguese flags. He was especially close to the French Jesuits Gaubil, d'Incarville, and Amiot. If there was a competition between both groups, Hallerstein certainly ended it once the primary profession of the Beijing Jesuits shifted from religion to science in the last decades before the suppression of the Jesuit order. During this period, the joint use of instruments and information exchange became extremely important.

Hallerstein tried persistently to convince his European correspondents that he lacked sufficient astronomic and physics equipment. He cleverly exaggerated his need so that he could get better instruments, of which he would certainly make good use. Hallerstein's European correspondents in London and elsewhere accepted his reasons, helped him, and provided the best equipment for his accurate observations.

2. Hallerstein's European Scientific Background

Hallerstein was able to see further because he stood on the shoulders of giants. Johann Philipp von Schönborn played a decisive role in Emperor Leopold's election under the influence of Hallerstein's Ljubljana compatriot Prince Janez Vajkard Auersperg, the prime minister of the Viennese court. Auersperg helped Guericke in his early vacuum Regensburg experiments in 1654 as von Guericke would later describe in his book *Experimenta Nova*,[3] which Hallerstein read in Beijing under his usual bookplate indicating the Jesuit ownership with a phrase *Collegii Societatis Jesu Pekini*. Guericke made his first vacuum pump in Magdeburg in 1648. Two years later, he finished a pump that he used for his famous Regensburg experiments, in which horses tried in vain to separate two hemispheres with a vacuum in between them. After that success, many princes wished Guericke's pump. Guericke sold one of his instruments to Schönborn, who had offered the greatest amount. Schönborn was the Bishop-Prince in Wurzburg and Worms, as well as the Archbishop and Prince-elector of Mainz; as such, he never lacked for funds. He hadn't bought Guericke's instrument for himself, however; rather, he donated it to the Jesuit University of Wurzburg. Athanasius Kircher's student Gaspar Schott traveled through Mainz and described Guericke's pump to his teacher on June 22, 1655. The new professor of mathematics of Wurzburg University, Schott was excited even before he got the pump in his hands.

The air pump resembled "big science" because that pump was the most expensive instrument of the era.[4] The Chinese eventually accepted the pump, but more slowly than they accepted European astronomy, because they urgently needed accurate predictions of heavenly phenomena to improve their calendar. The Chinese clearly knew how to use Hallerstein's observations of nebular bodies, but the Beijing Court regarded the air pumps, the Jesuit Lana Terzi's vacuum balloon described in three copies of Lana's books in the Jesuit Chinese libraries,[5] and the electricity as tools of little use.

Hallerstein had a great deal of opportunity to learn vacuum in his native Ljubljana,

[3] Guericke, 1986, 76–78.
[4] Shapin, Schaffer, 1993.
[5] Rinaldi, 2006, 38; Verhaeren, 1969, 516, 572–573, 971.

where Auersperg spent his last years. Auersperg's collaborator Guericke closely connected the vacuum experiments with the electrical ones while inventing the very first electrical generator. The Ljubljana Jesuit Professor Bernard Ferdinand Erberg, acquired the electric machine by 1755, and it was also available by that time in Franklin's Philadelphia, Hallerstein's Beijing, and Tokyo. Auersperg's former customs officer, Lenart von Erberg, was the grandfather of Bernard Ferdinand Erberg and of Hallerstein's mother, Susana Elizabeth Baroness Erberg.

3. Beijing Electricity Experiment

Hallerstein was able to study Pascal,[6] Schott, Newton, Lana, Musschenbroek, and Laurentio Gobart's vacuum experiments in his Uncle Franc Mihael Baron Erberg's Ljubljana library, and he studied similar books in the Beijing Jesuit library. Magnetism appears to have been Hallerstein's first love. He measured the declinations of magnetic needle while sailing to China. He made further observations in Beijing,[7] where Nicola Cabeo's *Philosophia magnetica*[8] and Ferdinand Verbiest's magnetic theory still prevailed over the more modern William Gilbert's followers,[9] although Nicolas Trigaut had already acquired Gilbert's *De magnete* (1600) in Beijing.[10] Hallerstein avoided writing his name in his books' bookplates and wrote just the name of the college he headed; the present catalogues may not contain all books that belonged to the Beijing missionaries because some of them could have been lost or borrowed.[11] Before he landed in Canton in September 1738, Hallerstein was well aware of the new ideas, including the electricity research of Stephen Gray (1729), Charles François Du Fay (1732), and Du Fay's student Abbé Jean Antoine Nollet.

In 1750, the Beijing Jesuits at Hallerstein's Portuguese college of St. Joseph (*Tongt'ang*) received an electrical machine and an instrument to observe eclipses. Sanchez[12] provided the instruments with the help of his London and Dutch friends. De Souza, the bishop of Beijing, assisted in getting them shipped to the college.[13] No document mentioned exactly what Hallerstein's electrical machine was, but it was probably an electrostatic frictional device, and not Musschenbroek's Leyden jar, which was invented in November 1745 and publicized in January 1746. As a former Leyden student, Sanchez knew the Musschenbroek's Leyden jar experiments. During this period, Peter Collinson of the Royal Society of London shipped a Leyden jar across the Atlantic to Benjamin Franklin. Sanchez corre-

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[6] Pascal's *Provincials* (Verhaeren, 1969, 150, 669–670, 803–805).

[7] Amiot, October 2, 1784 *Mémoires*, 11: 563; Pfister, 1934, 760.

[8] The Beijing copy had no bookplate but both copies of Cabeo's *Meteorologicum* (1646) had bookplates of the Chinese Jesuits Francisco Pereira (* 1607 Lisbon; † China) and Martin Martini (* 1614; † 1661 China): *Applicado a Missao da China ou ao Collegio de Macao Fr. Francisco Pereira. Coimbra 1656* and *Ad usum p. Martini.—aplicados a Igreja de Hâm Cheu* (Verhaeren, 1969, 336; Pfister, 1932, 220, 256).

[9] Guan, 2005, 143.

[10] Bookplate *Bibl. Trig.* (Verhaeren, 1969, 494–495).

[11] Walravens, 2001, 188.

[12] Gaubil, 1970, 617.

[13] Gaubil, 1970, 703.

sponded with Collinson and sent him a rhubarb plant obtained from the Beijing Jesuits.[14] On October 25, 1753, Collinson sent a mimosa flower to the Hallerstein's friend, glass-maker, and Emperor's Beijing gardener Pierre Noël Chéron d'Incarville.[15]

As the leading scientist among the Beijing Jesuits, Hallerstein took part in the electricity experiments. His collaborator from the French college called *Pé-t'ang*, Amiot, was especially interested in electricity. According to Hallerstein's friend, the French Beijing Jesuit Gaubil, the French college of Beijing had poorer electrical instruments than Hallerstein's, so Amiot had to borrow his machines from the nearby Portuguese college.[16] During that time, Amiot, Hallerstein, and Gogeisl collaborated on measuring the apparent height of the star Gamma in Andromeda to match the order of Espirit Pézenas[17] and two other Jesuits, who made similar measurement in Marseilles.

The Beijing Jesuit electrophorus experiment, described in a letter mailed from China to St. Petersburg, Russia, was a collaborative work that was highly praised in St. Petersburg academic circles. In a 1779 letter addressed to D'Incarville's Beijing successor, the Emperor's gardener Cibot, St. Petersburg academicians still expected the Beijing Jesuits to continue their research on electricity,[18] accomplished a quarter of century earlier. In 1755, the Beijing Jesuits electrified a thin glass plate by friction and put it on the glass covering a magnetic needle. They probably used the "electric machine" which Hallerstein had received five years earlier. The needle suddenly rose and adhered to the inner side of the glass plate for some hours before returning to its normal position. When the Jesuits removed the previously electrified glass plate, the needle rose again and remained in touch with the glass cover. When they returned the plate, the needle dropped again. The Jesuits repeated the experiment many times[19] with similar results and experimental settings.

On January 12, 1755, Gaubil received an undated letter of Georg Wilhelm Richmann as well as a letter from Kratzenstein letter dated April 12, 1753, addressed to the Jesuits of Beijing. Gaubil wrote back to both St. Petersburg academicians on April 30, 1755, and mentioned Amiot's experiments "which should make you happy." Gaubil added that the Chinese were not very interested in electrical experiments,[20] as compared to the extreme European or North American interest in the subject at that time, soon after Musschenbroek's invention of the Leyden jar. Even the medical use of electricity did not appeal to the Chinese; however, when he was ill, Kangxi (康熙帝, ruled 1662–1722) highly praised the anatomical knowledge[21] of Harvey and Vesalius[22] to the French Jesuits Dominique Parrenin and Joachim Bouvet.

On November 25, 1753, the Russian Academy of Science proposed an award for the

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[14] Chalmers, 1816, 27: 88; Gaubil, 1970, 37.

[15] Rinaldi, 2006, 153, 159.

[16] Hsia, 2009, 4, 172.

[17] Gaubil, 1970, 840, 843, 850. Espirit Pézenas (* 1692 Avignon; † 1776 Avignon).

[18] Pray, 1781, 270; Pfister, 1934, 891; Bernard-Maitre, 1948, 175; *Nova acta academ. Scient. Petropoli* 1779, 7: 22.

[19] Aepinus, 1979, 130.

[20] Gaubil, 1970, 803, 810–811; Heilbron, 1979, 405; Kloss, 1987, 41; Koplevič, Cverava, 1989, 55; Cverava, 1986, 58.

[21] Asen, 2009, 33–34.

[22] Niu, 2006, 65.

best discussion on "the true causes of electricity and its theory" with a deadline of June 1, 1755.[23] They were interested in the chemical and physical aspects of electricity.[24] On September 6, 1755, the Empress announced the awards without mentioning Beijing's contribution, although they probably entered the competition. The first award (*praemio coronato*) went to Leonhard Euler's son Johan Albert Euler for his *Disquisitio de causa physica electricitatis*. The other two researchers who received an award were Paul Frisi, a professor of Pisa University from Pauline clerical order[25] who discussed the causes of electricity, and Lalande's Jesuit teacher Laurent Béraud, the director of Lyon observatory, who developed a theory of electricity. Euler tried to calculate the speed of electricity from the elasticity of ether, and experimented with the conductivity of a vacuum above the mercury in a barometer. Euler used Musschenbroek and Kleist's Leyden jar, and mentioned Martin Frobenius Lederemüller's experiments with the spirit of wine. Frisi developed Kratzenstein's experiments to please the Kratzenstein's fellow Russian academicians.[26]

A copy of Euler, Frisi, and Béraud's (1757) electricity research was received by the tertiary Franciscan Alexander de Gouvea, who was appointed Bishop of Beijing in 1782 and used his stamp as the book's bookplate.[27] Petersburg research was obliviously very well known in Beijing. In August 1755, Gaubil sent both Amiot's packets and other presents to Razumovskii.[28] Gaubil knew that Richmann and Kratzenstein widely published on electricity, but he was not aware of Richmann's fatal accident with lightening of August 3, 1753.[29]

Johan Ernst Zeiher replaced Kratzenstein in 1756 and reported to Gaubil how Richmann's unfortunate death[30] had shocked the scientists worldwide. A. Hallerstein's first cousin Franc Volbenk Danijel Baron Erberg bought Kratzenstein's report on vapors research reprinted in Trnava in 1763.

Franz Aepinus eventually replaced Richmann. He was born in Rostock, Prussia,

[23] *in veram electricitatis caussam, veramque ejus condatur theoria* (Euler, Frisi, Béraud, 1757, 1: 3–4, 10).

[24] Euler, Frisi, Béraud, 1757, 1: 8. On September 6, 1751, the Empress Elisabeth and the Academy president Count Kiril Grigorjevič Razumovskii had proposed a competition for the best lunar theory, and on November 26, 1753, the competitors had to describe the dissolution of silver in *aqua fortis*. In 1756, the Academy offered an award for corpuscular theory and in 1757, the competition question concerned diurnal planetary motion.

[25] Frisi, 1755. *De existentia et motv aetheris sev de theoria electricitatis ignis et lvcis dissertation.* Later, Beijing missionaries obtained Frisi's anthology *Opuscoli filosofici* with the second article *Dei conduttori elettrici* (1781. Milano: Giuseppe Galeazzi) (Verhaeren, 1969, 958).

[26] Frisi used Mairan's Parisian theory, Bernoulli's vibrations, Bose, Beccaria, and Jean T. F. Jallabert's experiments. In his final experiment, Frisi repeated Franklin's Leyden jar experiences, and discussed the theory of John Théophile Désaguliers. He also relied on the ideas of Monnier, Franklin's antagonist Nollet, Martin Frobenius Lederemüller, and Winkler. Frisi added some simple calculations with corresponding figures attached to the end of the book. Béraud used L. Euler's theory of force in Boyle and Hale's molecular theory, and heavily relied on his compatriot Nollet's experiments, while just briefly mentioning Franklin (Euler, Frisi, Béraud, 1757, 2: 8–12, 35–36, 49, 54, 57, 59, 61–64, 68, 77–80, 84, 88, 90, 96–97, 101, 103, 106, 121, 131, 140, 143, 150, 153, 173, 187, 194, 198, 202).

[27] Verhaeren, 1969, XXII, XXIII, 199; Pfister, 1934, 942, 1034.

[28] Gaubil, 1970, 818.

[29] Russian calendar date July 26, 1753. Soon afterward, on August 13, 1753, Kratzenstein left the academy of St. Petersburg and became a professor of medicine and physics at the University of Copenhagen (Koplevič, Cverava, 1989, 80).

[30] Cverava, 1986, 58.

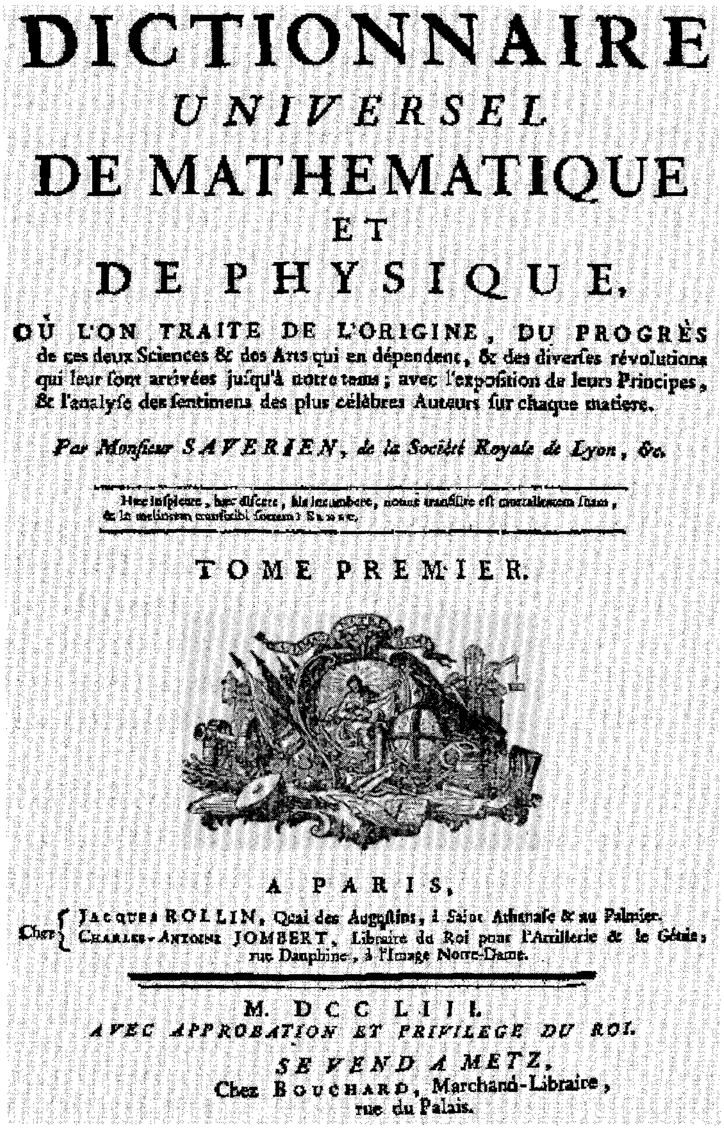

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Figure 1. Title page of Alexandre Saverien's Dictionary of Mathematics and Physics (Saverien, 1753) used in Gouvea's Beijing Library.

where he completed his studies and taught. He and his Swedish student Johann Karl Wilcke developed an early type of condenser, similar to one used in a Beijing Jesuit experiment which Volta later developed into electrophorus. After working in Berlin for a short time, Aepinus got Richter's post in the St. Petersburg academy. On May 10, 1757,[31] Aepinus arrived in St. Petersburg and remained the professor of physics attached to the academy until 1798.

As the new professor of physics, Aepinus immediately analyzed the Beijing electric

[31] Novik, 1999, 10.

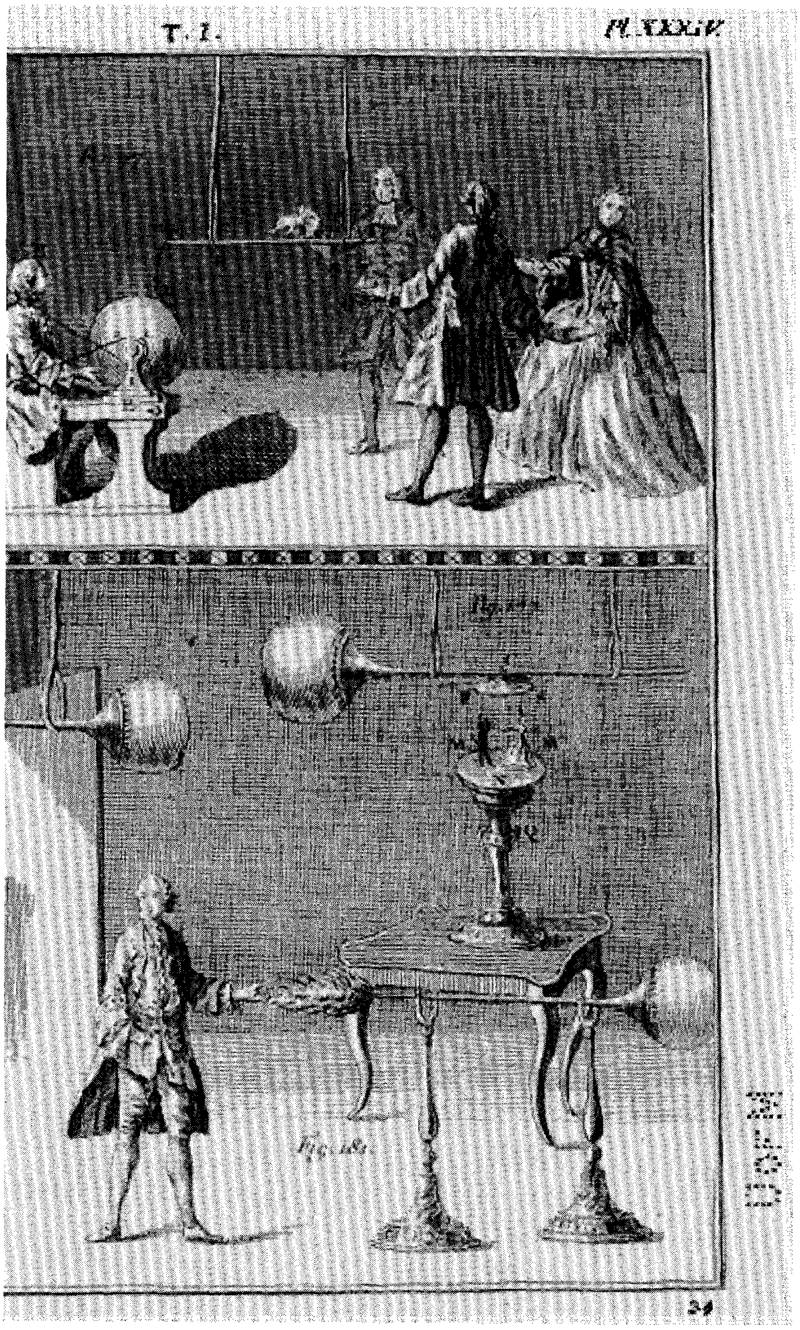

Figure 2. Electrical experiments with machine and isolated accumulator in Saverien's Dictionary (Saverien, 1753, table 44).

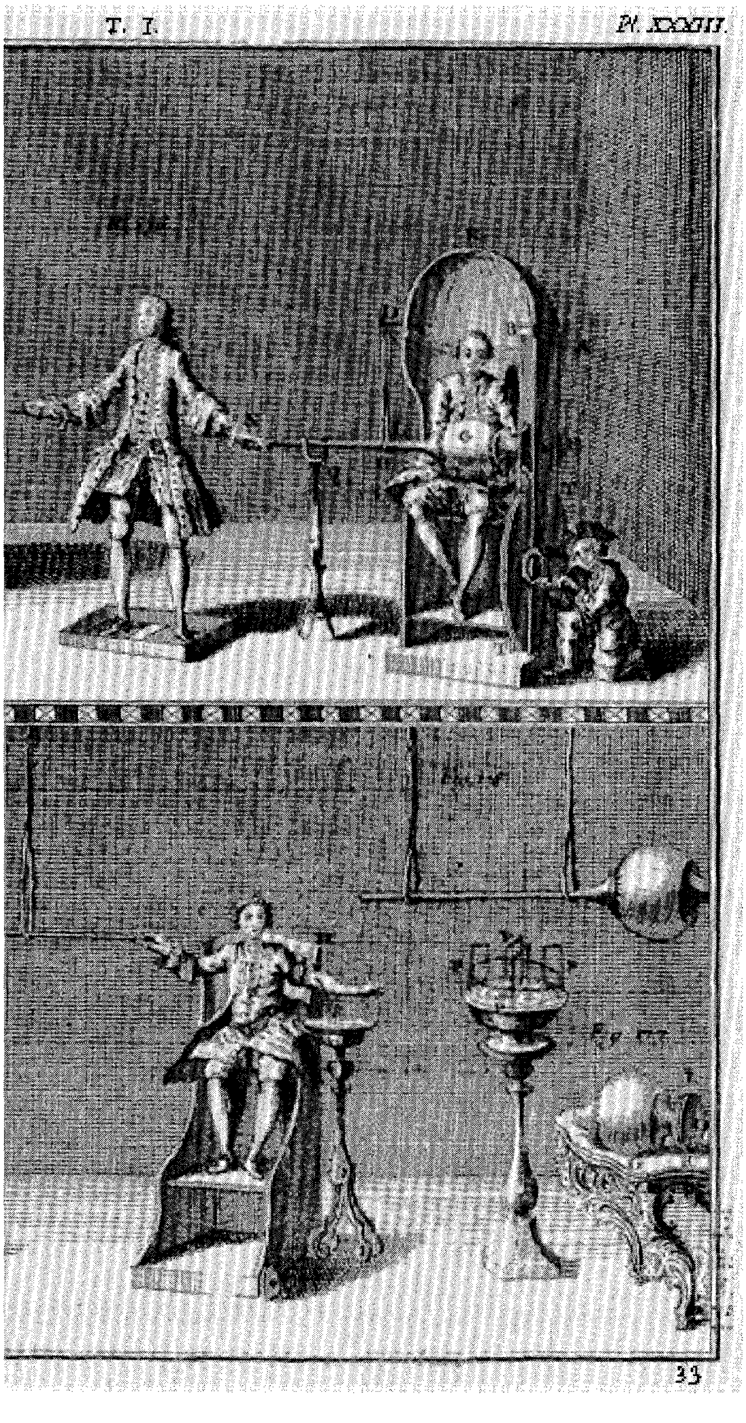

Figure 3. Electrical charging of the insulated person in Saverien's Dictionary (Saverien, 1753, table 43).

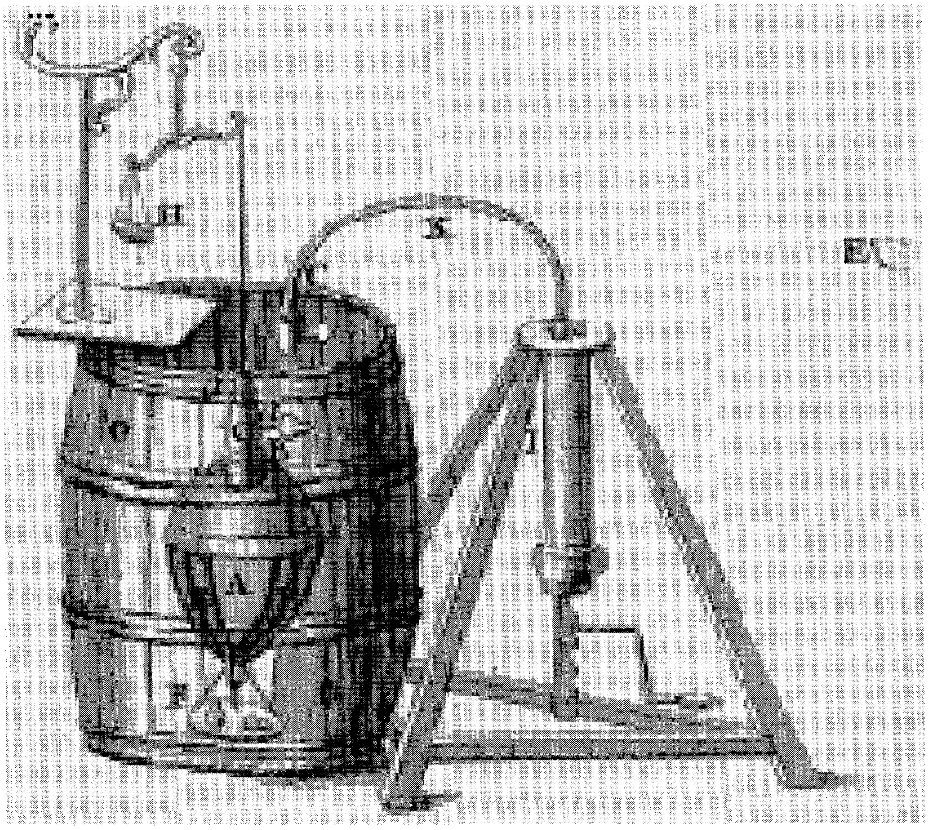

Figure 4. Vacuum experiments in Saverien's Dictionary (Saverien, 1753, table 21).

experiments which interested the Russian authorities. A few months later, he reported on the Beijing experiments to the St. Petersburg academy[32] and described his own research on March 9, 1758. Aepinus explained the Jesuits' Beijing experiment involving the low conductivity of glass, which allowed the induced charge on the compass' glass cover, slow transmission of the charge into the attached compass needle during the experiment, and the equally slow return of the charge after the induced charge was removed. Aepinus successfully repeated the Beijing experiment and conducted 12 similar experiments of his own. He believed that the Beijing experiment fully confirmed Franklin's theory of singular electric fluid,[33] which was certainly had political overtones, given Franklin, Bošković and Count Buffon's Parisian quarrels against d'Alembert and Nollet support of the theory of two electrical fluids. The Beijing Jesuits' support of Franklin's ideas was in accord the Jesuit physicist Rudjer Boskovic's close friendship with Franklin. Hallerstein knew about the research being done by Boskovic, who was a few years his junior, because he used Boskovic's astronomical data.[34] Aepinus' mathematical theory of electricity was

[32] On November 17, 1757 (Novik, 1999, 11) or on December 1, 1757 (Aepinus, 1979, 492).

[33] Aepinus, 1761, 23–24; Aepinus, 1758.

[34] Boskovic frequently visited his Brussels friend the Habsburg Netherlands minister Count Janez Karl Filip Kobencl from Hallerstein's native Ljubljana. Augustin's brother Vajkard Hallerstein was the confessor of the

a part of the scientific mainstream to which Beijing Jesuits' electricity research also belonged. Hallerstein and other Jesuits in China did not have the books written by Franklin, Beccaria, or Boskovic's followers. There is no proof that they read Franklin's letters to the wealthy English Quaker Collinson about the electricity generated by the Leyden jar, published in English (1751) and French (1752), or Beccaria's Latin compilation (1751) before they prepared the Beijing electrical experiments, which were drastically different from Franklin's achievements. Sanchez and Collinson provided the necessary equipment for both Franklin's group in America and Hallerstein's Jesuit College in Beijing. Both research groups proved extremely successful and returned the gift with unexpected extraordinary new discoveries. Sanchez and Collinson both collaborated with the London Royal Society, but Franklin did not directly cooperate with the Beijing Jesuits although, as previously mentioned, the leading European Jesuit Boskovic became his close friend. The research groups in America and China communicated solely through their European connection. Franklin himself probably did not bother to repeat the Beijing Jesuits' experiments because he switched to diplomatic and political pursuits soon after he gained his fame in the field of electricity. The Beijing Jesuits' experiments actually brought more fruit through Volta's research, even if the Jesuits received far less fame than the clever diplomat Franklin.

Aepinus discussed electrical and magnetic forces for the Academy and dedicated his research to the Empress on September 7, 1758. He used experiments with a Leyden jar to forward the analogy between electricity and magnetism, developed a mathematical theory of electricity, but he did not mention the Beijing report, although he used the Beijing Jesuits' data. On June 4, 1759, Aepinus presented his book to the academy and dedicated it to Razumovskii in late November.[35] He used his favorite Franklin theory of one fluid, again without mentioning the Beijing experiments.[36]

Aepinus' explanation of electricity experiments did not please everyone. He apologized to his readers for using overly sophisticated mathematics to explain his theories of electricity, because philosophers and experimentalists traditionally avoided higher mathematics. Robert Symmer conducted two sets of experiments similar to the Beijing ones, which Symmer apparently had not heard about. Symmer presented his results to the Royal Society of London between February 1 and December 20, 1759. He concluded with an essay about two distinct electrical powers,[37] which pleased Franklin's one fluid theory opponents.

Gian Francesco Cigna was the first to comment on Aepinus' analysis of the Jesuits' experiment,[38] and Cigna's uncle Giacomo Battista Beccaria was interested in Beijing Je-

Emperor's brother in Brussels, Karl Alexander duke of Lorraine (* 1712; † 1780), after 1748 the governor of the Habsburg Netherlands in the approximate boundaries of modern Belgium. Kobencl and the duke were two top people representing Habsburg Netherlands authority. The duke lived in the beautiful palace built in 1756/1757, which today houses the museum dedicated to the 18th century. In 1744, he married Maria Anna (* 1718; † 1744), the younger sister of Maria Therese (* 1717; † 1780); but his wife died in the same year.

35 Novik, 1999, 12–13.

36 Aepinus, 1979, 130–131.

37 Symmer, 1759, 380; Aepinus, 1979, 406.

38 Aepinus, 1979, 200.

suits' results, too. In 1747, Beccaria became a professor of experimental physics at the University of Turin. Although he was a member of a different religious order, called Scolopi or Piaristen, he was a close friend of Boskovic and an admirer of Franklin's achievements. In 1767, he improved upon the Beijing Jesuits' experiment. He charged the coated glass plates, removed the coating from the negative plate, and put another neutral uncoated glass plate nearby. He coated the uncharged plate and used the conductor to connect its coating with the coating of charged plate. The entire area of both plates touched one another. If he separated the plates after they were in touch for some time but before they stuck together, the charged plate received a positive charge on both sides and the uncharged plate got a negative charge on both sides. If he separated the plates after they fused, the charged plate became negative on both sides, and the uncharged became positively charged on both sides. If after the fusion, he separated and then joined the plates again, the small circle of paper underneath the uncharged plate fused to it after each separation and was repelled after each touch. Beccaria was able to repeat the experiment as many as 500 times after he only charged the plate one time.[39] It was a great advancement over the Leyden jar experiment where the jar needed to be recharged after each experiment. The era of the steady electricity current was approaching, thanks to the Beijing experiments.

In 1769, Beccaria reprinted the Beijing report, referred to Aepinus' mathematical explanation as incomplete, and offered an explanation of his own Franklin's one fluid theory called "electricitas vindex."[40] Beccaria was an experienced researcher, but even he had his shortcomings. Alessandro Volta was not satisfied with Beccaria's theory; his search for other possible explanations led him to the invention of electrophorus several years later, as described in a letter to Joseph Priestley dated from Como on June 10, 1775.[41]

4. Dutch Science Exported to the Habsburg Monarchy (1713–1795) and to Japan (1720–1853): the Case Study of Electricity

After comparing the export of European electrostatic instruments to Franklin's America and to Hallerstein's Beijing, it would be valuable to compare the export of science from Leyden University to the Habsburg monarchy and to Japan, even if it is clear that the Habsburg monarchy did not experience the huge language barrier the Japanese *rangaku* did.[42] The Catholic region of the Netherlands, which roughly had the borders of the present-day Belgium, belonged to the Habsburgs between the peace of Utrecht (1713) and the French invasion after 1792. Empress Maria Theresa's minister Gerard van Swieten imported his native Netherlands' science to the somewhat backward mid-European part of the Habsburg monarchy at the same time as the Dutch *rangaku* interpreters introduced it to Japan. Many members of both exporting groups studied at the Dutch University of Leyden. Somewhat

[39] Beccaria, 1767, 297–298. Beccaria (1767, 297) noted the wrong volume citation for Aepinus' commentary on the Beijing experiment (*Phil.Trans.* 8: 276). Priestley (1775, 1: 316) later repeated the error.

[40] Beccaria, 1769, 44–47; Heilbron, 1979, 405–410.

[41] Aepinus, 1979, 131; Volta, 1816, IV, 108.

[42] *Rangaku* was the Japanese science based on Dutch works which prevailed in Japan for over a century after 1720.

later, the Japanese also used Viennese research, especially after they translated the commentaries by the Leyden-trained Viennese physician Gerard Baron van Swieten, which were widely used by the Beijing missionaries, and a treatise by Swieten's student Anton Stoerck.[43]

The Viennese experts welcomed new electro-dynamic data because Volta was a Habsburg North Italian employee teaching in Como Gymnasium (High School) and later in the Habsburg University of Pavia, where Boskovic and former Carniolan naturalist Anton Scopoli used to lecture before him. Volta's electrophorus was quickly introduced in the Habsburg court, especially after the van Swieten successor, the Empress Maria Therese's personal physician Dutch Jan Ingenhousz published his own electrical research. The Viennese physician Niklas Karl Molitor provided a German translation of Ingenhousz's work in Vienna (1781), just before Ingenhousz returned to England. It was already too late for Hallerstein to benefit from this research because he died in 1774. The Dutch physician Ingenhousz and his compatriots exported their knowledge to Hallerstein's native Habsburg monarchy. They distributed the same electrical knowledge taught in the University of Leyden, which the other Dutch physicians exported overseas to Japan as a part of *rangaku*. Ingenhousz corresponded with Franklin in 1776 and published his electrical and magnetic research in the *Philosophical Transactions* of 1779–1781, which Molitor translated, adding his and Ingenhousz' undated introductions.[44]

Ingenhousz further developed Franklin's electrophorus theory in his Bakerian lecture, delivered on June 4, 1778, and published in *Phil. Trans.* Ingenhousz acknowledged Franklin's "ingenious system," accepted Franklin's theory of electricity and discussed Volta's recently invented electrophorus in conjunction with his own theory, which was based on experiments with William Henly's apparatus that showed the impermeability of glass to electric fluid.

Ingenhousz researched both the torpedo fish and thunder after Colonel John Walsh published his ideas in *Phil. Trans.* (1773). Ingenhousz bought his instruments from the Amsterdam shop of Jonathan Cuthbertson,[45] who produced the air pumps, electrical jars, generators suitable for artillery, navigation, and medical-biological research[46] that Japanese *rangaku* found especially useful for the import of Dutch medicine to Japan. Ingenhousz described Richmann's fatal accident,[47] and concluded his introduction by citing the electricity research of Malzet, a professor of geography and natural philosophy.[48] Ingenhousz described Beccaria's experiments and theory, mentioned Volta, and explained all facts with

[43] Verhaeren, 1969, 850, 851. Western inventions reached Vienna more quickly than Tokyo: on June 6, 1784, Ingenhousz performed the very first hot-air balloon flight over Vienna without passengers. Two decades later, in 1805, the Swiss Johan Caspar Horner (* 1734; † 1834) and Prussian Georg Heinrich von Langsdorff (* 1774; † 1852) of Ivan Fedorovich Kruzenshtern's (* 1770; † 1846) mission met withwith Russian Ambassador to Japan, Nikolai Petrovich Rezanov (* 1764; † 1807), and heated a balloon made of Japanese paper (*washi*).

[44] Ingenhousz, 1781, 1–32. In 1784, Molitor became a professor of chemistry, pharmacy and *materia medica* in Mainz University of the Prince Friderich Karl Josef (Wiesner, 1905, 42).

[45] Ingenhousz, 1789, XLVII/XLVIII, 359; Ingenhousz, 1781, IV–VIII, XII, 6, 18–19, 21, 33.

[46] Cuthbertson, 1786, pl. VI fig. 2, pl. X fig. 1 & 10, 157.

[47] Ingenhousz, 1781, 21, 25.

[48] Emperor's librarian from Emperor's native Loraine Louis-Sébastien Jacquet de Malzet's (* 1715 Nancy; † August 17, 1800 Vienna).

Franklin's theory. Ingenhousz experimented with a glass vessel full of mercury. During the winter of 1780, Ingenhousz experimented with nine or 10 pairs of ball-shaped electricity jars connected with a wire. Ingenhousz mentioned Newton's experiments with magnets, and experimented with the Leyden jar in Franklin's manner. The Archduke Ferdinand of Milano was also interested in experiments with electrophorus. Ingenhousz mentioned Abbé Jean François Pilatre de Rozier's experiments published in his *Journal de Physique* in 1780.

Ingenhousz described the electrophorus as a kind of Leyden jar, especially in reference to the electrophorus' metallic plates and its sparks. He used Canton's theory of fluid in glass with positive and negative electricity. On July 9, 1778, he described his study of the pressure of the electric atmosphere with the long electric spark. In the experiment, he considered the spark covering the area 8 to 10 quadratic inches. He used the electric machine on the table of his room to ignite combustible powder. A month earlier, Cavallo had used a similar vessel in his experiment, and Ingenhousz used Volta's pistol invented several years earlier to produce a 4-inch-long spark in a hermetically closed vacuum vessel. He also studied the effect of Volta's pistol in the nearby air, referred to Benjamin Robins' *New Principle of Gunnery*, Hauksbee, Amontons, and Belidor's theory of powder published in *Phil. Trans.* Ingenhousz described two examples of the mahogany wood used for the barrel of the pistol, and concluded his treatise with his discovery of the gaseous part of air which did not contain phlogiston. He dedicated his own French translation from English[49] to Sir John Pringle on October 12, 1779, and an improved edition appeared in 1787.

Ingenhousz researched the role light plays in life. He studied in Leyden with P. Muschenbroek and chemist Hieronymus David Gaub, himself a student of Boerhaave. Ingenhousz become a practical physician in 1757. In England, Ingenhousz met Pringle, a personal doctor of the British queen Charlotte of Mecklinburg-Strelitz and the president of the Royal Society (1772–1778). Ingenhousz befriended many London physicians, among them anatomist and gynecologist William Hunter, the pediatric George Armstrong, and Ingenhousz' teacher Monro, himself the student of surgeon William Cheselden (* 1688; † 1752). Monro's son and brother were also physicians. Ingenhousz' friend in Edinburgh was William Cullen, the Glasgow professor of chemistry from 1746. On March 15, 1768, Ingenhousz was dining with the Habsburg representative in London when he learned the Empress Maria Theresa needed him as her Viennese physician. The other candidate for Ingenhousz' Viennese post was Boerhaave's other student Anton de Haen who had settled in Vienna in 1754. Ingenhousz visited Brussels, where he met the count Janez Karl Filip Kobencl, Habsburg, who had been appointed a Netherlands minister in 1753, and Prince Karl of Loraine, whose confessor was A. Hallerstein's brother. Ingenhousz left London in early April 1768 and Kobencl gave him instructions for his Viennese journey; he left Brussels on April 22, 1768, and arrived in Vienna on May 14.[50] The Emperor Josef's wife Duchesse of Parma died in 1765, and that tragedy paved the way of Ingenhousz's inoculation of the Imperial family on September 10, 1768.

[49] Ingenhousz, 1781, 40–41, 52, 59, 65, 75, 77, 85, 88, 93–95, 98, 100–104, 107–109, 117, 127, 129, 133, 134.

[50] Wiesner, 1905, 1, 17, 19–21, 24, 26; Wiesner, 1905b, 199.

In a letter to William Hunter dated February 4, 1783, Ingenhousz strongly opposed Mesmer's animal magnetism promoted in Vienna. Ingenhousz' opinion was supported by the Paris Academy and Franklin, but not by Viennese physicians Barth and Stöck. On July 14, 1788, Ingenhousz met his friend Franklin in Paris.[51] Both were Masons[52] in Joseph Jérôme Le François de Lalande's Parisian lodge, together with A. L. de Jussieu, A. F. Forcroy, Chaboneau, J. S. Bailly, Condorcet, G. Romme, Thomas Paine, J. Banks, F. Fontana, Joseph Priestley, A. Strzecki, and many others. The Parisian Masons provided some courses in physics, chemistry and mathematics. Franklin was the key person in the official reception of Voltaire into the lodge on April 7, 1778.[53] Along with with Scheele, Priestley and Lavoisier, Ingenhousz researched the study of air without phlogiston, but Priestley and Ingenhousz did not like each other. Ingenhousz learned from the Dutch Nikolaus Joseph Baron Jacquin in Vienna about the compounds of fixed air identical to the atmospheric ones. Ingenhousz admired Pastor Jean Senebier's extraction of air from plants with the air pump,[54] and collaborated with the Jacobin revolutionary chemist Jean Henry Hassenfratz, the promoter of humus theory. Ingenhousz was one of the first to use a microscope[55] in his botanical research. He experimented with plants in vacuum,[56] arranged a lightning rod for the Viennese Emperor's powder store,[57] and examined the physiological effects of electricity[58] in early medical use. He did not refer to the Lazarist professor of experimental physics Nicholas Bertholon's invention of electro-vegetal-meter,[59] the Parisian *Société de Physiciens' Nouveau dictionnaire raisonné de physique* (1770), or Joseph Aignan Sigaud-Lafond's *Précis historique et expérimental des phénomènes électriques* (Paris 1785),[60] which Beijing Jesuits read in French.

Ingenhousz constructed an electric light for houses[61] using Volta's 1776 Como design, which was the very first electric light, but did not credit Volta. Ingenhousz made the lamp in Vienna during the summer 1781, and used the metal plate of an electrophorus. The pistons he designed for a vacuum pump prevented inflammable air from entering the vacuum vessel.[62] Since 1782, Ingenhousz was aware of the possible danger of the hydrogen that filled the lights.[63]

In May 1769, Ingenhousz was in Florence, where he inoculated the Archduke Leopold's family and met Felice Fontana.[64] Ingenhousz then returned to Vienna after three years of travel.[65] On his return, he designed the Viennese double-piston vacuum pump

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51 Wiesner, 1905, 27, 31, 46, 229–230.
52 Hans, 1953, 513, 517, 519.
53 Hans, 1953, 516, 521.
54 Wiesner, 1905, 65, 82, 97, 104; Ingenhousz, 1789, XXV–XXVI.
55 Wiesner, 1905, 131, 137.
56 As did Benjamin Thompson, later Count Rumford (Ingenhousz, 1789, 85, 142, 327–399).
57 Like Benjamin Wilson in England (Wiesner, 1905, 185; Ingenhousz, 1781, 28).
58 Ingenhousz, 1789, 250–260.
59 Bertholon, 1783 (Verhaeren, 1969, 26).
60 Verhaeren, 1969, 176, 177.
61 Wiesner, 1905, 26.
62 Ingenhousz, 1784, 1: 214–215, 218, 223, 225.
63 Ingenhousz, 1785, 146–147; Brenni, 2004, 9.
64 Wiesner, 1905, 37.
65 Ingenhousz, 1784, 435.

using Fontana's research of absorption on coal, which Ernst Mach praised very highly.[66] Ingenhousz mixed powder with olive oil to get a hermetic seal, and illustrated the whole instrument and the parts of the pump.[67] The Viennese Jesuits were not involved except for Jesuit numismatist and mathematician Josef Khell von Khellburg, with whom Ingenhousz corresponded on June 20, 1772. Hallerstein learned about Ingenhousz's work from the Viennese circle of academics that included Hallerstein's editor, the Jesuit Maximilian Hell. The Jesuits presented a vacuum pump to the Chinese Emperor on March 10, 1773.

F. Fontana and Ingenhousz corresponded in 1771 on scientific instruments and proposed a scientific academy of Florence. Fontana permitted Ingenhousz to describe Fontana's invention of the eudiometer when Ingenhousz left Vienna for England in 1782. Ingenhousz designed the vacuum vessel with a copper-messing cover but did not share Fontana's hope that such a design would make a better vacuum than an ordinary pump. He modified Fontana's principle for the technical analysis of gas mixtures with a hand-eudiometer and bettered Fontana's apparatus for oxygen inhalation, which Thomas Beddoes later practiced in Bristol.[68]

5. Volta on the Beijing Jesuits' Electrophorus Experiment

Volta taught in Como during his early acquaintance with the Beijing Jesuits' experiments. Priestley analyzed the Beijing contribution in his masterpiece.[69] In that way, the Beijing electrical experiments paved the way to modern electricity.

The Royal Society elected Volta to a "foreign list" in 1791, and on October 8, 1792, Volta sent a letter to famous researcher of electricity Tiberius Cavallo, a naturalized Englishman of Italian origin, published in *Philosophical Transactions* in March 1794.[70] Volta

66 Wiesner, 1905, 190; Ingenhousz, 1784, 431–446.

67 Ingenhousz, 1784, 441, 450–451 (Tab. II), and fig. VII, 451 and Tab. II, fig. VIII, IX, X.

68 Wiesner, 1905, 72, 197, 208, 210, 225, 229; Ingenhousz, 1784, 445–446; Ingenhousz, 1787, 197–198, 200, 228.

69 Priestley, 1775, 1: 315–316.

70 Cavallo passed the letter around and Beddoes († 1808) heard about it. Madame Elisabeth Fulhame, whose book Zois had, had declared that electric fluid revives the metals in a manner similar manner to what other combustible bodies do, that is, with the decomposition of water. Beddoes praised her work but denied the water decomposition before Nicholson's definite proofs. Beddoes supported Lavoisier's claims against all sorts of invisible fluids, but Humphry Davy also refused Lavoisier's caloric. In 1797, Alexander von Humboldt's *Attempts* supported Galvani and Galvani's nephew Aldini against Volta. Beddoes supported F.A.C. Gren's *Grundrise der Naturlehre* (Halle, 1808) imagining the electricity between light (phlogiston) and caloric. In autumn 1798, Davy joined Beddoes as "superintendant" to the *Pneumatic Institution* build with the patronage of Watt and others in Bristol. Davy and Beddoes debated Davy's experiments and published them in the recently launched Nicholson's London *Journal of Natural Philosophy, Chemistry and the Arts*, beginning with Davy's publication in summer 1800. Davy spent a lot of money for Beddoes' batteries with 110 and more plates of zinc and silver. The London *Morning Chronicle* printed the first British news on Voltaic battery on May 30, 1800, and Davy was publishing his Bristol reports from late June 1800 until January 23, 1801. On December 23, 1800, Beddoes described Davy's experiments to Watt, who was in touch with Davy during those months. The chemist Nicholson, whose book Sigismund Zois had in Hallerstein's native Ljubljana, declined Volta's strictly physical interpretation, but only Davy brought the Voltaic battery business from physics to chemistry. Davy avoided theory; rather, he dealt with the concrete, discovering new metals potassium and sodium (1807). Aldini used galvanic current to dissect the body of poor George Foster in London. John Corry ridiculed both Aldini and Beddoes in his *Satirical View of London*, because Beddoes was a good focus for ridicule after he had to leave his previous position. In March

announced his pile invention for the first time in the spring 1800 session of the London Royal Society, and mailed to London the 1000-word description of his "artificial electric organ," which imitated the electric organs of the torpedo fish-battery. The news quickly spread through Europe, reaching Beddoes, Davy, and Beddoes' mentor Erasmus Darwin's Bristol in a few months. A Belgian amateur magician, Étienne Gaspar Robertson, built the first Voltaic battery in Paris in the summer of 1800, publishing his results in *Annales de Chemie*. Volta's invention revived the Aristotelian debate between the possibility that inanimate beings produce "animal" electricity and the Aristotelian inability to find similar material in the sub-lunar and supra-lunar spheres. Friederich Wöhler's synthesis of urea (1828) and Chladni and Schreiber's proof of the extraterrestrial origin of meteors supported Volta's view.

E. Darwin began to sell "galvanic" cures to his wealthy female patients. Darwin was more deeply interested in electricity than Beddoes because of its connection with his meteorological research. After his early Bristol Voltaic experiments, (late June 1800-January 23, 1801)[71] Davy became Thomas Garnett's assistant at the Royal Institution (March 1801). He left the more radical Bristol for the aristocratic Royal Institution to hide his former radicalism. In 1803, he reviewed Aldini's *Account of the Late Improvements in Galvanism* to the recently launched *Whig Edinburgh Review*.[72] Davy eventually became a good friend of the magnate Baron Sigismund Zois in Ljubljana, where Zois read early works from Davy and Nicholson. On November 7, 12, and 22, 1800, Volta experimented with his pile to please and interest Napoleon in Paris. Volta and his companion, Luigi Valentino Brugnatelli, who took Scopoli's Pavia chair for chemistry, performed their experiments with the aid of de Luc and Lalande. Rumford, Berthollet, Haüy, and Biot also attended the show. Brugnatelli and Volta joined Cuvier in the Jardin des Plantes on September 29, 1800,[73] where Cuvier had already examined the curious cave animal *Proteus*, which Zois had sent him from Ljubljana. Napoleon's soldiers carried Volta's invention to Ljubljana. The Illyrian Provinces Governor, General Marmont, showed his Ljubljana caloric experiments to Gaspard Monge Count de Pélouse, Marmont's former teacher Laplace,[74] Bertholett, Humboldt, and Gay-Lussac in Paris. Gay-Lussac refuted Marmont's claim of weighting the caloric. The Duke Marmont had to recognize his incompetence[75] and donated Volta's piles from his Ljubljana laboratory to the Ljubljana professor Janez Krstnik Kersnik in 1811. There were no more Jesuits in those Napoleonic times to spread the fruits of electrical observations back to their adopted Chinese homes. The Beijing electrophorus experiment seems to be the very last of the Beijing inventions developed in Europe and

1799, the Medical Pneumatic Institution of Bristol was officially opened and in early April 1799, Beddoes and Davy (ab)used the pure hydrogen and the nitrous oxide. They noticed tremendous effects, but Watt did not, so he joked that the effects became less and less noticeable the farther one went from Bristol. Watt began such chemical self-experiments before Beddoes was involved in the chemical research of "pneumatic practice," which later became extremely popular among the British physicians (Levere, 2009, 224; Pancaldi, 2009, 247, 252–254, 258, 259; Morus, 2009, 263, 270; Jay, 2009, 297; Stewart, 2009, 234–235, 240).

71 Chladni, Schreibers, 1819: Schreiber, 1820; Pancaldi, 2009, 247–250, 254–256.

72 Morus, 2009, 268, 271.

73 Santangelo, 2001, 26, 29, 31–32.

74 Hahn, 2005, 103.

75 Marmont, 1857, 446–447.

brought back to Beijing. There was certainly a "small" difference, because this time, the inventors were the adoptive Beijing inhabitants, namely the Jesuits.

6. Vacuum for the Chinese Emperor

The famous electricity experiment was certainly not the sole accomplishment of Hallerstein's time among Jesuit physicists of Beijing. Telescopes had already facilitated the acceptation of the Tychonic system in China[76] and they were soon accompanied by more expensive vacuum instruments. On January 12, 1773, new French missionaries, with the help of their superior in Canton, Joseph Louis le Fèvre, brought many presents to China, including the excellent mirror telescope and the first air pump to Beijing, more than a century after its European invention. The French missionaries were the watchmaker Méricourt[77] and the artist Panzi,[78] who traveled on the orders of French minister Bertin.[79] Both Jesuits knew the working conditions of the pump because they were instructed in Paris before they sailed for China. On January 18, 1773, the emperor had the pump carried into the Ruyiguan (如意館, Jou-y-koan) building where the European artists worked. It became a sort of chamber of wonders where the Emperor Qianlong kept his European gifts. Hallerstein's friend Giuseppe Castiglione took care of architecture, Jean-Denis Attiret and Sickelbarth provided the decoration of buildings, Gilles Thébault arranged the ironworks, and Benoist was in charge of the hydraulics.[80] Benoist became an expert on the hydraulics needed for vacuum pump operation, and on February 26, 1767, Sickelbarth succeeded his teacher Castiglione as the director of an art academy in the court of Beijing. During the spring, Benoist and Sickelbarth[81] presented the pump and explained its abilities to the emperor. Benoist worked with the pump for a few months to make it suitable for the demonstration and more pleasing to the Emperor. He explained to one of the Chinese how to handle the pump and trained him as his assistant. He chose the most interesting experiments for the emperor, made copper engravings of their design, and explained them in a little book. He kept the pump in a room with a controlled temperature, as extreme cold could damage it. Méricourt and Panzi taught the eunuchs to handle the pump and Yuan Mingyuan translated their orders to the eunuchs.

Four eunuchs manipulated the pump for the first vacuum experiments on March 10, 1773 in Ruyiguan. Three missionaries, Méricourt, Archange, and Ventavon,[82] examined

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76 Wang, Wu, Sun, 2008, 324.

77 Father Hubert de Méricourt (Li Tsuen-Hien Si-Tschen, * November 1, 1729 France; † August 20, 1774 Beijing) died soon after his Beijing vacuum experiments (Pfister, 1934, 974).

78 Brother Joseph Panzi (Pansi, P'an T'ing-Tchang, Jo-Ché, * about 1733 Italy; † before 1812 Beijing) was a member of the French Chinese mission in 1771 (Pfister, 1934, 971).

79 Henri-Léonard-Jean-Baptiste Bertin count de Bourdeilles (* March 24, 1720 Périgueux; † 1792 Spa in Belgium) was the minister for the agriculture, and in 1774 for the foreign affairs. He was an honorary member of the Paris Academy (Amiot, 1774, 519).

80 Rinaldi, 2006, 210.

81 Ignac Sickelbarth (Sichelbarth, Ngai K'i-Mong Sing-Ngan, * September 26, 1708 Neudeuk (Neudeck, Nedejk) in north Bohemia; † October 6, 1780 Beijing (Dehergne, 1973, 247)) arrived to Macao in 1744 and went to Beijing next year (Koláček, 1999, 41).

82 Jean Matthieu de Ventavon (* September 14, 1733 Gap; † May 27, 1787 Beijing (Sommervogel, 1898, 8:

all parts of the pump in their Chinese clockmaker shop, which indicates that the device was mostly in charge of the French Jesuits, who probably just asked the distinguished older expert Hallerstein for advice. The eunuchs were excited when Benoist compressed, rarefied, or otherwise manipulated the air for them. They had enormous difficulty in accepting the concept of air pressure, although it had been discussed in Europe a century earlier after Torricelli's letter (1644) which described the barometer for the first time, because most Jesuits preferred the Jesuit Linus' Aristotelian view or the views of the Jesuit Nicolo Zucchi's *Nova de machinis philosophia*. The Jesuits refused to accept complete emptiness almost until Boskovic's publications. The Beijing Jesuits had two 1649 editions of Zucchi's work, and a single 1669 edition of Zucchi's work with the bookplate *V Prou^ae^ Sinensis*. Even Descartes and Leibniz refused the concept of the Torricelli-Galilean vacuum. The Chinese Jesuits used Galileo's[83] works up to the Florentine 1718 Italian edition acquired by Hallerstein's friend, Bishop Laimbeckhoven of Nanjing;[84] Torricelli's mathematical works; the humanistic part of Leibniz' publications; many of Descartes' works on optics and geometry;[85] and two editions of the Jesuit Claude François Millet Dechales' careful support of William Gilbert and Galileo[86] with the Chinese vice-provincial's bookplate.[87] The Beijing Jesuits wanted to save some money; therefore, they bound several Galileo's works with the books of Ph. Apian's *De utilitate trientis* (1586. Tubingae), Kepler's *Dioptrice* (1611), Giulio Cesare La Galla's *De phenomenis in orbe lunae novi telescopi usu a D. Gallileo Gallileo* (1612. Venetiis: Thomam Balionum), Franciscus Sitius' *Dianoia astronomica* (1611. Venetiis: Peter Maria Bertan),[88] A. Piccolomini's *Parafrasi sopra le Mecanice d'Aristotle* (1582, Roma), and others. Hallerstein also got a somewhat dubious version of Galileo's *Dialogo* (1632. Florence) in Matthias Bernegger's 1635 translation,[89] but he did not have Galileo's *Discorsi*.

The Chinese emperor liked the vacuum experiment, whatever philosophy was hiding in its shadow. At 8 p.m., the emperor demanded the explanation for all the experimental results. He examined the inside parts of the pump. Benoist had to explain to him the meaning of the numerous copper engravings concerning with the pump. The emperor ordered Benoist to repeat all the experiments from Ruyiguan that eunuchs had arranged for him.

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565)) published several letters and translated Chinese publications.

83 Verhaeren, 1969, 916, 958–959.

84 Bookplate *Do Bispo de Nankin* (Verhaeren, 1969, 958) of Gottfried-Xavier Laimbeckhoven (Nan Hoai-Jen Ngo-Te, * 1702 Vienna; † 1787 T'ang-kia-hiang near Su-choua in China).

85 Verhaeren, 1969, 2, 62, 160, 416–418, 589–590.

86 Dechales, 1674.

87 Hallerstein and Laimbeckhoven personally used Dechales' book for triangulation during their sailing for the Far East. They probably carried the 1690 edition (bookplates *Coll. Pek. S.J.* in 1674 edition, and *Applicado à V. Provincia da China.—Vice Provinciae Sinesis* in later 1690 edition (Verhaeren, 1969, 364–365; Laimbeckhoven, 1740, 71)), while as Ljubljana student and teacher Hallerstein used the 1674 edition, which Ljubljana Jesuits adorned with their bookplate in 1678 (today NUK-4209, catalogued in *Verzeichnis* (1775) under No. 431). It is their oldest preserved mathematical book, with the bookplate from the former Ljubljana Jesuit library. Hallerstein and Laimbeckhoven also brought the German 1726 edition of Bion's Mathematical school (Verhaeren, 1969, 1126–1127), and Wolff's edition of *Elementa matheseos universae* (1732–1735), both containing vacuum pump descriptions.

88 Verhaeren, 1969, 815.

89 Bookplate *Collegij Soc. Jesv Pekini* (No. 1656, Verhaeren, 1969, 482–483).

On the next day, March 11, 1773, the eunuchs reported to Benoist immediately after his arrival in Ruyiguan. They described the events of the previous day. The Emperor ordered the preparation of the new experiments, and Benoist took the pump apart to examine the working condition of all its pieces. Before noon, Benoist explained to the emperor the use of the different valves, the great pipe on the other side of piston, which prevented the outer air entrance into the pump, and the outer security valve, which stopped the transition of the outer air into the recipient. When emperor learned about all parts of the pump, he ordered the experiments to begin. During the preparation for the experiments, the emperor posed many questions, as was typical for him. Benoist demonstrated 21 selected experiments to the emperor. The first six of them proved the existence of air pressure. The experiments followed one another in rapid succession. When emperor listened to the explanation of the previous experiment, they were already preparing the next one. Benoist brought a barometer and thermometer to the hall. The Emperor posed several questions, wondering how the air pressure lowered the level of the mercury in the barometer, how it raised the water in the pump, and why the change in pressure was proportional to the height of the mercury. Benoist used the explanations common in Europe of that time and explained that air density changes with the weather conditions.

The second group of Benoist's experiments showed the elasticity and the compressibility of the air. The emperor liked them very much and his good will enabled the vacuum research to enter China a hundred years after the pioneering European experiments.

In Ruyiguan, Benoist wanted to call the pump "the tube for the air research" (*yan qi tong* (研氣筩, *yen chhi thung*), *nien-ki-tung* in the French transcription). The Emperor decided to use the word *hou* (*heou* in the French transcription) instead of *yan* (*nien* in the French transcription). The Emperor considered that name better and nobler; therefore, they preferred it in classical Chinese books for describing observations of the sky, planning of agricultural activities, and the changing of the yearly seasons. Therefore the Emperor chose the name "tube for the air observation" (*hou chhi thung*, in the French transcription, *heou-hy-tung*). Both proposed names did not truly express the usefulness of the "new" device, although the use of vacuum barometer must have been clear to the Chinese.

At the end of the presentation of the pump, the Emperor politely thanked his wives and the other ladies for their help during the experiments. The presence of high society ladies was not uncommon even during Viennese public astronomic observations of those times. The emperor stood near the pump during the entire long exhibition. After it was over, he retired to his rooms and ordered the servants to bring the pump. He presented Benoist, Méricourt, and Panzi with three huge pieces of silk.[90] François Bourgeois described the vacuum pump experiment to Father Duprez on November 1 and 29, 1773.[91] Bourgeois' research on the Shanghai dialect was published in Shanghai (1934, 1939), and he eventually submitting Hallerstein's statistics concerning Chinese inhabitants for Parisian publication. Soon after his vacuum experiments, Benoist died of a stroke, a few days before Hallerstein

[90] Sickelbarth was the first to paint the female musk deer for Hallerstein's publication in London *Philosophical Transactions* (1753), and Panzi later drew a huge emperor's portrait (Bernard-Maitre, 1943, 457).

[91] Pfister, 1934, 926, 948; *Recueil de Zi-ka-wei*, pp. 37–41, 42; Aimé-Martin, 1843, 4: 223–224; Benoist, letter to persons unknown dated November 4, 1773; Needham, Ling, 1959, 3: 451; Bernard-Maitre, 1948, 155.

himself died.

Which air pump did the Jesuits give to the emperor? Francis Hauksbee's pumps from the beginning of the century still prevailed, but in 1721, Emanuel Swedenborg had fabricated a new type of pump, and the Ljubljana Baron Zois had bought Swedenborg's works discussing physics and technology. Swedenborg used an evacuated sail bell. He connected the iron vessel to the iron tube with mercury flowing through it. Swedenborg was involved in scientific research before he became a philosopher and spiritualist. In 1797, the physician Joseph Knight Baader used Swedenborg's principle for his pump, which replaced Marly's in Versailles in 1806. The French engineer Michel of the Bavarian mapping service (1764–1770) used Swedenborg's pump, and Jean André Cazalet described it in 1796. Most contemporaries did not know of Swedenborg's discoveries, and Friedrich Albert Carl Gren decided to reprint them with comments.[92]

The French minister Bertin could have sent the Parisian vacuum pump of Michel and Cazalet to Beijing, but the most important Paris pump manufacturer at the time was Jean Nicolas Fortin of the Bureau of Longitude. Lavoisier arranged for Fortin's manufacture of the experimental tools. In 1778 and 1779, he presented his vacuum pump to the Paris Academy, using the double walk for the first time in France. In 1784, he produced the gas gauge. In 1788, he prepared a large accurate balance for Lavoisier, and invented a very useful transportable mercury barometer. After Lavoisier's execution, Fortin sold his laboratory on November 10, 1794, and eventually made the gauge for Gay-Lussac's air expansion measurements in 1806.

Fortin used two pumping mechanisms made of brass in his vacuum pump. A chain with hooks directed the pistons in the opposite directions of the lever. Fortin connected both pistons to diminish the force used to overcome the air pressure. Denis Papin, P. Musschenbroek's collaborator Willem Jacob's Gravesande, and Hauksbee had already developed that idea and Beijing missionaries used's Gravesande's book with Gouvea's bookplate.[93] Two conducting tubes that came out of the pump merged in one and opened in the middle of the horizontal plate with the vacuum vessel. The pressure of the force on the vessel affected the side testing tube, which contained a siphon barometer with equal legs. The barometer measured the small pressures as the difference of the mercury lever in both legs. Fortin measured the rest pressure in barometer with the vertical tube on the second side hole, with the ends sunk into the vessel full of mercury. When the pressure in vacuum vessel was lowered, the mercury ascended in the vessel. The pipe in front of the plate released the air into the vessel, which would be impossible without vacuum, because the vessel's air pressure would stop the incoming air. With the later improvements, Fortin added a second barometer and a small sideways pipe in front of the barometer to release the gas into the previously evacuated vessel.

[92] Gren, 1791, 409–410.
[93] Verhaeren, 1969, 507–508.

7. Conclusion

Hallerstein's role in the Beijing Jesuits' electrical and vacuum research was not as evident as his leading role in astronomic, cartographic, and Chinese demographic research publications. Many of those accomplishments were joint projects commissioned under the Qing court.[94] Because he was a leading Jesuit scientist in Beijing, we could reasonably suppose that he played his part in electricity or even later vacuum activities. For the very first time the Beijing Jesuits' electricity research as the foundation of the later Volta's success was placed under historical examination.

Two centuries of the Old Society of Jesus' presence in China had its ups and downs. The Jesuits were not always helpful to their hosts in all aspects of their work. They tried to sell their superior scientific and technological knowledge to their hosts, believing they would serve as keys to unlocking the Chinese hearts and, more important, their souls. The Jesuits especially desired to save the souls of their noble hosts, especially the Chinese emperor, because the Jesuits hoped to repeat the Roman Emperor Constantine's example of conversion.

Hallerstein devoted most of his strength to the development of science in both Europe and China. The science Hallerstein offered to the Chinese was not always up-to-date, as the Lisbon-Canton ship returned his mail only once in two years, which is far from modern standards in telecommunications. Hallerstein did not deliberately hide his European knowledge from the Chinese. He was extremely proud of his observatory and loved to show it to visitors. European scientific journals before the French Revolution freely published military-oriented experiments that would today be considered as top secret. There was no reason for the Jesuits to hide the European knowledge from the Chinese, except that they feared that their Chinese students would learn enough to make Jesuit help unnecessary. The Jesuit Ferdinand Verbiest manufactured the best guns he could for the Chinese, and Hallerstein was willing to do the same. On the other hand, the Chinese Jesuits clearly acted as intelligence agents, delivering valuable military, geographic, and demographic data to their European correspondents, which ultimately enabled European success in the Opium Wars (1839–1841)[95] because the English knew much more about the Chinese than vice versa. The Jesuits, with Hallerstein as their last scientific leader, benefited Chinese science and technology, but the Chinese lost them too early before the Opium Wars to profit from the export of European military and technological knowledge to China. The early days of vacuum and electrical research in Hallerstein's time paved the way for the later dynamos and electric incandescent lamps[96] that were developed after Opium Wars and devastation of the Summer Palace.[97]

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94 Hostetler, 2007, 126–127.

95 Tse-Hei Lee, 2008, 274.

96 Lambert, Dilaura, 2004, cxcvi.

97 Rinaldi, 2006, 210. It's interesting to speculate more deeply and try to figure what could have happened if the Slovene Gabriel Gruber (* 1740 Vienna; † 1805 Petersburg) brought Hallerstein's Chinese friends, the Bishop Laimbeckhoven, Poirot, Cipolla, and the other ex-Jesuits, under Gruber's Jesuit flag, which Gruber tried very hard as the Jesuit General in Petersburg. With the Chinese Jesuits still on board, the Chinese technological gap would not broaden so deep as it did after Hallerstein's death. The Chinese would not be lacking the newly developed European vacuum-based steam engines and electro-chemical devices which Hallerstein and especially Gruber

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Bibliography

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NM-Erberg = Former books of Hallerstein's uncle Erberg, now in the Library of National Museum of Ljubljana, Slovenia

NUK = Signatures in National and University Library of Ljubljana, Slovenia.

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knew so well, and the Beijing Manchu Emperors could have escaped the humiliating military defeats during the unhappy 19^{th} century.

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