# Johann Beckmann (1739-1811) and Modern Chemical Technology

Juergen Heinrich Maar.

Retired, Departamento de Química, Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil.
juergen.maar@gmail.com

**Received**: Oct 23, 2022 **Revised**: Dec 06, 2022 **Just Accepted Online**: Dec 06, 2022

**Published**: Xxx



Please cite this article as:

Maar J. H. (**2022**) Johann Beckmann (1739-1811) and Modern Chemical Technology. **Substantia**. *Just Accepted*. DOI: 10.36253/Substantia-1870

**ABSTRACT.**

Modern chemical technology, in the humanistic spirit of the Enlightenment, begins with Johann Beckmann (1739-1811). It followed pre-modern technologies associated with Cameralism and *Chemia Applicata*. Beckmann's holistic approach to technology, expressed in "Anleitung zur Technologie" (1777) and "Entwurf einer Allgemeinen Technologie" (1806), also engages with economic, social, cultural and ethical problems, giving the term 'technology' a new meaning. Viewed with skepticism in his time, there was a revival of Beckmann's ideas by Franz Exner (1840-1913) in 1878. Only in recent decades his contribution to technology was more extensively studied. Examples of Beckmann's ideas are presented.

**KEYWORDS**: Johann Beckmann; history of chemical technology; practical chemistry before Beckmann; cameralism and *chemia applicata*; sugar industry; refutation of criticism of technology.

*"I believe I am only a fragment of humanity, but yet that I must try to look at things from the point of view of the whole, and not of the fragment".*

(George Sarton)[1]

**INTRODUCTION**

Despite his overwhelming importance in the evolution of chemical technology, including its introduction as a university course, Johann Beckmann does not receive in many places the recognition he deserves. His name is frequently omitted from histories of chemistry. This omission is especially serious when we consider that his work began during the phlogiston era and continued under the aegis of Lavoisier's new oxygen theory. Beckmann's theoretical work, however, shows no break in continuity, no significant structural change, or no paradigm shift (in Kuhnian terminology). On the contrary, Beckmann's work on chemical technology is an example of a subject's linear evolution in terms of knowledge.

Beckmann's oblivion in many countries is not a consequence of opinions or attitudes against Beckmann himself, a typical representative of the Enlightenment, but a reaction against the very idea of technology being necessary. As an example, in contemporary Latin America there is a double origin for this pre-conceived idea against technology and innovation. The Iberian world is contrary to the concept of "technics", an idea succinctly expressed by Miguel de Unamuno (1864-1936), with his famous "… *que inventen ellos!"* ("let others invent!")[2] . Post-modern ideas, ever so popular in the Latin world, tend to minimize the role of scientific rationality and efficacy, often overemphasizing the importance of practical knowledge, and resisting "rationalization of work" – as Bruno Jacomy puts it[3].

The entry of Technology in History, in the History of Science - regardless of the semantic issue associated with the term - and, therefore, in Culture in general, occurred from mid-19th century. In general, in the pioneering countries of the Industrial Revolution, such as Great Britain and France, the revolution occurred with few concerns about technique and technology. In countries of more recent industrialization, such as Germany and the United States, there was a greater concern with a possible 'methodology of technological progress'. In these cases, it was part of the effort in favour of technology to awaken the interest of young people in the subject and to integrate the so-called 'technological' subjects in university curricula.

Obviously no theory, neither technological nor economic, caused the old method of "trial and error" to leave the scene – we are here in face of chance as cause of social and economic development. But real progress is rare. What is of importance is an efficient "methodology of technology", similar to an efficient methodology of scientific work.

Also Johann Beckmann and his enlightened spirit are important. Science and Technology develop and advance by means of a pre-conceived, structured methodology, from time to time revised in accordance with its own principles, allowing a reliable application of the conditions underlying scientific knowledge, as defined by Sir Karl Popper (1902-1994) and by Imre Lakatos (1922-1974).

**EVOLUTION OF SOME CONCEPTS**

Some seemingly very modern concepts, like Technology and "Fine Chemistry" are in fact not so new. Such precursor periods in the 'arts' or 'techniques', of artisanal and pre-industrial production, were necessary for the emergence of a chemical technology and later of a chemical industry in a broader sense. The Alchemists by no means occupied themselves solely with transmutation or with the elixir of life, but they were possessors of a wide range of knowledge about mining, metallurgy, medications and chemical processes in general (production of saltpeter and gun powder, of several acids, dyes and pigments, dyeing and tanning, and many others). This explains the presence of alchemists in the courts of kings, princes and potentates in 16th and 17th centuries[4]. Leonhard Thurneysser (1531-1596), an alchemist of paracelsian tradition, was not only the physician of Prince-Elector John George of Brandenburg (1525-1598), but his consultant for mining and metallurgy. Thurneysser set up in 1574 in the Greyfriars Monastery, the former convent of the Franciscans in Berlin (now in ruins), a manufacturing plant for diverse chemicals, employing 300 workers and producing saltpeter, mineral acids, alum, colored glass, pharmaceuticals and several essences. These expensive products were sold, and had, as we would say today, 'high added value', so he earned considerable wealth. I see in Thurneysser the first representative of Fine Chemistry[5].

A first 'chemical technology' not yet methodologically or scientifically organized, but surpassing the purely practical aspects of the alchemists, arose in the 18th century, as an answer to immediate commercial necessities and availabilities, like the production of saltpeter and gun powder, or the economic reconstruction of Central Europe, devastated by the Thirty Years War (1618/1648). For the majority of historians, Johann Rudolf Glauber (1604-1670) was the most important representative of the period which Principe and Newman call 'chymistry', a term coined to avoid the parallel use of 'alchemy' and 'chemistry', to avoid speaking simultaneously about alchemical theories and practices and of chemical theories, concepts and activities[6]. However, due to his knowledge of chemicals it would not be wrong to consider him a precocious inorganic chemist, and also as the first chemical technologist[7]. I regard him as a precursor of chemical technology, a task for which his immense knowledge of inorganic chemicals was a deciding factor. In Schmauderer's opinion[8], this 'technology' begins in the spirit of the science of the baroque period, at first in obedience to a religious precept that states the researcher's responsibility in applying his knowledge as well as the natural resources presented to us by God for the welfare of his brothers. In the context of the mercantilism typical of the 18th century's economy, this ethical-religious precept changes, and allows a new 'technology' acting in the interest of the absolutist State, in which economic issues dictated the rules: protectionism, state monopolies, prohibition to export or import certain products. In his Amsterdam laboratories, Glauber began in 1650 his technological activities, surpassing the work of precedent 'technologists', which were specialized in metallurgy, or glass, or ceramics. Glauber's production was more widespread, ranging from fermentation to metal analyses, from preparation of acids to treatment of textiles. Glauber produced according to the capitalist concept: to obtain products with the best possible quality, with the least possible number of employees, and using the minimum of resources. He analysed the costs of each step of the proposed or necessary procedure, the yields, and even calculated the minimum quantity to be produced of each compound to warrant a cost-effective process. It must be said that these frankly capitalist system was preceded by 'pre-capitalistic' initiatives of predecessors, like those of Jakob Fugger the Rich (1459-1525) in Banska Bystrica (Neusohl), Slovakia, or in his mines in Tyrol or Carinthia in Austria.

The alchemist Johann Joachim Becher (1635-1682) is best remembered in connection with his creation of the phlogiston's theory and the chemical philosophy expressed in his *Physica Subterranea*.[9] His chemical technological achievements are undervalued by most historians of chemistry. As an entrepreneur, he was in disadvantage by his boundless imagination and lack of sense of practicality, visible for instance, in his dreams of colonisation in South America, in lands inherited from the Count of Hanau, between Suriname and the Amazon. This was already the opinion of John Stillman (1852-1923) a long time ago[10] . Today, Becher's activities are seen in a better light. His technological activities were mainly that of an organiser, in duty of the Duke of Bavaria (1664/1670) and the imperial Court in Vienna (1670/1672), where he founded the Chamber of Commerce, the *Kommerzienkolleg*, and several industries (chemicals, textile goods), frequently without the expected success. Sponsored by the imperial government, Becher founded in Vienna a chemical laboratory, where he produced saltpeter, salt-ammoniac, borax, vegetable dyes, pigments (cinnabar, minium), and constructed new equipments, like experimental ovens for the glass and ceramics industry. His plant in Tabor, near Vienna, founded in 1667, produced pigments (cinnabar, minium, verdigris, lead white), and incorporated plants for refining sugar, produce "Venetian" glass, as well as noble metals.

The third alchemist precursor of modern chemical technology is Johann Kunckel (1630-1703), famous for his vast experience with the technology of glass production ("*Ars Vitraria Experimentalis*", 1679) and the invention of the artificial ruby, a very valuable red glass (1679)[11]. Kunckel stood in the services of Prince-Electors John George II (1613-1680) in Dresden, and Frederick William the "Great Elector" (1620-1688) in Berlin. Frederick William presented him with the Peacock Island (*Pfaueninsel*), where he built not only his glass factory but also a "secret laboratory", which allowed him to work "without being disturbed or observed". His posthumous "*Laboratorium Chymicum*" (1716) describes a great number of chemical and metallurgical processes, showing that his importance surpasses by much the invention of the *Rubinglas*: he describes for instance how he obtained phosphorus in Dresden, and all the processes necessary to produce the artificial ruby, processes which he pretended to maintain secret.

Baroque science and technology had a religious origin, but gradually 18th century technology assumed a clear capitalist aspect, and almost all political economists of that time were alchemists: alchemists transform useless materials (our raw materials) in new and valuable materials (our commodities). The original intention of obtaining gold from less noble metals, turned into obtaining money and other financial resources, and in the opinion of Rudolf Soukup from the Vienna Polytechnic, it makes sense to call upon alchemists as economical consultants, and economical theory may be defined as the "alchemy of the future"[12] .

Glauber, Becher and Kunckel are forerunners from the same cultural context as Beckmann. There are of course many early contributions to a pre-technological activity from other contexts. The amalgamation process (*beneficio de patio*, *patio* process), developed in Mexico by Bartolomé de Medina (1503-1585) is a very important contribution to metallurgy and technology[13], ignored during centuries by European historians of science and technology. An important pioneer of technology was the

Frenchman Jean Helot (1685-1766), particularly with respect to dyeing and porcelain making[14] (Wisniak, 2009, 111-121).

## THE IMMEDIATE ORIGIN OF MODERN CHEMICAL TECHNOLOGY: CAMERALISM AND *CHEMIA APPLICATA*.

Christoph Meinel suggests that the intertwined relation of cameralism and 18th century chemistry is similar only to the intertwined relation of chemistry and medicine observed a century earlier[15]. Cameralistics or cameralism (*Kameralistik*, *Kameralwissenschaften*), the science of public revenue, is typically a German university course, generally taught at Law Schools, addressed to future public servants; it may be viewed as a German version of mercantilism (whether cameralism is a form of mercantilism is still a matter of debate)[16]. This course included the study of economical and administrative problems, arts and crafts, techniques and other topics of interest for the future public servant. It included general aspects about crafts, manufactures and industries, from which slowly emerged the "Chemical Technology". The first chairs of cameralism were created by the initiative of King Frederick William I (1688-1740) of Prussia in 1727 at the universities of Halle and Frankfurt-Oder; they were more practical than theoretical, and still directed to an agricultural economy. The new university disciplines were agriculture, forestry and veterinary (may be a surprise, however knowledge about dairy products, wool, leather, fats and oils were lectured).

For several reasons cameralism as a depositary of chemical knowledge was important for the evolution towards a Chemical Technology[17]:

- cameralism emphasizes the role of chemistry in modern Society.
- cameralism included chemistry in the wider economical and administrative objectives of the State.
- this substantiated chemistry as an independent academic activity.
- cameralism highlighted the importance of a scientifically based technological and industrial activity.
- Society learned about new perspectives of development, by means of the universities, through thoroughly trained graduate professionals.

During the first decades of the 19th century cameralism as a discipline began to break down. Matters related to finances and public administration were incorporated in Law or Economics, matters related to the arts, crafts and techniques were housed in the *Écoles Centrales* in France and in the *Gewerbeschulen* in Germany, and at university level in the Polytechnic Schools, the first and possibly most respected the *École Polytechnique* in Paris, founded in 1794 by the Commission for Public Works, under the leadership of Lazare Carnot and Gaspard Monge. In Germany, Austria, Switzerland, the Netherlands and the Scandinavian countries were created the *Technische Hochschulen*, viewed initially with certain contempt by the traditional universities.

In Sweden, long before cameralism was firmly established in Germany, chemistry was no more a subsidiary discipline for physicians and Medicine, but a subsidiary in economic activities, like mining, metallurgy, industry. The first chemistry chairs in Swedish universities were held by chemists involved with these practical activities. The dominant personality in formally organizing this "practical chemistry", the *chemia applicata*, was Johann Gottschalk Wallerius (1709-1785), professor at Uppsala University (1750/1767). In a publication from 1751, Wallerius distinguished between *chemia pura* and *chemia applicata*, defining them as follows:

> *"Chemia pura is a science on fundamental matter and its reactions ( - mixtures). Chemia applicata is operative, is an art showing how by means of mixtures or decompositions of bodies we can prepare several new substances, possibly useful in daily life".*

Wallerius separated theoretical from applied chemistry, but did not keep them as distinct entities, avoiding the artificial distance created by Pierre Joseph Macquer (1718-1784) when he published "Elements of Theoretical Chemistry" (1749) and "Elements of Practical Chemistry" (1751). Wallerius considered practical chemistry more important than theoretical chemistry, and classified *chemia applicata* in nine branches[18] : (1) medical chemistry; (2) mineralogical chemistry (*lithurgica*); (3) chemistry of salts (*halurgica*); (4) chemistry of combustion (*thejurgica*); (5), metallurgy; (6) glass chemistry; (7) agricultural chemistry (*chemia oeconomica*); (8) chemistry of colours (*chemia chromatica*); (9) chemistry of arts and crafts (*chemia technica, opificiaria*).

By advocating such posture, Wallerius contributed to promote and value practical chemistry, so we must not downplay his importance in the synthesis of several substances during the "chemical revolution", substances like sulphuric acid, ammonium salts and many others, as well in process improvements in the production of glass, porcelain and ceramics, sugar, beet sugar, bleaching, dyeing, among others. Wallerius was criticised by his colleagues, particularly by Torbern Bergman (1735-1784), his successor in Uppsala, for having done only a few experiments himself, using instead existing knowledge about these subjects. Wallerius was the first organiser and systematiser of a pre-technological chemistry, and in the opinion of B. Bensaude-Vincent, from the University of Paris, the correct proportion of theoretical and practical chemistry allowed a transition from Science into Art without great conflicts. Wallerius theoretical chemistry was phlogistonist, the same theory advocated by countrymen Bergman and Scheele and the one referred to in cameralism.

**JOHANN BECKMANN AND CHEMICAL TECHNOLOGY.**

The first university professor to teach technological matters (metallurgy) was probably Johann Conrad Barchusen or Barkhausen (1666-1723), at the University of Utrecht, where he had been active since 1693[19] .

The philosopher Christian Wolff (1679-1745) tried in 1728, with little success, to introduce a modern concept of technology (*technologia*), in a short philosophical essay: "it is the science of the things which man produces by using the organs of the body, especially the hands"[20] .

But modern chemical technology begins with the publication in 1777 of "Anleitung zur Technology" (Introduction to Technology) by Johann Beckmann (1739-1811). Beckmann coined the term "technology" (= *Historia Artium*), contrasting with Natural History, and in 1772 defined technology as: "*the science which teaches how to transform natural products, or the knowledge of the arts, industries and manufactures*" [21]. Before choosing the term "technology", Beckmann considered using "*Handwerkswissenschaft*", or the "science of tasks"[22]. Beckmann was also the first formal teacher of chemical technology, as professor of Philosophy (1766) and Economics (1770) at Göttingen University. "Chemical Technology" as a university discipline developed from cameralism. In 1878, centennial of the publication of Beckmann's "Anleitung", Wilhelm Franz Exner (1840-1913), professor of General Technology at the Vienna Polytechnic, published a biography and delivered lectures in Vienna, with the aim of preserving Beckmann's memory. In Exner's words[23] :

> "*The founder of Chemical Technology, Professor Johann Beckmann, has already fallen into oblivion among the public at large. Specialists from several fields still value his contribution and use his works, but even they probably know nothing about Beckmann's life history".*

In fact, outside the context of his profession, Beckmann is now unknown or undervalued. The decay of cameralism was also the decay of technology. The *Johann-Beckmann-Gesellschaft*, Hoya, founded 1987, tries to preserve his memory.

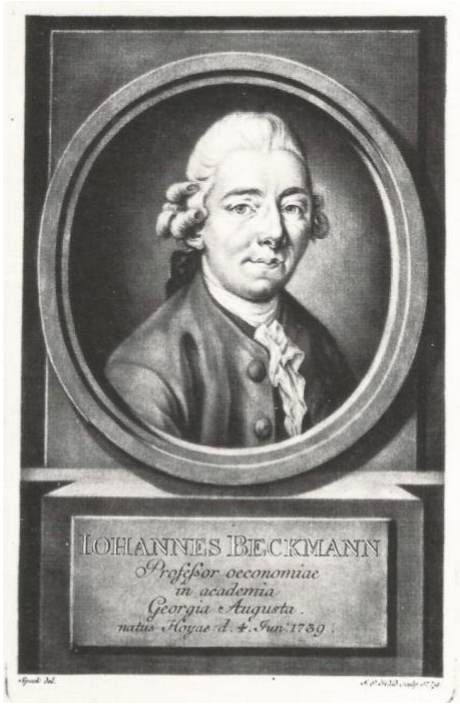



*Figure 1. Johann Beckmann. Lithography by F. E. Haid. (Courtesy Johann-Beckmann-Gesellschaft, Hoya).*

Johann Beckmann[24] was born on 4 June 1739 in Hoya, a small city at the Weser river, in Northwestern Germany, in the Principality (1806-1866 Kingdom) of Hannover, son of Nicolaus Beckmann (1700-1745), tax collector and administrator of the post office, and Dorothea Magdalena Beckmann (1718-1763). After his first school years in Hoya, he went to study in Stade, near Hamburg; in 1759 he enrolled at Göttingen University, studying theology, physics, mathematics and natural sciences; he undertook studies also in Leiden (where he entered a Masonic lodge), and with Carl von Linné (1707-1778) in Uppsala in 1765. Anton Friedrich Büsching (1724-1793), geographer and historian, professor and minister of the German community in Saint Petersburg, convinced Beckmann, then in need of money, to establish himself in the Russian capital (1763), where he stayed for only a short time. But even a short residence sufficed to turn Beckmann into an intermediary between Russian and German science. He travelled in Russia, Sweden, Denmark and the Netherlands, visiting mines and industries. In 1766 he was appointed extraordinary professor of *Weltweisheit* (literally “Wisdom of the World” = Philosophy) in Göttingen; very successful as a teacher, in 1770 he was appointed regular professor of Physics and Natural Sciences, and later of Economics.


*Figure 2. View of the city of Hoya, 17th century. Engraving by Matthäus Merian the Older (1593-1650). (Courtesy Johann-Beckmann-Gesellschaft)*

The University of Göttingen was founded in 1737, following planning by Adolf Baron von Münchhausen (1688-1770), innovative since its establishment, offering 'modern' disciplines, like geography and physics, and extracurricular disciplines like modern languages and design. Regular instruction in economics and technology belonged to the 'modern' disciplines. Beckmann approached the different industrial 'arts' and handcrafts, from both theoretical and practical viewpoints, in accordance with the principles of Enlightenment. In each case, Beckmann was concerned about origin and evolution of the technique under study, including its history: in the opinion of Friedrich Klemm (1904-1983), from the *Deutsches Museum* in Munich, Beckmann is also the founder of the History of Technology[25]. Ruy Gama (1928-1996) concludes that Beckmann's main interest was to bring together scholars and manufacturers, taking to the Academy and to the University the production processes for different *commodities*, allowing the development of more rational and modern processes, a task performed also by other technologists[26]. The role of the University in the creation of technology and innovation can be found in this 'meetings of savants and craftsmen'. Technology entered Göttingen University even before its economic importance was properly appreciated. Johann Beckmann lectured at Göttingen for more than thirty years. He died in Göttingen on 3 February 1811, aged 71, likely from pneumonia. His lectures were famous, attracting students from other universities, like Alexander von Humboldt

(1769-1859). His weekly classes on *Practicum camerale* were renowned, and constitute perhaps the first example of interdisciplinarity, or maybe of multidisciplinarity. His classes were theoretical and practical, including visits to mines and industries, and working in the '*Modellkammer*', a kind of simulation of the processes studied[27] .


*Figure 3. Stamp issued in honour of Beckmann in1989 by the former German Democratic Republic.*

Beckmann was a member of the *Academia Leopoldina* in Halle (1771), of the Göttingen (1772), Munich (1809), Saint Petersburg, Stockholm (1790), the Netherlands (1809) academies. Little is known about Beckmann's private life, and his biography is awaiting interested historians. In 1767, he married Sophie Karoline Schlosser, from Kassel. The couple had two children, the twins Samuel Johann Beckmann (1771-1841) and Johanna Petronella Sophie Beckmann (1771-1831). Today, Beckmann's descendants live in Germany, in the United States and in Brazil.

**BECKMANN'S TECHNOLOGICAL WORK**

Beckmann's fundamental contribution to Technology, the most important for the History of Technology, the most praised (and most criticized) is doubtless his "*Anleitung zur Technologie*" (1777, Göttingen, seven editions until 1823, "Guide to Technology"). It is not yet an exhaustive, systematic work including all branches of technology, but instead, an organized, formal, essentially qualifying and descriptive work on the diverse manufactures and handicrafts. The first edition (1777) still had as theoretical foundation the phlogiston theory; in the fourth edition (1796) Beckmann embraced "Lavoisier's anti-phlogistic theory". As mentioned by Otto Gekeler (1912-1999), Beckmann describes as follows the general concepts of his "*Anleitung*"[28]:

> - *Handcrafts should be ordered not only following the used materials and the produced objects, but also following the common parts and analogies during their processing and the principles upon which these are based.*
>
> - *Knowledge of handcraft, fabrics and manufactures is indispensable: what has been made, ordered, qualified, handled, gained, used, and performed should at least be known and understood.*
>
> - *"when basic knowledge fails, the craftsman should be left upon his own or he will receive plans which cannot be performed".*

In somewhat random fashion, Beckmann mentions 324 crafts, 58 of which relating to chemistry[29]. In the introductory section he emphasises the economic aspects of production (Beckmann was professor of economics), suggesting the use of by-products of a chemical process, or discussing costs related to labour, transportation of materials and final products, interest rates due to funding for the purchase of raw materials, which would be sold as products many months later.

He describes in detail, 32 manufactures, 23 of them chemical in nature, like production of soda, potash, sulphuric acid, nitric acid, vitriols and other salts, saltpeter, common salt, sugar, distillation of tar and coal, gun powder, porcelain and glass, dyeing of wool and silk, tanning, production of pigments (lead white, Prussian blue, ultramarine) and dyes (indigo, woad, litmus, India ink, carmine), fermentation processes for wine, beer, vinegar, liquors and other distillates, and many more.

The themes chosen and the approach to their discussion suggest two theses accepted by historians: Beckmann describes the manufactures still deficient in Germany, or he presents proposals intended to solve these deficiencies.

Many chairs of "technology" were created at several universities after publication of Beckmann's book, and "technological" literature appeared very quickly, and, as Gekeler, wrote:

> "*It is out of doubt that the actual presence of technology in the wide range of realisations depends directly upon the publication of this technological standard book, wherein, for the first time, several products such as paper, beer and porcelain are treated and classified in the way they can be produced*"[30] .

The first German universities in which technological matters were lectured were Giessen (1777), Stuttgart (1781, the *Karlsschule*), Vienna (1781), Ingolstadt (1782, today the University of Munich), Mainz (1784). Outside Germany, Beckmann's technology spread to a lesser extent: in France, Isaac Haffner (1751-1831) taught technology in Strasbourg and Jean Henri Hassenfratz (1755-1827) promoted the diffusion of technological contents in other institutions. In Italy, short lived lectures (1819/1823) at the University of Padua, and in Scotland there was a discipline of technology in Edinburgh, which did not survive the death of the lecturer, George Wilson (1818-1859)[31] .

The case of cane sugar production captured Beckmann's attention[32]. In the 1777 edition, still having the phlogiston theory as theoretical foundation, "*the components of sugar are water, earth, acid and a fine oily or combustible component*" (in this last component should be found the "sweetness" of sugar). The 4th edition (1796) follows Lavoisier's anti-phlogistic theory, and sugar is composed by carbon, oxygen and hydrogen, and the different qualities of different sugars, of tartaric

Anleitung
zur
Technologie,
oder
zur Kentniß
der
Handwerke, Fabriken und
Manufacturen,
vornehmlich derer, die mit der
Landwirthschaft, Polizey und
Cameralwissenschaft
in nächster Verbindung stehn.

Nebst
Beyträgen
zur
Kunstgeschichte.
Von
Johann Beckmann
ordentlichem Professor der Oekonomie in Göttingen.

Mit einer Kupfertafel.

Göttingen,
im Verlag der Wittwe Vandenhoeck. 1777.

*Figure 4. Front Page of "Anleitung Zur Technologie", 1777 edition.*

acid and oxalic acid are due to different proportions of oxygen. Strangely, Beckmann does not mention the "*Sacharologia*" (1637) by Angelo Sala (1576-1637), probably the first monograph about sugar, published in German in Rostock[33] , and does not mention the discovery of beet sugar in 1747 in Berlin by Andreas Sigismund Marggraf (1709-1782) – most likely because the process was not yet exploited commercially, an exploitation which would occur in 1798 by Franz Karl Achard (1753-1821) in a small factory in Kunern, Silesia (now Konary, in Poland). Beckmann restricted his discussions and descriptions to processes used in his own time.

Still about sugar, Beckmann presents a historical introduction, classifications based on various criteria, geographical for instance (sugar from St. Thomas, Guadaloupe and Martinique, Madeira, Pernambuco, Bahia), or aspect, grades of purity, among others. He mentions other plants containing sugar (maples, *Aceraceae* like European *Acer campestre*, or Canadian *Acer saccharinum*), and briefly describes the production of cane sugar and sugar refining, an industrial activity still done mostly in Europe. Although interested in joining theory and practice, Beckmann describes in detail the sugar production process proper. From the many details presented, Ruy Gama (1928-1996), a Brazilian historian of technology and authority in the history of sugar production, says "we could think these authors [Beckmann and his contemporaries and successors, even Marx] knew the sugar factories", but this is obviously not the case[34] . Sugar refining is a perfect example of an activity in which chemical technology could offer great improvement: refining at the places of production would reduce costs and increase productivity. Beckmann suggests that refining in the same place where sugar cane is produced would improve profitability. Charles Edward Howard (1774-1816), a self-educated English scientist, designed a new vacuum evaporator and other accessories for the sugar industry (first patented in 1812), which were used in West Indian factories and elsewhere[35] .

Gun powder is another product discussed by Beckmann[36]: its origin, he says, is unknown, but it certainly is not an invention of Bertholdus Niger[37]. Beckmann discusses the properties of powder and the desired qualities of its ingredients, he distinguishes "strong" from "weak" powder, which resulted from the different proportions of saltpeter, sulphur, and carbon. In his time, the best powder was produced in Essone, France (we know about Lavoisier's efforts in improvement of powder), and its typical composition would be: 75 pounds of saltpeter, 9,5 pounds of sulphur and 15 pounds of carbon. Beckmann's observation that powder was used in mining, in Rammelsberg by the year 1200, before its military use, is indeed surprising. The mines of Rammelsberg are located near Göttingen, and he may have heard this from local miners, so that the information may be not devoid of truth.

The "*Anleitung*" knew six more editions, in 1780, 1787, 1796, 1802, 1809 and 1823. This text from 1777 is greatly responsible for Beckmann's reputation and importance, but the first of his books to draw attention was the "*Grundsätze der Deutschen Landwirtschaft*" ("Basics of German Agriculture", 1896), from 1769, one of the most read 'technological' texts of its time, responsible for introducing agriculture as a university discipline, the first economic activity to gain university status.

*"Vorbereitung zur Waarenkunde"* (Göttingen, 1793/1800), or "Introduction to the Commodity Sciences", is probably the first general treatise on what we call today the commodities (*Waren* = marketable products). Beckmann describes in detail 42 products or groups of products, qualifying them as natural products or products of "the arts". These *Waren* included the so called *Kolonialwaren*, products which the Europeans brought from their colonies: cotton, rubber, soy, coconuts, ivory, musk, indigo and other dyes. Beckmann endeavoured to turn these raw materials into useful products, but also showed concern with the possible extinction of some of them[38]. Alexander Kraft relates that in 1772 king Frederick II the Great (1712-1786) ordered Andreas Sigismund Marggraf (1709-1782), from the Berlin Academy, to try to obtain artificial chocolate and vanilla aromas from small-leaved linden tree (*Tilia cordata*) barks and fruits. Cocoa and vanilla were too expensive, and Frederick forbade their import[39] .

Among many other publications by Beckmann, the five volumes of "*Beiträge zur Geschichte der Erfindungen*" (Leipzig, 1782/1805), published in English as "History of Inventions, Discoveries and Origins" (1798, 4th edition 1846), deserves some commentaries. It is a collection of easy-to-read texts aiming at diffusing science and technology. But it also contained detailed descriptions of the evolution of some chemical processes, like the process for obtaining alum. The collection shows the breadth of the historical knowledge of the author, dealing with a wide range of themes: Italian Renaissance accounting, gold refining, the origin of the names of the elements, plants, animals and minerals, street lighting, glass engraving... Friedrich Klemm (1904-1983) considers this collection the very beginning of the historiography of technology[40]. History of Technology was restricted to the evolution of practical and productive activities in a European context, and activities or even innovations originated in peripheral countries were of no interest in face of the innovations of the Industrial Revolution[41] .

A very important book, in Exner's opinion, is Beckmann's "*Entwurf einer Allgemeinen Technologie*" (1806, Göttingen, "Draft on General Technology"). A new edition in 2006, organised by Bernd Meier and Helmut Meschenmoser, calls the book "the birth certificate of General Technology". In this booklet of only 72 pages Beckmann "normatizes Men and Machines", establishing a systematic classification for Technology, based on the systematic classification developed by Carl von Linné (1707-1778). Linnean taxonomy or systematics has a ranked hierarchy, with kingdoms (mechanical processes, chemical processes), divisions (or *phyla),* classes, orders, families, genera, species. As an example, in the kingdom "chemical processes", there is an order "filling of imperfections" (of the bodies), which can be done by greasing, varnishing or glazing/vitrifying (these are three "families"). "Species" for greasing are bee wax, carnauba wax, candelilla wax; for varnishing, there is lacquer (shellac); for glazing, there is lead oxide. Before Beckmann, other technologists made use of binary classifications; Johann Georg Krünitz (1729-1796) qualified in his "*Oekonomische Encyclopaedie*" (1790) different types of coal in accordance with a binary system: *Carbo Anthrax* ( = charcoal), *Carbo Lithoanthrax* ( = hard coal), and others[42].

Beckmann's publications and teachings were rich and prolific. His rational work, derived from late Enlightenment, was very distant from the Romantic thinking then dominant in Germany. This dominance was another reason for Beckmann's oblivion in the German Romantic period. Otto Gekeler takes this text of 1806 as an obvious complement for the text published in 1777.

> "*It may be stated that "Beckmann's viewpoints are trivial and universal at the same time: one object can be made following different systems; one system can be used for different objects"*[43].

He was the first to mention what chemical engineers today call 'unit operations', a concept introduced by Arthur Dehon Little (1863-1935), professor at the *Massachusetts Institute of Technology*.

In his treatise from 1806, Beckman presents his "principle of completeness" (*Ganzheitsprinzip*), in the following words[44] (Beckmann, 1806):

> *"We must obtain the material and immaterial benefit from the commodity with a minimum of nature and human substance throughout the commodity's life - with due regards to health, political, ethical and other relevant aspects".*

Multidisciplinarity hidden in the *Ganzheitsprinzip* unveils Beckmann's concern in producing science and technology 'for the people'. Quoting Gekeler[45] ,

> *"This conscious appreciation of all possible implications of technology and commodities, encountered at all stages of their existence (from production over usage and/or consumption to waste management) will be called the 'ganzheitliche Betrachtung' or contemplation in entirety*".

This is clearly in the spirit of universal Enlightenment.

A group of Japanese researchers, leaded by Tetsuo Tomita, translated Beckmann's treatise from 1806 and the "History of Inventions" into Japanese (1976/1982), wishing to understand and better assess how technology was transferred from Europe to Japan[46]. Tomita writes:

> *"Our purpose was not necessarily to learn the history of technics of Europe but to compare the basic civilization and technics of Europe depending upon their climate and geophysical elements with those of Japan, particularly before the developments in the field of electricity and modern synthetic chemistry had been attained. Such trails will make it possible for us to find suggestions for analysis and prediction of conditions and reactions of technological transfer in future"*[47] .

Sometime before, in 1786, in Göttingen, and in the spirit of Enlightenment, Johann Friedrich Gmelin (1748-1804) published the first textbook on Chemical Technology, *"Grundsätze der Technischen Chemie*" (Foundations of Technical Chemistry); a second edition (1795) was titled "*Handbuch der Technischen Chemie*". Gmelin used terminology in the sense we mentioned, saying that *"Technical Chemistry is that part of Applied Chemistry which teaches the basics of factories, manufactures, arts and crafts, and the advantages of applying these principles to these activities*"[48] . Some of these crafts existed since remote times, in Gmelin's opinion, but others are unimaginable without technical chemistry. Among the oldest crafts related to chemistry, practiced since the thirteenth and fifteenth centuries, Gmelin mentions in his "*Geschichte der Chemie*" (1797, "History of Chemistry") activities like metallurgy, obtention of alum and vitriol, ceramics, glass, dyeing, pharmacy. In any case, also for Gmelin, Chemical Technology dates from the second half of the eighteenth century, the "great century" of chemistry, among other reasons because of the emergence of methodologically organised Chemical Technology.

Characteristic features of Beckmann's *Technologie* are, as mentioned by Guido Frison:

- *"the object of Technologie corresponds to something which may be called "industrial work"; and the subject who is interested in Technologie is the ruler of the process of production.*

- *Technologie is a science, or more accurately an analysis of production from a naturalistic perspective.*

- *Technologie examines the productive procedures; i.e., what goes on between the social actor and his means of labour but not from a sociological point of view;*

- *the knowledge of Technologie allows innovation"* [49].

Such characteristics, according to Frison, are still distant from an ideal productive procedure. At the same time Beckmann creates his '*Technologie*' as a discipline, his friend and colleague in Göttingen, historian August Ludwig von Schlözer (1735-1809), conceives a new form of presenting the *Universal-Historie*, a general and universal history, in which he considers Technics and Inventions (in the sense given by Beckmann) as driving factors for human and cultural development[50]. Schlözer suggests four "methods" for structuring History: the chronographic, technographic, geographic, and ethnographic methods. The chronographic method is a simple chronologic record, unable to analyse the relation between facts. The technographic method explains progress and retrogression of Humankind in terms of progress and retrogression of *Technologie* and inventions. The geographical method accounts a systematized harmony of the diverse geographical regions. In the ethnographic method, the inhabitants of the Earth are brought together on the basis of behavioural similarities, in groups, "peoples" or "populations" – although it remains unclear how many "peoples" would exist.

**EVALUATION**

The evaluation of Johann Beckmann has varied much according to place and time, sometimes viewed as positive, and sometimes not so much. It is not really an evaluation of Beckmann himself, but of the methods he proposes for the creation, management and improvement of technological processes or procedures. One same process can be analysed and explained in accordance with different stances: as a purely empirical sequence, disconnected from every theoretical association, as sequences of trial-and-error reactions; or, as a rigorous application of a "technological methodology", similar to a scientific methodology. The most emblematic example is the explanation of Leblanc's process for producing soda (1791): Charles Gillispie (1918-2015) suggests an artisanal and empirical sequence of trial-and-error reactions[51]; John Graham Smith suggests a typical case of rigorous application of a technological methodology[52].

Beckmann intended – and for this he is often criticised – to include in university teaching all aspects related to technology: raw materials, rationalisation of technological processes, use of by-products and many others.

In pioneering countries of the Industrial Revolution, like France and Great Britain, empiricism alone lead to satisfactory results with respect of quality and costs of products obtained, and theoretical concerns, as expressed by Beckmann, seemed to be irrelevant. As Frison observes, the notions of "technique" and "technology" are absent from the works of Adam Smith (1723-1790) and John Stuart Mill (1806-1873): terms like 'art', 'trade', industry', 'manufacture' are found instead[53]. In fact, as Ruy Gama observes, Beckmann does not exist in French or British technological literature, he is not cited in the monumental "History of Technology" by Charles Singer (1876-1960), or in the famous article about mills, which Marc Bloch (1886-1944) published in 1935 in the *Annales*. Authors less famous today, although fundamental for the evolution of this area of knowledge, as George Sarton (1884-1956), Lewis Mumford (1895-1990) or Edmund Oskar von Lippmann (1857-1940) attribute minor importance to Beckmann. Karl Marx (1818-1883) was a frequent reader of Beckmann and quotes him several times in his "*Capital*", as a source of factual data. Marx became familiar with Beckmann's works through one of the latter's students, the technologist Johann Heinrich Moritz von Poppe (1776-1854)[54]. He utilized as a definition of technology that used by Beckmann and J. H. Poppe. Marx was aware of the meaning and originality of this new discipline created by Beckmann[55] .

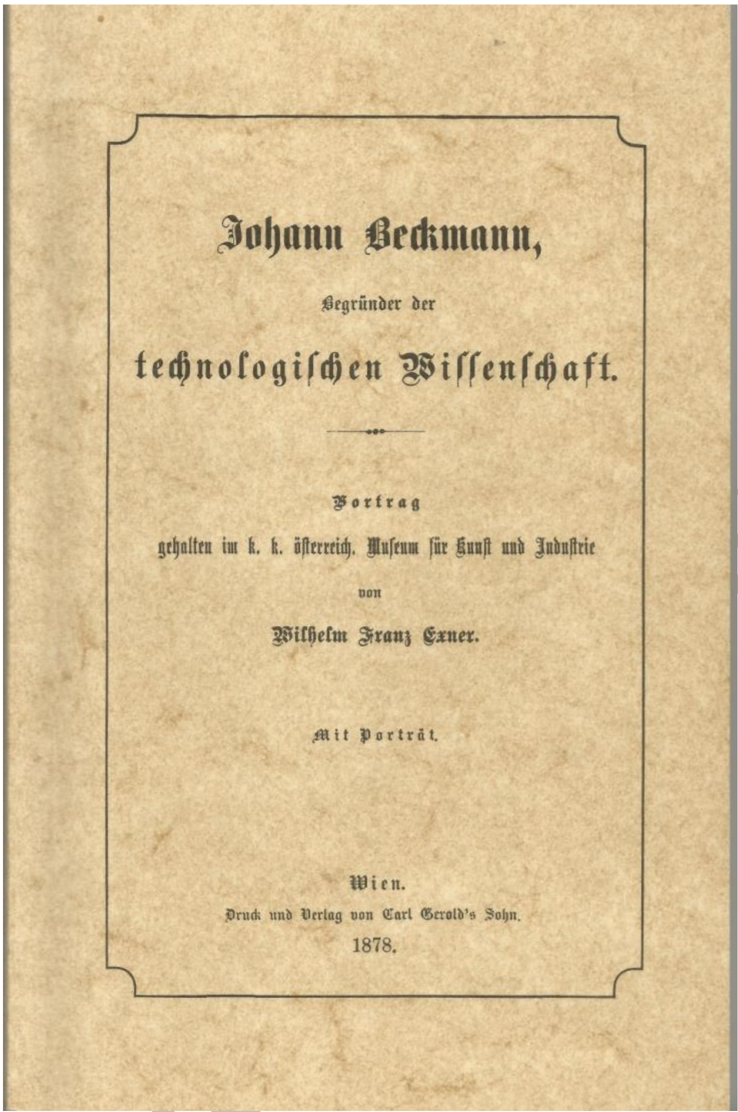
A renewed interest for Johann Beckmann arose in the 1970s in former German Democratic Republic. Marx's interest in Beckmann can be found in several essays and papers on techniques and technology. With the collapse of the socialist system of production in Eastern Europe the interest of historians and scholars even for this critical interpretation of the Marx-Beckmann relationship diminished.

Wilhelm Exner, in his presentations in Vienna in 1878, the centennial of the publication of "*Anleitung*", regretted the oblivion of Beckmann in his own country, for which there is, however, a plausible reason. Beckmann advocated during all his career at Göttingen the inclusion of technological matters into university teaching, an initiative which brought him many opponents. For the incredulous and sceptics, Beckmann wrote in the Introduction of the *Anleitung* [56]:

> *To those who do not understand, and to those who do not want to admit, that Agriculture, Technology and Commerce can be taught with good results at University, I ensure that I know the contrary based on ten years of experience, and I could mention people who now occupy high positions, whose duties require such knowledge, and who would … confirm it.*

It is obvious, he comments, that artisans learn their activity in workshops, merchants in their offices, but it would be ridiculous to assert they do not need any theoretical knowledge in their professional practice. Exner was too pessimistic. Industrialisation in Germany, an unified nation only since 1871 – “the nation which arrived too late” – began in the middle of the 19th century, and the contribution of universities to the productive process would be successful only with the involvement of a third partner: the State. The chemist August Wilhelm von Hofmann (1818-1892) was personally engaged in establishing this conjunction of factors. The equivalence of traditional universities and *Technische Hochschulen* was recognised formally in 1900, including the privilege to grant *Ph.D.* titles.

Technology is an inseparable and irreversible part of modernity. This realisation, from which one cannot escape, gave origin to Philosophy of Technics or Philosophy of Technology, dedicated to, among other purposes, identifying the limits between the rational and the irrational, the artificial and natural, mechanization or “machinization” (in the sense of replacing the work of a person with that of a machine). From the inevitability of Technology in our context, good or evil, we derive the inevitability of ethical/normative questionings. To discuss these issues falls outside the scope of this paper. Our aim is to discuss the role of Beckmann in the history of Technology and social progress.



Johann Beckmann,
Begründer der
technologischen Wissenschaft.

Vortrag
gehalten im k. k. österreich. Museum für Kunst und Industrie
von
Wilhelm Franz Exner.

Mit Porträt.

Wien.
Druck und Verlag von Carl Gerold's Sohn.
1878.

*Figure 5. Wilhelm Franz Exner's essay on life and work of Beckmann, 1878.*



A common critique of Technology and of Beckmann suggests that technology or technical science is still a project, a project which tries to reshape the world according to machinery principles, and dreaming in turning its principles into the basis of a unified knowledge. This proposition is a denying one, and ignores the history of science. Leblanc's process for soda production is an example that technology is not a project, but that it advanced far beyond a project. Other examples are the Solvay process for soda production, the contact process for producing sulphuric acid, the electrochemical and the Haber-Bosch processes for ammonia production, among others. Artificial production of fertilizers is, as the chemist William Crookes (1832-1919) puts it as a follower of Malthus, a basic condition for maintenance of life in later days[57]. Beckmann's strategy can be seen in all of these processes, even for those who do not want to admit it: maximum utilization of raw materials, search for alternative raw materials, recycling raw materials and their rejects, usage of by-products, removal of environmental damage, reduction of costs. Obviously, this did not occur overnight, but is the result of a gradual ripening of a *technological project*. The gap between the "two cultures" – the scientific/technological and the humanist – of Charles Lord Snow (1905-1980), makes it impossible, or at least very difficult, to have a full understanding of problems like the importance of Beckmann.

Another kind of critique is presented by post-modern authors, as Bruno Latour (1947-2022), for whom the notion of science hold by scientists is irrelevant for scientific activity[58]. But without taking into account what scientists and technologists think about their activities, philosophers and sociologists of science could not explain how it was possible to technologists like Beckmann, or to chemists like Martin Heinrich Klaproth (1743-1817), to change from phlogiston theory to lavoisierian anti-phlogistic theory without any rupture in their work. Philosophers and sociologist of science would not be able to work out a methodology of scientific practice, nor decide about the scientificity or not of a theory.

Finally, it must be said that in Beckmann's time there was no distinction between a "scientific" culture and a "humanist" culture. In other words, the "two cultures" show the comprehensiveness of all their vast knowledge: historical, philosophical, educational, practical and technical. This was a time of optimism about technology, distinct from today's fears about possible (probable?) technological excesses damaging the fabric of society.

Beckmann looked at technology and its evolution in terms of his *Ganzheitsprinzip*, or, as a unified whole, including historical, cultural, social, political, ethical, and environmental aspects. For today's skeptics with respect to the environmental cause, let us see Beckmann's opinion on using ivory: "*aesthetics associate to artworks and objects made of ivory on one side, on the other side, the irrationality of pursuing animals for sake of aesthetics*"[59]. *Nil sub sole novum*. But this is a paper about the past and about Beckmann, for whom the advantages of Technology surpass in much the risks; but nowadays risks are greater day after day, so that George Sarton himself suggested caution with machines[60].

**TRIVIA.**

I had the pleasure to be in correspondence, during several years, until his death, with Egon Max Beckmann (1925-2012), descendant of Johann Beckmann. His grandfather Adolf Beckmann (1861-1934) came as an immigrant to Brazil, and in 1887 founded in Joinville the *Hotel Beckmann*, a meeting point for voyagers and local people. Sold in 1915, it reopened later as *Hotel Palácio*. I stayed there for a few days in 1951, with my mother, during school holidays. Such incredible coincidences cannot be predicted....

**AKNOWLEDGEMENTS**

To the former *Johann-Beckmann-Gesellschaft*, Hoya/Germany, for providing bibliography difficult to access, as well as iconography about Beckmann; to Detlef Meyer, Mayor of Hoya, for permission to reproduce the images; to Helga Lühmann-Frester, former secretary of the *Johann-Beckmann-Gesellschaft*, for providing iconography.

**REFERENCES.**

[1] . G. Sarton, "The History of Science and the New Humanism", Cambridge/Mass. Harvard University Press, 1966, p. liv.

[2]. Unamuno, M., "Del Sentimiento Trágico de la Vida", Editorial Alianza, Madrid, 2008, p. 307. (Original Spanish edition 1912; English translation, 'Tragical Sense of Life, by J. Crawford Flitch, 1913).

[3]. Jacomy, B.,"A Era do Controle Remoto", Editora Zahar, Rio de Janeiro, 2002, p. 103.

[4]. Weyer, J., Chemie an einem Fürstenhof der Renaissance, *Chemie in unserer Zeit*, **12**, 241-249 (1992).

[5] . Thurneysser was a controversial figure, and his work in this field is lesser known. Older historiography (e.g.Stillman) considers him an adventurer, but more recent research shad a new light on his multiple interests (e.g. B. Herold, História Natural de Portugal, *Ágora*, nº **19**, 305-334 (2017).

[6]. Newman, W., Principe, L., Alchemy vs Chemistry: the Etymological Origins of a Historiographic Mistake, *Early Science and Medicine*, **3**, 32-65 (1998), p. 32.

[7]. Debus, A., "The Chemical Philosophy", Dover, New York, 2002 [1977].

[8]. Schmauderer, P., Glaubers Einfluss auf die Frühformen der Chemischen Technik, *Chemie-Ingenieur-Technik*, **42**, 686-696 (1970),

[9] . Soukup, R., "Chemie in Österreich", Vienna, Böhlau. 2007, pp. 443-455.

[10] . Stillman, J. "History of Alchemy and Early Chemistry", New York, Dover, 1960 [1924], p. 420.

[11]. Lärmer, K., Johann Kunckel der Alchemist auf der Pfaueninsel, *Berlinische Monatschrift*, 2000, pp.10-16. Rau, H., Johann Kunckel, Geheimer Kammerdiener des Grossen Kurfürsten, und sein Glaslaboratorium auf der Pfaueninsel in Berlin, *Medizinhistorisches Journal*, **11**, 129-148 (1976).

[12] . Soukup, R., "Chemie in Österreich", Böhlau, Vienna, 2007, p. 414.

[13]. Roche, M., “Early History of Science in Latin America,” *Science*, **164**, 806-810 (1976).
[14]. Wisniak, J., Jean Hellot. A pioneer of chemical technology, *Revista CENIC Ciencias Químicas*, **40**, 111-121 (2009).
[15]. Meinel, C., Reine und Angewandte Chemie. Die Entstehung einer neuen Wissenschaftskonzeption in der Chemie der Aufklärung, *Berichte zur Wissenschaftsgeschichte*, **8**, 25-45 (1985).
[16]. Frison, G., The First and Modern Notion of Technology from Linnaeus to Beckmann and Marx, *Consecutio Rerum*, Anno III, nº 6, 147-162, (2018), p. 152.
[17]. Meinel, C., Artibus Academica Inserenda. Chemistry’s place in eighteenth and early nineteenth centuries Universities, *History of Universities*, **8**, 89-115 (1988).
[18] . Meinel, C., Theory or Practice? The Eighteenth-Century Debate on the Scientific Status of Chemistry, *Ambix*, **30**, 121-132 (1983).
[19] . Linde, R., Johann Conrad Barkhausen (1666-1723) – der bedeutendste Sohn der Stadt Horn in Lippe, Lippische Mitteilungen aus Geschichte und Landeskunde, vol. 53 (1964).
[20] . Frison, G., The First and Modern Notion of Technology from Linnaeus to Beckmann and Marx, *Consecutio Rerum*, Anno III, nº 6, 147-162, (2018), p. 148.
[21] . Beckmann, J., “Anleitung zur Technologie”, Vandenhoeck, Göttingen, 1777
[22]. Lühmann-Frester, H., “Europa in der frühen Neuzeit”, Böhlau Verlag, Vienna, 1999, Vol. 5, (Ed. E. Donnert), pp. 627/628.
[23]. Exner, W., Johann Beckmann, Begründer der Technischen Wissenschaft, Hoya, Johann Beckmann Gesellschaft, 1989, introduction. This is a facsimile reprint of Exner’s original edition, Vienna, Carl Geralds, 1878.
[24] . Biographies of Beckmann may be found e.g. in Exner’s book from 1878 (reprint 1989), or in O. Gekeler, Johann Beckmann and the Consideration of Commodities and Technology in their Entirety, *Sartoniana*, **2**, 139-171 (1989).
[25] . Klemm, F. “Geschichte der Technik”, Rowohlt, Hamburg, 1983. See also W. König, H. Schneider, “Die Technikhistorische Forschung in Deutschland seit 1800”, Kassel, Universitätsverlag, 2007.
[26] . Gama, R., “Tecnologia e Trabalho na História”, EDUSP, São Paulo, 1986, p. 74.
[27] . Lühmann-Frester, H., “Europa in der frühen Neuzeit”, Böhlau Verlag, Vienna, 1999, p. 631.
[28] . Gekeler, O., Johann Beckmann and the Consideration of Commodities and Technology in their Entirety, *Sartoniana*, **2**, 139-171 (1989), p. 149.
[29] . Beckmann, J., “Anleitung zur Technologie”, Vandenhoeck, Göttingen, 1777.
[30]. Gekeler, O., Johann Beckmann and the Consideration of Commodities and Technology in their Entirety, *Sartoniana*, **2**, 139-171 (1989).
[31]. Frison, G., The First and Modern Notion of Technology from Linnaeus to Beckmann and Marx, *Consecutio Rerum*, Anno III, nº 6, 147-162, 2018.
[32]. Beckmann, J., “Anleitung zur Technologie”, Vandenhoeck, Göttingen, 1777, pp 324-341.
[33]. Gelman, Z., Angelo Sala, an Iatrochemist of the Renaissance, *Ambix*, **41**, 142-160

(1994) (on p. 147/148),
34. Gama, R., " Engenho e Tecnologia", Editora Duas Cidades, São Paulo, 1983, p. 342.
35. Wisniak, J., Charles Edward Howard – explosives, meterorites and sugar, *Educación Química*, **23**, 230-239 (2012). Kurzer, F., Life and Work of Charles Edward Howard, *Annals of Science*, **56**, 113-141 (1999).
36. Beckmann, J., "Anleitung zur Technologie", Vandenhoeck, Göttingen, 1777, pp. 342-353.
37. Bertholdus Niger (Berthold Schwarz), a legendary alchemist (14th century) from Freiburg, often credited with the invention of gun powder, is not a historical character. See R. Oesper, 'Berthold Schwarz', *J. Chem. Educ*., **16**, 303-306 (1939).
38. Reith, R., introduction to Meyer, T. (Ed.), "Luxus und Konsum – eine historische Annäherung", Waxmann, Münster, 2003, pp. 18-19.
39. Kraft, A., Chemiker in Berlin – Andreas Sigismund Marggraf (1709-1782), Jahrbuch des Vereins für die Geschichte Berlins, 2000, p. 23.
40. Klemm,, F., "Geschichte der Technik", Rowohlt, Hamburg, 1983.
41. Saldaña, J., La historiografia de la tecnología en América Latina: contribución al estudio de su história intellectual, *Quipu*, **15,** 7-26 (2013), p. 23.
42. Krünitz, J., Oekonomische Encyclopaedie, Tressler, Brünn, 1790, Part 43, p. 4.
43. Gekeler, O., Johann Beckmann and the Consideration of Commodities and Technology in their Entirety, *Sartoniana*, **2**, 139-171 (1989), p. 154.
44. Beckmann, J, "Entwurf einer Allgemeinen Technologie", Göttingen, 1806.
45. Gekeler, O., Johann Beckmann and the Consideration of Commodities and Technology in their Entirety, *Sartoniana*, **2**, 139-171 (1989).
46. Tomita, T., cited by O. Gekeler, *op. cit*., p. 146.
47. Troitzsch, U. , postfacium, facsimile edition of Exner, Hoya, 1989.
48. Gmelin, F, "Handbuch der Technischen Chemie", Gebauer, Halle, 1795, p.1.
49. Frison, G., Linnaeus, Beckmann, Marx and the Foundation of Technology between Natural and Social Sciences; a Hypothesis of an Ideal Type, *History and Technology*, **10,** 161-173 (1993).
50. Lühmann-Frester, H., Europa in der frühen Neuzeit, Böhlau Verlag, Vienna, 1999, pp. 632-634.
51. Gillispie, C., The Discovery of the Leblanc Process, *Isis*, **48**, 152-170 (1957).
52. Graham-Smith, Science and Technology in Early French Chemistry, Colloquium 'Science, Technologie et Industrie', Oxford, 1979.
53. Frison, G., "Technical and Technological Innovation in Marx", *History and Technology*, **6,** 299-324 (1998).
54. Müller, A., Unbekannte Excerpte von Karl Marx über Johann Beckmann, in G. Bayerl, J. Beckmann, "Johann Beckmann (1739-1811)", Waxmann, Münster, 1999.
55. Frison, G., "Technical and Technological Innovation in Marx", *History and Technology*, **6,** 299-324 (1998).
56. Beckmann, J., Anleitung zur Technologie, Vandenhoeck, Göttingen, 1777, in the preface.
57. Crookes, W., speech at the BAAS meeting in Bristol, published in *Science,* edition

from 28 October 1898, pp. 561-575. The Haber-Bosch process was invented only in 1908, but in 1898 there was already known the Frank-Caro process (1895).

[58] . Latour, B., Woolgar, "Laboratory Life – the Construction of Scientific Facts", Princeton University Press, 1971.

[59]. Gekeler, O., Johann Beckmann and the Consideration of Commodities and Technology in their Entirety, *Sartoniana*, **2,** 139-171 (1989), p. 148. In this sense, Beckmann would welcome Leo Hendrick Baekeland's (1863-1944) invention of bakelite (1909).

[60] . Sarton, G., "History of Science and the New Humanism", Harvard University Press, 1962, pp. 161-162.