EARLY JAPANESE LEYDEN JARS AND AIR PUMPS

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1.- Introduction.

In the times when Japan was closed to all European influences except the small Dutch colony in the artificial Deshima Island in Nagasaki bay, the Magdeburg mayor Otto Guericke invented his air pump in early 1650-s. Probably in the year 1663 he successfully designed the very first crude sulfur ball friction electrostatic generator. His pioneering achievements tightly connected the early explorations of vacuum and electrical technology devices for
times to come. Both research fields eventually completely joined again and forever during the worldwide research of the new scientific instruments which followed Heinrich Geissler’s invention of the vacuum cathode tubes in 1855. Geissler worked Bonn, not far from Guericke’s Magdeburg, and he achieved his part of fame two centuries after Guericke’s success. Geissler’s vacuum cathode tubes proved to be the basis of the 20th century science, technology, and, last but not least, the entertainment industry. The modern vacuum technology seems to be the output of Guericke’s early efforts supported by the high politicians interested in technology or scientific tools, as was Guericke’s collaborator, the Viennese prime minister Janez Vajkard Prince Auersperg from Ljubljana1. The grandfather of the president of Beijing Astronomical Bureau Auguštin Hallerstein (*1703; †1774) was Auersperg’s customs officer Janez Daniel Erberg (*1647; †1716), which influenced Hallerstein’s interest in new technologies.

Guericke’s instruments were widely known among the mid-European aristocracy even before the Jesuit Gaspar Schott reported on Guericke’s experiments in printed book for the first time2. Guericke published his discoveries in the Dutch town of Amsterdam much later in 1672. In the times of Guericke’s Amsterdam publication the Dutch vacuum technology was already near its culminating point, with Huygens’ fame spreading worldwide. The Dutch Christiaan Huygens (*1629 The Hague; †1695) did not hesitate to continue Guericke’s electrostatics research. Huygens preferred the Descartes’ theory of the vortices, because Descartes spent a good deal of his life in Holland in friendly connections with Huygens’ family. Huygens paved the way to his compatriot Pieter van Musschenbroek (*1692; †1761) in spite of the fact that electricity was never main Huygens’ research field.

The father (Johan) and the uncle (Samuel) of Leyden jar inventor Pieter van Musschenbroek manufactured the best air pumps of their times in their shop near the Leyden University headquarters. Guericke, Huygens, and Musschenbroek’s examples give us the opportunity to study together both research fields, electrostatics and vacuum technologies, while trying to find the way how their inventions expanded from their hometowns connected with Netherlands to the regions with underdeveloped technology as were the mid-18th century Habsburg Monarchy, China, or Japan. The Japanese

2 SCHOTT, 1657, 640.
case is especially illuminating because the Dutch were eventually the only Europeans allowed to enter Japan after 1639, although the Japanese more or less confined even Dutch to the artificial Deshima Island in Nagasaki Bay. The following century during Huygens and Pieter van Musschenbroek’s era witnessed the greatest success of Dutch vacuum technologies and electrostatics research. Both Huygens and Musschenbroek studied at the University of Leyden, and most of the Dutch physicians visiting Deshima acquired their knowledge from the same famous Leyden Alma Mater. It is therefore only natural to suppose the relatively swift entrance of Huygens or Musschenbroek’s vacuum technology and electrostatics instruments into Japan, which we will try to prove in this research. In addition, most of the technicians or scientists which Viennese imported from the (Habsburg) Netherlands studied in Leyden University, including Gerhard van Swieten (*1700; †1772), Nikolaus Joseph baron Jacquin (1727; †1817), or Jan Ingenhousz (*1730; †1799).

Fig. 2. Abbé Jean-Antoine Nollet’s (*1700; †1770) vacuum instruments with Guericke’s Magdeburg hemispheres copied from the book kept in Ljubljana Franciscan monastery (NOLLET, 1751, 3: table of pictures No. 2 (Courtesy of Dr. Prof. Miran Špelič, OFM)). Nollet translated to French language Musschenbroek’s January 1746 letter announcing the discovery of Leyden jar, the term Nollet actually coined.
2. - Dutch Excellency on Technology and Scientific Instruments.

The Jesuits under Portuguese flag never tried the systematic introduction of Western technology and scientific instruments in Japan as they urged to accomplish in China. They preferred the straightforward evangelisation of Japanese which began in the year of the publication of Copernicus’ *De Revolutionibus*\(^3\). That coincidence stimulated Nakayama’s research of early Japanese uses of Copernicus’ book. So far less attention received the introduction of more up-to-date vacuum pumps or Leyden Jars in Japan, although they were the direct production of Dutch know-how via Huygens or Pieter van Musschenbroek, and therefore immediately available to the Japanese translators from the Dutch language called rangaku as a part of the introduction of Western science to Japan called yogaku (洋學)\(^4\). The Protestant Dutch were far less interested in religious propaganda compared to their Catholic Portuguese predecessors. The primary Dutch concern was the profit of their business. Considering the Japanese connection with the Dutch one could expect that the Japanese learned easily about the Dutch Christiaan Huygens’ vacuum experiments performed initially in November 1661 in Huygens’ native The Hague after Huygens examined Boyle’s air pumps. Huygens loudly finished his research of vacuum techniques in Paris on April 14, 1668 in pretty dangerous exploding circumstances compromising him and even more his Paris Academy spectators. The professor Burchardus de Volder (*1643 Amsterdam; †1709) became the executor of Huygens’ last will, and he continued Huygens’ work in collaboration with the Leyden shop just across the street of the University. The shop owners were Pieter’s uncle Samuel Joosten Musschenbroek (*1639; †1681) and Pieter’s father Johan Joosten Musschenbroek (*1660; †1707) who manufactured the pump invented by Boerhaave’s professor of Aristotle’s philosophy, Wolferd Senguerd (Senguerolus, *1646; †1724). Senguerd described the one piston air pump in his 1680 *Philosophia Naturalis* using Robert Hooke, Denis Papin, and their master Robert Boyle’s design. Senguerd and Boerhaave’s student Pieter van Musschenbroek got his chair for physics in the Leyden University in 1739. The Dutch Deshima physicians quickly learned the details of Pieter Musschenbroek’s and his student lawyer Andreas Cunaeus’ (*1712; †1788)
Leyden jar invention, announced in November 1745. Boerhaave’s medicine and chemistry was another convenient Dutch product for the Dutch exportation to Japan\(^5\) combined with the medical use of electricity. Viennese or Petersburg authorities also liked to employ Boerhaave’s students as were van Swieten or his classmate Antonio-Nunes Ribeyra Sanchez (Ribeiro Sanches, *1699; †1783).

![Fig. 3. Musschenbroek’s vacuum technology copied from his book kept in the library of Ljubljana Franciscan monastery (MUSCHENBROEK, 1745, table of pictures No. 10 (Courtesy of Dr. Prof. Miran Špelič, OFM)).](image)

**3.- Japanese Erekiteru’s answer to the rangaku’s challenge.**

The transfer of Dutch electrical research to Japan was accomplished with greater speed compared to the Chinese Jesuits sources imported from Lisbon, Vienna, and London for the Beijing Jesuits under Portuguese flag, or from Paris for the French Jesuits’ mission in Beijing. The Dutch-Japanese connections enabled the use of Japanese electric generators *erekiteru* (エレキ, エレキテル) in medical practice which specially interested the rangaku translators.

The Japanese literati had several advantages compared to their Chinese contemporaries. The Chinese did not develop a dynamic city like the Japanese

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Osaka where the merchant Masuya Kouemon (Yamagata Banto, *1748; †1821) collected the Dutch dictionaries or books focusing on astronomy, geography, medicine, astrolabes, globes, celestial globes, binoculars, and clocks after Anthonij Kluijt brought the first European clock to Shogun in 1736. The Osaka wealthy merchants’ interests in practical science (jitsugaku) combined with their interests in useful Western physics. Maruyama Ōkyo (円山応挙, *1733; †1795) created the stereographic pictures in Western Style, and Shiba Kōkan (司馬江漢, *1747?; †1818) made copper etchings after 1783, and later successfully compiled the first Japanese map of the world in 1792. It was already a high time for the original Japanese contributions which culminated inerekiterus designs.

Tanuma Okitsugu (田沼意次, *1719; †1788) became the senior councillor (Rōjū) in 1769. The craze for electrostatic generators callederekiteru, which the Japanese also used for medical treatment, originated in Grand Chancellor Tanuma Okitsugu’s Era between the years 1760 and 1786. In a kind of modern era Renaissanceerekiterus became extremely popular nowadays in Japan.

How did the idea oferekiterus enter the Japanese islands on the first place? In 1765, the herbalist Gotō Rishun (後藤梨春, *1696; †1771) introduced theerekiteruin his book Orandabanashi (紅毛譯, Kōmōdan, Talks about Holland). Few years after, the Dutch presented to the Shogun improved Guericke’s rotating friction electrostatic generator of John Dollond’s son-in-law, Jesse Ramsden (*1735 Halifax; †1800 Brighton). Ramsden introduced the glass disc rubbed by four pads in London in 1766. The Shogun examined Ramsden’s electrostatic generator for the first time in Edo around the year 1770, which was immediately after Ramsden’s discovery if we take into account several months of sailing between London and Japan of those times. The curator of Dutch Teylers Museum in Haarlem, Martinus van Marum (*1750 Delft; †1837), successfully demonstrated the Leyden jar combined with his electricity machine for his spectators, and Marum’s fame soon reached Japan through the Dutch colony of Deshima Island.

Fig. 4. Ramsden’s electrostatic generator, which the Shogun examined in Edo around the year 1770.

In 1776 Hiraga Gennai (平賀 源内, pseudonym Fūrai Sanjin, 風来山人, *1728/29; †January 24, 1780) procured a broken Dutch electrostatic generator in successful attempt for building his own electrostatic machine. He called the device erekiteru after he transformed the previously coined Japanese word erekiterishiteito rendered from the Dutch elektriciteit⁹. Gennai charged his Leyden jar in a wooden box a quarter of century after Hallerstein and Franklin got their Leyden jars from England. During 1760s Gennai assisted the exploitation of a Chichibu coal mines west of Chichibu city in Saitama Prefecture (埼玉県, Saitama-ken), and helped to develop the Akita copper mines¹⁰ in Akita Prefecture in 1773/1774, in connection with Sumitomos and other miners families. During his mine industry research, Gennai came across the problem of subterraneous water pumping which was most successfully solved with the vacuum based European steam-engines. In 1764 Gennai collaborated with the Dutch and the Dutch interpreters in Nagasaki, therefore they gave him the books he needed for his research: Jan Jonston’s (Johnston, *1603; †1675) bestiary, Flemish Rembert Dodoens’ (Dodonaeus, *1517; †1585) herbarium, and George Eberhard Rumphius’ (*1627; †1702 Ambon) treatise on Indonesian fossils D’Amboinsche Rariteitkamer published with F. Halma in Amsterdam in 1705. In 1787 Gennai’s student and Rangaku specialist Morishima Chûryô (Katsurgawa Hosan, pseudonyms Shinra Manzô or Nisei Fūrai Sanjin meaning Fūrai Sanjin the second, 森島中良, *1754?; †December 29, 1810) in his book Kōmō zatsuwa (紅毛雜話, Dutch Miscellanea) provided

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⁹ MONTGOMERY, 2000; YAJIMA, 1964, 345.
¹⁰ GOODMAN, 2000, 192.
detailed explanation of the construction techniques and working conditions of electrical machines. Morishima Chūryō was most of all a popular novel fiction writer and never became a professional scientist. In 1798 Akisato Ritō (秋里穰島, flourished 1780-1814) and Takehara Shunchōsai (竹原春朝斎, †1800) described the Hikida’s store in Fushimi ward in Kyoto where the merchant of the Chinese and Korean products displayed the artisan Ōe’s (大江) construction of an erekiteru. They pictured one of the guests writing the limericks in Western script. A legitimate private trade of the Dutch captains and crews visiting Nagasaki occasionally brought several important geographical, medicine, and pharmacy books to Japan. Yoshio Kōzaemon (吉雄幸左衛門, *1724; †1800) read the Dutch books and asked Dutch doctors about their medical methods he used. He proved well acquainted in astronomy, geography, and botany through his translations. Yoshio Kōzaemon worked as the interpreter for thirteen times, beginning in 1742. The influential Hoashi Banri (帆足万里,* 1778 Kyūshū; † 1852) wrote On natural laws (窮理通, Kyūri-Tsū) combining thirteen Dutch books including Dutch editions of Lalande’s astronomy, Musschenbroek’s physics, Anthelme Richerand’s (* 1779; † 1840) physiology, the botanical works of Adolphus Ypey (* 1749; † 1822) and Carl Ludwig Wildenow (* 1765 Berlin; † 1812). After Hoashi Banri’s death, one of his students published a part of his work in eight volumes in 1863. In 1788 Hashimoto Sōkichi (橋本宗吉, Donsai, *1763 Osaka; †1836) became a student of the famous Ōtsuki Gentaku (大槻玄沢,*1757; †1827). In his private rangaku academy Shirandō established in 1801 in Edo, Benjamin Franklin’s supporter Hashimoto taught and treated his patients. In 1811 Hashimoto wrote the study of his famous electrostatic generator called erekiteru in the very first printed Japanese electricity manual entitled Fundamentals of the Erekitera Mastered by the Dutch, also translated as Studies on static electricity originated in Holland (Oranda shisei erekiteru kyūrigen, 阿蘭陀始制ヱレキテル究理原). In that time Hashimoto promoted his electrical apparatus in the business-oriented town of Osaka, which was far the best choice in those days Japan. Hashimoto built his electrostatic machine in 1813 under the name Erekitera, which meant the Static Electricity. Hashimoto relayed on the

11 NUMATA, 1992, 52, 56, 57, 60, 61, 88-89, 177.
12 YAJIMA, 1964, 343-344, 348. Wildenow named Zoysia the species of grass originating in the Tropic Asia including the Japanese lawn grass called Zoysia Japonica after the Baron Hallerstein’s Carniola compatriot botanist Baron Karel Zois (*1756 Ljubljana; †1799 Trieste).
13 BOWERS, 1970, 94; GOODMAN, 2000, 133.
Dutch Egbert Buys’ (*ca. 1725; †1769/75) encyclopedia and Musschenbroek’s Leyden jar research before the Japanese found in the mid-19th century that Dutch were not the leading technicians or scientists compared to English, French, or Germans. The Dutch eventually proved their weakness when French revolutionary armies subordinated the Netherlands into the satellite Batavian Republic and later Kingdom of Holland between the years 1795-1815. The Japanese new acquired conviction on the European distribution of forces, technology, and scientific abilities was certainly the right one because the Dutch technology or science really declined after Huygens and Musschenbroek’s great successes. Hashimoto wrote under the protection of Hazama Shigetomi (間重富, Taigyo, Juichiya Gorobei, *1756; †1816) of the Astronomical bureau and observatory (Tenmonkata, 天文方), because Hazama was the official astronomer to the Bakufu14. Hazama Shigetomi was an affluent pawn broker and former student of the astronomer Asada Gōryū in the eve of modern Japanese technology and physical sciences.

Horiguchi Tachu (堀口多翀) entered the static electricity field later in 181415 and brought new light to Japanese research. Sakuma Shōzan (佐久間象山, Zōzan, *1811 Shinshu; †1864) eventually discussed the use of Japanese homemade induced current for electroshock therapy for the first time in 186017, and designed new erekiteru. The early modern Japanese called their physical sciences kyūrigaku (窮理学, the investigation of the principle of things) like in Neo-Confucian China. The Japanese chemistry got the name seimigaku (舎密学) from the Dutch word chemie. The Japanese later replaced the word seimi by more appropriate kagaku16. Japanese called the electrostatic apparatus erekiteru, borrowed European (namely Dutch) names for barometer, electricity (electriciteit), or chemistry, but not for clock or physics, which indicated the Japanese opinions about the Japanese-Chinese domestic inventions compared to the imports from Europe.

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14 HASHIMOTO, 1940.
15 GOODMAN, 2000, 95, 133.
4.- Early Japanese Air Pumps.

The Japanese introduced the vacuum pumps after *erekiterus*, although they could have examined their air pump pictures in the later editions of Winkler or Martin’s works available in Japan. Philipp Franz Balthazar von Siebold (*1796 Wurzburg; †1866 Munich) brought some air pumps, Volta’s galvanic apparatus, and similar devices to Japan in 1823, but Japanese eventually build their first pump earlier on January 1, 1820. Tanaka Hisashige (田中 久重, *1799 Kurume; †1881) designed airtight structure and pump for his air gun and *mujintō* being “never extinguishing lamp” as the predecessor of his son-in-law’s success with the Toshiba Corporation which adopted its present name in the year 1978.

Aochi Rinsō’s (青地林宗, *1775; †1833) published the first Japanese vacuum pump description in his classical Chinese Physics (気海観瀾, *Kikai Kanran*) of 1825/27 based on Johannes Buijs’s (*1764; †1838*) Natural History. Aochi Rinsō expertly described the working conditions of Siebold’s Voltaic pile. Later in 1834 Udagawa Shinsai (宇田川榛齋, *1769; †1832) demonstrated the air needed for breathing or combustion and calculating air density in nine volumes of his work. Udagawa Shinsai collaborators were Ogata Kōan (緒方洪庵, *1810; †1863) and Udagawa Shinsai’s son-in-law Udagawa Yōan (宇田川 榕菴, *1798; †1846) who constructed the first Japanese Voltaic pile in 1831 and compiled the Opening principles of Chemistry (舎密開宗, *Seimi Kaisō*) in 1840, Udagawa Shinsai used William Henry’s *Elements of Experimental Chemistry* (1799) with Dutch compilations of Lavoisier’s chemical and caloric system. Lavoisier’s original publication was a half of a century old in the time of Udagawa’s publication.

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19 HASHIMOTO, 2009, 33-34.
Fig. 5. Udagawa Shinsai’s air pump (1834) using simple almost two hundred years old Guericke’s mechanical principles.

Besides air pumps, the barometer and the concept of air pressure also interested the Japanese, although somewhat late, almost a century and half after Torricelli’s invention in 1644. Motoki Ryōei (本木良永, Yoshinaga, *1735; †1794) was the third generation of Motoki family of interpreters and translated Dutch botany (1771) on Hiraga Gennai’s request. Between the years 1773/74-1788 Motoki Ryōei translated the astronomy of George Adams the elder (*1720; †1773) including the Copernican theory and Kepler’s ellipses explanation based on I. Kögler and Hallerstein’s Beijing work. George Adams the elder was a mathematical instrument maker of the king George III. In 1792, Motoki Ryōei translated Adams’ book from the Dutch compilation without offering to much original new ideas. In 1792, Motoki Ryōei also translated the Additional explanation of the barometer (Oranda kōshōgi fukai) which provided some pioneering new knowledge about vacuum and air pressure to the Japanese audience. Shizuki Tadao’s (志筑忠雄, Nakano Chūjirō, Ryūho, 中野忠次郎, *1760 Nagasaki; †1806) student Baba Sajurō (Sadayoshi, 馬場佐十郎, *1787; †1822 Edo) was the leading Dutch language teacher and the official of the bansho wage goyō department of the Japanese

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20 In 1826 according to MONTGOMERY (2000, 242); BUIJS, 1804.
21 MONTGOMERY, 2000, 238-239.
Astronomical Bureau, resembling the Beijing Astronomical Bureau where Hallerstein used to be the leader until 1774. Baba Sajurō extended Motoki’s book into the greater book Senkitō yakusetsu (Translated manual for the barometer) of 1810, also called Baromeetoru tenki keigi. In 1817, Baba published Taisei jiki zusetsu which was the Illustrated Explanation of a Western Clock. Baba also wrote more technically oriented Garasu seihōshūsetsu meaning a Complete Explanation of the Methods of Glass Making.\(^{22}\)

The same group of Japanese literati introduced the idea of air pressure and the Copernicus’ theory. Motoki Ryōei (Yoshinaga) presented his manuscript on Copernicus’ theory to the Astronomical bureau but nobody paid much attention before the professional Hazama Shigetomi of Astronomical bureau took the item in his expert hands. Hazama Shigetomi introduced the Sino-Jesuit Copernican astronomy to Japan, and the translator Shiba Kōkan passed the information to the general public in three printed Copernican books\(^{23}\). Motoki Ryōei (Yoshinaga) translated Dutch works on heliocentric system after the first draft published as a part of translation of Louis Renard’s navigational manual entitled Oranda Chikyū Zusetsu (Dutchmen’s Illustration of the Earth) in 1772\(^{24}\). The Copernican ideas could have penetrated in Japan much earlier with the translations of Huygens’ Copernican works, which the Dutch merchants and sailors widely used, because Huygens was deeply involved in pendulum and spine clock research needed for the longitude measurements on the open seas. Hallerstein had Huygens’ Horologium oscillatorium in the first Paris edition (1673) in his Beijing college library, and Hallerstein’s neighbours from the French Jesuits’ Beijing College obtained their own copy from the Lyon Jesuit College\(^{25}\). Hallerstein and his Jesuit friends eventually needed Huygens and other European technical achievements for their vacuum and similar techniques which pleased the Chinese Emperor, but also for the design of their musical instruments in Beijing Church of Xuanwu Gate, where Hallerstein liked to amuse his Chinese guests with the technical novelties\(^{26}\).

The new vacuum and electrostatics technique spread to the Far East also by their descriptions in the European textbooks books. Which books did the

\(^{22}\) DEYUAN, 2010, 162, 169.


\(^{24}\) NUMATA, 1992, 62-63, 101, 103-104.


\(^{26}\) NAKAYAMA, 2009, 8, 29; MONTGOMERY, 2000, 227.
early Japanese vacuum researchers use? Motoki commented the works of Benjamin Martin (*1704 Worplesdon; †1782 London) and Johann Heinrich Winkler (Winckler, *1703 Wingendorf by Lauban; †1770 Leipzig). Winkler’s book about electricity (1744/45) was available in Stična Cistercian monastery where Hallerstein’s younger brother was a Cistercian monk Father Abundius (* 1719; † 1768), and Winkler’s Anfangsgründe der Physik (1754), which Motoki Ryôei used in Dutch translation (1768), was widely read in Hallerstein’s Ljubljana Jesuit School after the year 1755. Winkler took over the Christian Wolff’s philosophy chair in Leipzig in 1739. After the introductory mathematical part he described Torricelli’s barometer in Rohault, Wolff, Musschenbroek’s and similar variants, but without Guericke’s or other vacuum experiments, which Winkler rather described in his Electricity book six years later.

Winkler discussed Musschenbroek’s quicksilver thermometric experiments, and provided the tables showing Ptolemaic, Copernicus, and Tycho’s astronomical systems. Motoki Ryôei used Martin’s juvenile oriented The Philosophical Grammar (1735). The later famous historian Jan Wagenaar’s (*1709; †1773) translated Martin’s book into Dutch under the title Filosofische Onderwijzer (1744 Amsterdam). Hallerstein’s uncle Baron Erberg had Martin’s book in Ljubljana in the Italian translation published in 1769. The Baron Zois had other Martin’s works on air pumps, steam engines, and optics in his Ljubljana Library, and the Japanese Mita Library acquired two Martin’s books published during Martin’s lifetime.

After his introductory part Martin wrote the last fourth chapter Of Hypotheses, of Experiments, of various Instruments where he discussed the air pump. Only in the later edition Martin added Hauksbee’s achievements with the picture of Hauksbee’s pneumatic engine included. The edition printed in 1735 did not have first three pictures of 1755 edition. Martin discussed the philosophical aspects of vacuum and electricity in the introduction, but he pictured nothing like erekiterus because he discussed static electricity in his other books. In all editions of his Philosophical Grammar Martin divided

27 GOODMAN, 2000, 162.
28 WINKLER, 1738, 248-254, fig. 5-7 of table 14; WINKLER, 1744, 5, 7.
29 WINKLER, 1738, 257, fig. 2 in tab. 27, fig. 1 in tab. 27, fig. 1 in tab. 28.
30 GOODMAN, 2000, 99.
31 MARTIN, 1735, 22-28; MARTIN, 1755, 19-28.
32 MARTIN, 1735, 27; MARTIN, 1755, 26, 27, plate 2.
33 MARTIN, 1735, 41 plate 1 was identical to plate 4 in MARTIN, 1755, 39.
the dialogs between student A and teacher B into four parts. The Aerology was the third part providing The philosophy of the Atmosphere, or Air as the first of four chapters. Martin’s persons A and B discussed Boyle’s air pump in Roberval’s design, added Keill’s calculations, latest Willem Jacob ‘sGravesande’s (*1688; †1742) and other vacuum experiments. In the first edition which Motoki Ryōei used, there were no pictures of double piston air pump, and there were also no long footnotes which surpassed the length of original text in the fifth edition of 1755, similarly as Newton’s notes in vacuum part of Rohault’s Physics were much longer compared to the original Rohault’s text. The pages devoted to vacuum research were the ones Martin (1755) and Newton (1718) most heavily footnoted while preparing the new edition. Their interests indicate the quick development of air pumps of those times which made pumps much cheaper and available to the broader audience including the Far East.

Fig. 6. Dalham’s picture of ‘sGravesande’s two pistons Air pump (DALHAM, 1753, figure 12 of table 18 (Courtesy of Dr. Prof. Kerry Magruder, curator of History of Science Collections of the Oklahoma University)).

34 MARTIN, 1735, 143-185; MARTIN, 1755, 105-106, 176-218.
35 MARTIN, 1735, 143-155; MARTIN, 1755, 176-187.
36 MARTIN, 1735, 147, 150; MARTIN, 1755, 177, 179, 184, figure 18 of plate 14.
The extremely popular Cartesian Jacques Rohault’s (*1620 Amiens; †1675) *Physica* (1718) in the Newtonian Samuel Clark’s edition put into the limelight the long Newton’s notes concentrated on Boyle and Huygens’ vacuum experiments. Newton’s additional text eventually surpassed original Rohault’s text in length indicating the extreme speed of changes of contemporary vacuum technology in Europe. After the Second World War the Mita Media Center Library of Keio University acquired the first edition, but also the later Clark’s edition of Rohault’s work published in London in 1723. Probably by coincidence the Sumitomo’s Library also acquired both editions after the First World War. On the other hand, the Beijing Jesuits preferred Rohault’s Geneva 1674 Latin and Paris 1683 French editions, which kept the flavor of the Cartesian original first published in 1671. The difference between the Chinese and Japanese acquisitions in a way mirrored the Catholic impact in Beijing in contrast to the more Protestant influenced Japan where the Protestant English books provided no obstacle for acquisition. Rohault did not publish many illustrations of vacuum experiments, although he pictured the schemes for optical and electrical research.

Besides European books, the Chinese books of European authors also helped the introduction of vacuum technologies in Japan. Just after the decline of ran-gaku and Commodore Perry’s threat of 1853 the modern vacuum instruments descriptions became available to the Japanese with Benjamin Hobson’s (*1816; †1873) Chinese compilation. Hobson took his M.B. in the London University College and worked in Macao, Canton, Hong Kong, and Shanghai. In 1855, he published the Chinese book on physics, astronomy, and zoology in Shanghai, which was widely read in Japan. Hobson provided the illustrations of air pumps, electrostatics devices, modern electrical industrial enterprises, electromagnets, and similar instruments, but omitted the discussion of Guericke or other inventors. Miyahara only recently introduced Guericke’s work to Japanese audience on broader scale as a kind of tribute to a man who enabled the modern excellence of vacuum technology in the Land of the Rising Sun, about which Guericke probably knew almost nothing during his lifespan.

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39 ROHAULT, 1718, fig. 3 on table 14.
40 MIYAHARA, 2009; MIYAHARA, 2003, 316; HOBSON, 1855.

The Tokyo book institute (Shozyaku Kan) was the first modern Japanese public library established in 1872. The Japanese well to do eventually accomplished huge private libraries already in rangaku times, although most of the 18th century technology and physical sciences books offered to Japanese were the Dutch encyclopedic works which did not take into account the Dutch translation of Keill. Mita Library acquired the original English Keill’s *Natural Philosophy* with Huygens’s appendix printed in London in 1726, which means that it was published after the Shogun released the ban on European books in 1720.

One of the earliest Japanese private libraries, the Sumitomo family library, began in the times of Masatomo Sumitomo’s (住友政友, *1585; †1652) medicines and books store in 1630 Kyoto, or in the era of his son-in-law and adopted son Tomomochi Sumitomo (*1607; †1662). Tomomochi Sumitomo studied foreign mining in Deshima to help his father Riemon Soga’s (*1572; †1636) Izumiya copper business in Kyoto established in 1590. Riemon married Masatomo’s elder sister and managed western method of copper and silver purification. Already in 1685, under the Sumitomos’ influence one sixth of altogether 300,000 Osaka inhabitants were involved in copper refining trade. A decade later in 1697 the Japanese exported to China almost 4,000 tons of altogether 6,000 tons of their whole yearly copper production. The Chinese used it for coins casting.

In 1903/1904, Kichizaemon XIII Sumitomo Tomoito (住友吉左衛門, *1865; †1926), 15th heir of the Sumitomo family, established the library in Osaka. Kichizaemon XIII Sumitomo Tomoito purchased old books immediately after the First World War in impoverished defeated Germany. Sumitomo mostly acquired the books which were not available in Japan up to date. The *erekiteru* or vacuum experiments were quite familiar to the well to do Japanese before Sumitomo’s acquisitions. Kichizaemon donated his collection containing 150 rare old books on August 20, 1920. Later, the library became the Osaka Prefectural Nakanoshima Library.

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41 YAJIMA, 1941, 112-114.
42 SUMITOMO, 1979, 6, 9, 13, 14.
43 SUMITOMO, 1979, 34.
Table 1: Beijing Jesuits, Mita, Waseda, and Sumitomo’s books about physics or astronomy published before Hallerstein’s death in 1774

<table>
<thead>
<tr>
<th>Book Details</th>
<th>Topics, year and title in Sumitomo’s library / Mita library / Waseda library.</th>
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<tbody>
<tr>
<td>Pe-t’ang Beijing library has the same book as Sumitomo, other edition of the same, other works of the same author, none of those.</td>
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<td>Ignazio Danti (*1537; †1586)</td>
<td>Astronomy 1569. Trattato dell’uso et della fabbrica dell’astrolabio. Firenze: Giunti</td>
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<td>Philippus van Lansberg (Lansbergius, Lansbergen, *1561; †1632)</td>
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<td>46; 1: 161</td>
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<td>Guarino Guarini (*1624; CRTh; †1683 Modena)</td>
<td>Astronomy 1683. Caelestis mathematicae pars prima. Milano: Montia</td>
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<td>Galileo</td>
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<td>Giovanni Alfonso Borelli</td>
<td>*1608; †1679</td>
<td>Mechanics 1686. De vi Percussionis / 1667 Bologna edition</td>
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<td>*1654; †1722</td>
<td>Mechanics 1690. Pesanteur / posthumous edition of Statique 1725</td>
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<td>Jacques Rohault</td>
<td>*1620; †1675</td>
<td>1716-1718. Physica / London 1723 edition</td>
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<td>Newton</td>
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<td>Johann Helfrich Jüngken</td>
<td>(Juncxii,*1648 Caldern; †1726 Frankfurt)</td>
<td>Physics – (1713. Compendium) Synopsis physicae veteris – novae</td>
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<td>Alexandre Saverien</td>
<td>*1720; †1805</td>
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<td>Nollet</td>
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<td>Electricity - 1754, 1755. French and Italian editions</td>
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<tr>
<td>Martin Frobenius Ledermüller</td>
<td>*1719 ; †1769</td>
<td>Microscopy - 1755 (=1756). Physikalische Beobachtungen derer Saamenthiergens. Nürnberg</td>
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<td>*1689; †1768</td>
<td>Optics 1755. Vollständiger Lehrbegriff der Optik nach Herrn Robert Smiths... Altenburg: Richter</td>
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<td>Abraham Gotthelf Kästner</td>
<td>*1719; †1800</td>
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<tr>
<td>Carlo Benvenuti</td>
<td>*1716; SJ; †1789)</td>
<td>Optics 1761. Dissertatio physica de lumine. Vienna: Trattner</td>
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<td>Rudjer Josip Boskovic</td>
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Up to date, the only three known Japanese copies of the famous Guericke’s book (1672) are in National Diet Library, Waseda University Library, and in Mita Media Center Library of Keio University (慶應義塾大学, Keiō Gijuku Daigaku). Sumitomos did not acquire earlier vacuum research of Huygens, Guericke, Boyle, Pascal, Kircher, or Schott, but preferred more modern recently published Huygens’ collected works (1905), which were brand new in the time of Sumitomos acquisition.

Mita has five early Schott’s publication but not Schott’s description of Guericke’s early experiments published in 1657. Mita acquired the second edition of Boyle’s *New experiments* (1662) with his defense against the Kircher’s student Franciscus Linus (Hall, *1595; †1675) and the philosopher Thomas Hobbes. Linus imagined the invisibly thin rarefied mercury threads called “Funiculus” in barometer, which supposedly kept mercury upwards. Boyle fairly considered that only the air pressure could rise the mercury upwards, as we also believe today. Mita acquired Huygens’ work on Saturn rings (The Hague, 1659), Huygens’ *Horologium oscillatorium* (Paris 1673), and several important Huygens’ posthumous works like *Opera varia* (Leyden 1742) and *Opuscula posthuma* (Amsterdam, 1728). Some of those books could have entered the Japan even before the relaxation of the official ban against the European books in 1720. Waseda eventually collected just Huygens’ mathematical and astronomical works published before 19th century, and did not bother to acquire earlier Huygens’ research of physics or astronomy.

Sumitomo family certainly bought much less Jesuits’ books compared to Beijing missionaries because in time of Sumitomo’s acquisitions the Jesuits’ work had more or less just antiquarian value. But Sumitomos’ got Boskovic’s

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44 OSAKA PREFECTURAL LIBRARY, 1963, 44.
De micrometri Objectivi inserted in Karl Scherffer’s Viennese Latin translation of Abbé Nicolas Louis de la Caille’s (1713 Rumigny; †1762 Paris) Optics published in 1757/1758, and Benvenuti’s Optics published on Boskovic’s behalf in one of its later Viennese editions45. Boskovic was certainly the only Jesuit author who entered the ideas of modern physics in its original form46. Sumitomos’ library did not particularly favor the old-fashioned Dutch rangaku items although Leyden publications prevailed among Sumitomos’ rare books acquisitions including Borelli or Musschenbroek’s research. Mita Media Center of Keio University Library have a copy of the early Musschenbroek’s work in Dutch language printed in Leyden, but also the later Viennese edition of Musschenbroek’s translation of the Florence Academy secretary Lorenzo Magalotti’s (1637; †1712) report on Florence Academy barometric experiments47, acquired after 1720.

Among the studies of mechanics published in the time of early vacuum experiments the Sumitomos’ library acquired Monte, Borelli, and Varignon. Galileo’s friend Guido Ubaldo del Monte’s books were also in Auersperg and Valvasor’s libraries in Hallerstein’s native Carniola. Ubaldo discussed simple mechanical principles and slowly approached their use in nicely illustrated machines48. Since Borelli’s posthumous edition was printed in Leyden, it could have been a part of rangaku export because of its nice illustrations in spite of its Latin language, which was not widely understood in Japan. Galileo’s student Borelli held once Galileo’s chair for mathematics in Pisa University and corresponded with the Roman mathematician and future cardinal Michelangelo Ricci (1619; †1682) on the forces of percussion. Somewhat earlier on June 11, 1644, Torricelli mailed to Ricci the very first letter on mercury barometer, which began the vacuum techniques worldwide. Borelli used Galileo and Torricelli’s ideas to explain hydraulic motions in caves, siphons, and cylinders. Borelli illustrated capillary effects and explained vacuum of Torricelli’s barometer, described Roberval’s experiments with the barometer immersed in vacuum in 1648, Mersenne’s gravity of the air49, used the concept of minimal particles of air50, but preferred to stay inside Florentine

45 OSAKA PREFECTURAL LIBRARY, 1963, 4, 73; not in YAMAZAKI, 1952.
46 JUŽNIČ, 2011, 27.
47 MUSSCHENBROEK, 1739; MUSSCHENBROEK, 1756.
48 UBALDO, 1615, 223, 225.
49 BORELLI, 1686, 226, 290-291 (tab. 9 & 12), 131 (fig. 6-7 in tab. 6), 141-142, 154-156.
50 BORELLI, 1686, 163.
Academicians’ barometric experimentation without using the more sophisticated air pumps with much better rearranged vacuum recipients enabling previously unimagined experiments.

Varignon was a Jesuit student in Caen and became a member of Paris academy in 1688. He used the calculus to describe the behavior of water clock and spring clock. He opened his discussion with statement on all prevailing gravity including the picture drawn from Descartes-Mersenne’s correspondence questioning the falling of perpendicularly shot missile in its shooting place without definite knowledge of the Gustave-Gaspard Coriolis’ force described much later in 1835. In the conclusion of his book, Varignon discussed vacuum related experiment holding the liquid upwards in the open pipe by covering its upper end with his finger51.

After the First World War the Sumitomo library acquired the first two volumes of the three volume Dalham’s Viennese Piarist Physics52, and Scarella’s Bolognese discussion on magnets53. Scarella was hardly popular worldwide and probably unknown in Beijing. On the other hand, Sumitomo library bought important Priestley’s German history of electricity54, Cavallo’s electrical experiments in late German 1782 edition, Volta’s letters on inflammable gas of moors (1778), Nollet’s French and Italian electricity research (1754, 1755)55.

The Franciscans in Hallerstein’s native Ljubljana also widely used Dalham and Nollet’s works. Florian Dalham a S. Theresia (*1713 Vienna; †1795 Salzburg) was the member of the Piarist order, which replaced the mid-European Jesuits’ teachers after the suppression of Jesuits in 1773. Dalham taught in Liechtenstein’s Salzburg Academy. He divided his lectures in the three volumes devoted to the mathematics, physics of particles and elements, and astronomy containing physical geography and the description of sky. Besides those topics, Dalham also taught history and later became Salzburg court librarian of Archbishop Hieronymus Prince Colloredo (*1732; †1812). Dalham clearly used atomistic approach to prove the existence of vacuum, added Guericke’s vacuum hemispheres experiments56 and described Torricelli’s barometer. He also used Boyle’s pump, but preferred the Dutch

51 VARIGNON, 1690, 1, fig. 27 in table 6.
52 OSAKA PREFECTURAL LIBRARY, 1963, 5; YAMAZAKI, 1952, 43.
53 Not in OSAKA PREFECTURAL LIBRARY, 1963; YAMAZAKI, 1952, 47.
54 OSAKA PREFECTURAL LIBRARY, 1963, 77; not in YAMAZAKI, 1952.
56 DALHAM, 1753, 2: 66-72 (fig. 6-9 of tab. 1), 139, 351 (fig. 6 of tab. 3), 361 (fig. 7 of tab. 19).
Musschenbroek and ‘sGravesande’s design with two pistons for numerous experiments\textsuperscript{57} including the Denis Papin’s (1647; †1714) digester which was described together with the Papin’s air pump in a pamphlet held just in the electronic form at the Mita Media Center of Keio University Library\textsuperscript{58}. In conclusion, Dalham discussed electricity while using William Watson’s (1715; †1788) measurement of its velocity (1748), Bose’s discussion on electric light, the Dutch experiments of Musschenbroek and ‘sGravesande. Dalham eventually still used just friction machine without Leyden jar needed for the complete *erekiteru*. He preferred simpler Newton’s attraction law and did not accept more modern Boskovic’s curve. Dalham still relied on French designed horse powered boats in spite of the recent improvements of steamboats using new vacuum technology, and dedicated a chapter to the ballistic\textsuperscript{59}.

Fig. 7. *Erekiterus* in Dalham’s Physics (DALHAM, 1753, figures 10-12 of table 24 (Courtesy of Dr. Prof. Kerry Magruder, curator of History of Science Collections of the Oklahoma University)).

Fig. 8. The title page of the first mathematical part of Dalham’s Physics widely used by the Franciscan provincial Gotfrid Pfeiffer (1707; †1775) and the Franciscan general lector Anton Oto Sprug († 1781 Ljubljana) in Hallerstein’s native Ljubljana (DALHAM, 1752 (FSLJ-15 b 27; Courtesy of Dr. Prof. Miran Špelič, OFM)).

\textsuperscript{57} DALHAM, 1753, 2: 152, 171 (fig. 8-9 of tab. 4), 347 (fig. 12 of tab. 18), 349-361 (fig. 1-7 of tab. 19).

\textsuperscript{58} PAPIN, 1687. Mita also holds three ‘sGravesande’s books published during his lifetime, and Waseda have only one ‘sGravesande’s item.

\textsuperscript{59} DALHAM, 1753, 2: 116-167 (fig. 10-11 of tab. 2), 225 (fig. 2 of tab. 13), 247 (fig. 3-5 of tab. 15), 361 (fig. 9 of tab. 19), 482, 483, 484 (fig. 10 of tab. 24), 488, 490.
Joanne Baptista Scarella (*1711; †1779) was a priest of the Theatines (Praepositus) order in his native Brescia, but his Latin work probably did not please the Japanese much, because he published just one picture in the end of his first volume showing the map of the distribution of winds. He thought the winds supposedly effected the variations of compass. Scarella inaccurately pictured the Japanese islands, and called Australia the _Nouve Hollande_. He eventually used geographical data accomplished in 1700 and 1744. Scarella believed in Cartesian magnetic vortices and in Euler’s system. He discussed Musschenbroek and Du Fay’s 1725 experiments, and relied on John Michell magnetic balance and Canton’s achievements. Scarella devoted his third book, which he published in the second volume, to the nautical use of magnetic inclinations and declinations. In his final fourth book, Scarella discussed only Musschenbroek’s experiments, which were extremely popular in the _rangaku_ Japan of his times. Scarella did not tell much about the connections between electricity and magnetism, and in his later publications he researched hydrostatics problems.

Fig. 9. Inaccurately pictured Japan in the end of Scarella’s work (SCARELLA, 1759 (Courtesy of Dr. Prof. Kerry Magruder, curator of History of Science Collections of the Oklahoma University)).

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60 SCARELLA, 1759, 1: 14-17, 30, 213, 223, 238, 267, 289, 316, 318.
61 SCARELLA, 1759, 2: 249.
6.- Conclusion.

The Chinese Emperors were the main supporters of the Jesuits’ Western technology and science export, while several different groups supported the Westernization of Japan in sequences: the astronomers and Dutch interpreters in 18th century in technical sphere, after them the physicians in the cultural free-lancing sphere, and in mid-19th century the Samurai in political sphere as reformed planners and administrators. Commodore Perry’s threat of 1853 proved to be the sufficient stimulus for traditionally Neo-Confucian Japanese. The Japanese had to adopt the Western trade and education in search for their future military superiority. The Dutch school of naval studies in Nagasaki attracted 150 Samurai students, but the Japanese soon witnessed the superior abilities of British trade, and replaced Dutch influence with English speaking one. After-rangaku Japanese favored German medicine, and Prussian education. As a member of the Japanese embassy in Europe, Matsuki Kōan found out that Holland does not match one hundredth of the entire European knowledge, and never more advised any beginner to study the Dutch Language. In 1868, over 80% of Japanese import and export trade was arranged with the British. The rangaku went into oblivion and became no more than a history. The Netherland-Japanese connection was over as was the Netherland-Habsburg one somewhat earlier when Habsburgs lost their Belgian territory to the French revolutionary armies in 1794.

The Dutch rangaku brought to Japan the similar technology and science, which Hallerstein and his Habsburg Jesuit collaborators introduced to Beijing in slightly different circumstances. Both exporting groups worked in the unlike philosophical milieu, because the Chinese imagined cyclic development of the world, while Japanese preferred the progressive time arrow. There was and still is an additional huge difference between Chinese and Japanese approach to the Western knowhow. While the Chinese liked to pretend that all European knowledge had ancient Chinese basis, the Japanese preferred

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62 NAKAYAMA, 2009, 216. The Samurai as highly trained 5% of the total Japanese population enabled the Meiji 1868 restoration based on their advanced educational system, but it was extremely hard for the young Samurais to switch from the traditional Neo-Confucian to the modern American scientific educational system (DUKE, 2009, 11, 18, 31).
63 KIM, 2010, 2.
64 BARTHOLOMEEW, 1974, 323.
65 NUMATA, 1992, 156.
other extreme, presenting themselves as mere copyists of the Western or Chinese accomplishments. The reality is somewhere in-between. The combined Sino-Western Jesuit effort in Beijing helped Volta’s Electrophorus and Pile discoveries, which became the basis of modern dynamic electrical research. The similar Japanese-Dutch erikiteru connection was by no means outdated in the times of the Dutch Huygens or Musschenbroek’s vacuum and Leyden jar research.

There are still many questions left unanswered because of the different research approaches. Needham thought that Japanese and Chinese knowledge would have developed in Western directions even without Western impact, but Nakayama as the Japanese “insider” supports the opposite opinion. In this research, we supported Nakayama’s viewpoint.

7.- Acknowledgements.

The professors of different involved nationalities, Hashimoto Takehiko, the Dutch Rienk Vermij, the American Stephen Weldon, and his Japanese wife Tomoko Weldon provided many useful hints for this paper in the Oklahoma University where the Mellon Fellowship covered the research costs. The presentation of Japanese personal names conforms to the Japanese custom, which puts the family name in the first place.

8.- Abbreviations.

Auersperg = The Library of Princes Auerspergs of Ljubljana, Slovenia.
NM-Erberg = Former books of Hallerstein’s uncle Baron Erberg, most of them now in the Library of National Museum of Ljubljana.
FSLJ = Signatures of the Franciscan Library of Ljubljana.
FSNM = Franciscan Library of Novo mesto, Slovenia.
Mita = Mita Media Center Library created in 1912 as a part of the oldest Japanese institute of higher education Keio University (慶應義塾大学, Keiō Gijuku Daigaku) in Minato, Edo (Tokyo), which Fukuzawa Yukichi founded in 1858. Most of Mita books were acquired after the Second World War.

67 NAKAYAMA, 2009, 190.
National Diet Library = National Diet Library (国立国会図書館 Kokuritsu Kokkai Toshokan) established in 1948 as the only National Japanese Library. It has main facilities in Tokyo and Kyoto.

NUK = Signatures of National and University Library of Ljubljana.

Sumitomo = Kichizaemon XIII Sumitomo Tomoito’s books acquired soon after First World War in Germany, now in Osaka Prefectural Nakanoshima Library.

Stična = Books from the Cistercian Monastery of Stična in Carniola, now mostly in NUK and in Viennese Austrian National Library.

Valvasor = Library of Baron Janez Vajkard Valvasor in Carniola, now central Slovenia, which are now kept in Zagreb, Croatia.

Waseda = Library of Waseda University (早稲田大学, Waseda Daigaku) abbreviated as Sōdai (Sōdai) in northern part of Shinjuku, Tokyo. In 1882, the Japanese established it as Tokyo Senmon Gakko (東京専門学校), and the school got its present name with the status of University twenty years later.

Zois = Karel’s Brother Sigismund Baron Zois’ Library in Ljubljana, now mostly in NUK.

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