installation is a prototype of the future automatic plant for briquetting of a waste of any metals and alloys annual production rate on a steel at one-shift work — from 500 ton to 2,5 thousand ton briquettes and at round-the-clock work — from 2 to 10 thousand ton. Equipment cost approximately corresponds to cost import briquette-press at essentially big technological possibilities. Plants, by calculations of the author, pay off within one two years.

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The pioneer of applied sciences

Paying the tribute to the talent, and width of views of the outstanding French natural scientist — Rene Anthony Farchault de Reaumur, his coevals called him the Pliny[1] of the XVIII century, and compared him with the great philosopher — Francis Bacon. However, the scientific knowledge at that time was a lot more uniform than it is today, and most of the scientists were carrying out investigations on a broader scale, and not in single scientific field, most of which just appeared. Yet, Reaumur's scientific achievements are astonishing. His fields of study included: mathematics for which he was awarded a membership at the Paris Academy of Science, development of the manufacturing process for French porcelain production, discoveries in the field of zoology, creation of a thermometric scale, and of course the amazing fundamental works in the field of ferrous metallurgy, that are not mentioned in any article at the Great Soviet Encyclopedia.

Rene Anthony Farchault de Reaumur was born at Rouchelle on the French Atlantic coast, on the 28th of February, 1683 at the noble family. The father of the future scientist, Rene Farchault held a rank of amicus curiae[2] at La Rouchelle court house. He died in 1684, when Rene Anthony was one year old. Rene was then educated by his maternal uncle. Rene Anthony graduated from the Jesuits college at Poitiers and then studied civil law at Bourges.

In 1702, Reaumur moved to Paris, and applied himself wholly to the mathematics under the guidance of Gine, who later introduces him to Pierre Varignon — mathematician and engineer, member of the Royal Academy of Sciences. That acquaintance played an important role in Reaumur's life. Varignon became Reaumur's close friend and a teacher. Besides, in 1708, Varignon helped Reaumur to enter the

[1] Pliny Senior, Guy Pliny Secund (23, or 24 Comum, modern Como - 79), Roman writer, scientist and statesman. The author of the "Natural History" 37 books (the antique encyclopedia of the natural knowledge). Contains information on: astronomy, physical geography, meteorology, ethnography, anthropology, zoology, botany, agriculture and forestry, medicine, mineralogy, metallurgy etc. Until the end of the 17th century was widely used as a knowledge base about nature.

[2] Court house adviser (Lat.)

Academy on a "geometry listener" position which is something like modern junior research associate. Reaumur presented his first report to the Academy of Sciences on 19th of March 1708, when he was 25. The report was dedicated to the way of the third degree curve plotting "Diokles cissoids". Reaumur later presented his reports on the quartic conchoids plotting theory at the Academy on the 4th of May and June of 1709. At his lay outs, young scientist used the infinitely small numerals theory. That theory was quite new for the geometry of those days. Reaumur also introduced the idea of "imperfect broaching bit". Unfortunately, Reaumur completed his investigations in mathematics. Once he became the member of the Royal Academy of Science, he then discovered a great variety of unsolved problems that challenged his acquisitive mind (Fig. 1).

During Reaumur's time, the Paris Science Academy was a recognized authority of the worlds' science and was approaching its 50. The academy was established during the reign of King-Sun, Louis the XIV, in 1666, soon after Jean-Baptiste Colbert (famous for his reforms) became a secretary of the treasury. Jean-Baptiste promoted the further development of the Science Academy that was assigned a task to use in practice the scientific knowledge for the benefit of the country. Reaumur enthusiastically took part at that work.

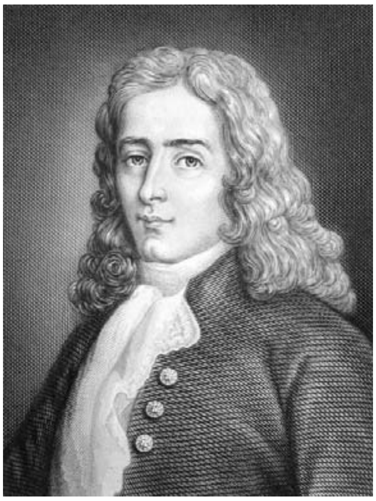

Fig. 1. Rene Anthony Farchault de Reaumur during his first years at the Royal Academy of Sciences

Let's investigate the French Academy of Sciences structure in the beginning of the XVIII century, and see what was Reaumur's role during all those years. In 1699, Louis the XIV introduced a regulation to the Science Academy, that gave him a privilege to introduce new members advised by the academy. The president and vice-president were introduced by the king from among the Academy honorary members. Altogether the Academy comprised of 70 members:

- 10 honorary members. Were assigned by the king and were supposed to be French Kings subject. They were also supposed to possess great knowledge in mathematics and physics.
- 20 boarders (that were payed and annual a salary). 3 in each branch of knowledge – geometry, astronomy, mechanics, anatomy, chemistry, botany. It also included a secretary and a "lifetime treasurer". These boarders did most of the everyday research and scientific work for the academy.
- 20 associated members: 12 French subjects (2 in each discipline) and 8 "free" members regardless of the occupation including foreigners.
- 20 listeners (adjuncts), that worked with boarders with corresponding speciality. They were engaged in experiment preparation and document procession.

Starting from the 1700s', among the 18 boarders (excluding secretary and the treasurer), a director and director's assistant were appointed. They substituted the president and the vice-president in case of their absence. In that way the academy existed with minor changes until the Lavoisier reforms that took place in 1785.

As it was mentioned before, Reaumur joined the Academy in 1708, when he was 25 years old, at a position of a geometry listener, and was attached to the boarder — Pierre Varignon. Starting from this moment, Reaumur regularly presented his reports to the Academy and took an active part in the work of the Academy. March 14th 1711, Reaumur took Louis Karre's place (mechanics boarder) after his death. Being a boarder, Reaumur was 10 times elected for a position of a director's assistant and 11 times a director (1713–1753).

During that period of time Reaumur commited himself to zoology. In 1715, he published his first work. That work was dedicated to the pearl formation in shell-fish. Later, Reaumur committed himself to the investigation of the social insects (like bees) behavior. From 1734 to 1742, Reaumur published successively 6 volumes of "History of Insects". However, Reaumur's investigations in the field of zoology were constantly interrupted because of the important work at the Academy.

In 1715, Regent Philip of the Orleans assigned The Science Academy to prepare a fundamental work "The description of arts and crafts". That project of the encyclopedia was first presented by Kolber in 1675, and was unique in its scope. The encyclopedia included 113 volumes (3 volumes of appendix), and was published from 1761 to 1788. The encyclopedia included all the industrial and handcrafts that existed in France at that time. The publication was illustrated by the engravings of the famous crafts man — Jean-Eli Bertrand. By order of the Science academy, Reaumur was selected to be the encyclopedias' lifetime chief-editor.

The "depth of that description" played a trick with Reaumur. During that time a group of leading French scientists and public figures lead by Diderot and d'Alembert were preparing the publication of the "Encyclopedia, or the defining dictionary of sciences, arts and crafts" that contained articles that reflected the "Enlightenment ideas". That fact assured the popularity of the "freethinking" "Encyclopedia" compared to the official state publication. Alongside with that, both publications contained (in one form or another) the same articles and even the same engravings. It is quit possible that was just simple plagiarism or that some authors cooperated with both editions, but the odds were that both of these facts took place.

During his work on the encyclopedia, Reaumur conducted vast investigations of a variety of crafts and manufactures. He investigated golden thread drafts, anchor clamps manufacture and the artificial pearls production alongside with mirrors manufacture, roofing slate processing, gold-plating the leather, iron ore mines field use, turquoise origin and production. He also made a mineralogical discovery, proving that some of the stones that were considered to be precious, were nothing but mineralized fossils of fossil animals. These assessments of the French crafts and arts, along side with the suggested improvements were also included in the 18th volumes that were published during the period between the years of 1761–1782.

Apart stand the fundamental works in the field of metallurgy that were supported by the regent Philip of the Orleans. During the period between 1720–1722 Reaumur presented about 12 articles that were later included in "The art of converting Iron into Steel, and the rendering cast Iron ductile" book[3]. For that fundamental research, regent presented Reaumur a lifetime pension of 12,000 livres annually. Reaumur used that money to build a laboratory in Paris suburb where he conducted most of his research work.

Reaumur's experiments in the field of metallurgy were mostly dedicated to the production of steel with the use of the wrought iron cementation. The choice was determined because France was importing most of its high quality steel from Germany and England. French manufacturers were only performing a case-hardening of the ready-made iron products. The range of commodities was limited to the short spectrum of the necessary tools and instruments.

A cementation process was used for the production of a high quality steel by means of carburization at a high temperature of the rod shaped wrought iron that were "packed" with an appropriate carbon source at airproof boxes. The manufacturing technology was improved by means of constant practice and had no scientific basis. Each manufacturer possessed his own secrets and carefully protected it from the others. The attempts to produce a high quality steel in France ended in complete failure. Later Reaumur wrote: "The King was disappointed especially by the fact that during the last three-four years French and foreigners, in attempt to get luck, presented them as the only holders of a true secret to convert the Royal iron into steel. Nevertheless they all failed... Those who promised to convert the Royal iron into steel were considered to be alchemists that searched for a philosopher stone". Thus, Reaumur was trying to solve a problem that was of great importance to the French metallurgical industry and also kindled his interest.

It should be mentioned that at the time when Reaumur began his experiments the scientific knowledge differed from the modern one. The case is, that carbon (playing a vital role in iron-metal conversion) was discovered by A. Lavoisier only at the end of 1780's. During Reaumur's time, a phlogiston theory was generally accepted. The true nature of fire was also unknown.

The phlogiston theory of combustion was created to describe the metal surface treatment. The alchemist ideas about the nature of combustion and body decomposition served the grounds for that theory. The phenomenological idea of metal surface treatment was widely known i. e. the metal turns into scale with the mass greater than the mass of the initial metal (V. Biringuccio showed in 1540, that the lead mass increases after being roasted); on the other side, when combusted, there is a gaseous products release the nature of which was unknown at that time. The phlogiston theory inventors were: Johan Joachim Becker, George Ernst Stahl. The main point of the theory, that was published in 1703, could be sated in the following fundamental positions:

1) There is a material substance that contains in all the combustible bodies i. e. phlogiston (Greek — φλογιστοζ — combustible).

2) The Combustion is body decomposition with a phlogiston release, that irreversibly dissipated in the air. The turbulent movement of a phlogiston that escapes the combusting body is in a form of visible fire. Only plans are capable of extracting the phlogiston from the air.

3) Phlogiston is always blended with other matter and could not be isolated.

4) Phlogiston possesses a negative mass.

The process of metal heat-treatment (within the frames of the phlogiston theory) could be presented in the following chemical equation: **Metal = Scale + Phlogiston**.

To receive a metal from a scale or an ore (according to the theory) any matching body could be used that us reach with phlogiston (charcoal or coal, grease, or a vegetable oil by a following reaction: **Scale + phlogiston rich body = Metal**.

The phlogiston theory allowed, in particular, to give an acceptable explanation to the process of metal smelting from ores that consists of the following steps: The ore containing phlogiston (in small quantity) is heated by charcoal that is rich with phlogiston. The phlogiston transfers from charcoal to iron ore. As a result one will receive a rich with phlogiston metal and a phlogiston-poor ash. Thus, to receive a pig-iron one must add a phlogiston to the iron ore. In order to receive a wrought iron, one must add a greater amount of phlogiston. Steel is a phlogiston rich iron. This phlogiston theory was later used to explain all combustion processes. At the latter half of the XVIII century, this theory was recognized by all chemists.

It is quite possible, that Reaumur was the first one, who attacked the problem of practical metallurgy with a scientist point of view, published his results (that were inconsistent with the generally accepted point of view) for the public. While planning his experiments, Reaumur developed an original experimental technique. He conducted his experiments by using identical initial samples of wrought iron. All samples were cut from the same metal block. To carburize the samples, Reaumur designed a small cementation furnaces (Fig. 2), that allowed to control the temperature conditions with great precision.

After conducting a series of experiments, that consisted of heating the iron to a certain temperature with the present of inert substances like chalk, clay etc, Reaumur excluded the possibility that the prolonged heating is sufficient to convert iron into steel. After that, he initiated a systematic investigation of the influence of different materials on the cementation process. He investigated the influence of a variety of substances (like plants moisture, salts, grease, animal and phytogenic carbon, ash, etc). Based on the first stage results, Reaumur concluded the following:

1) The fire itself does not convert iron into steel.

2) The conversion only occurs when "iron becomes soft", i. e. above a certain temperature.

[3] Full title "The art of converting Iron into Steel, and the art of rendering Cast Iron ductile, equally accomplished as forged iron products"

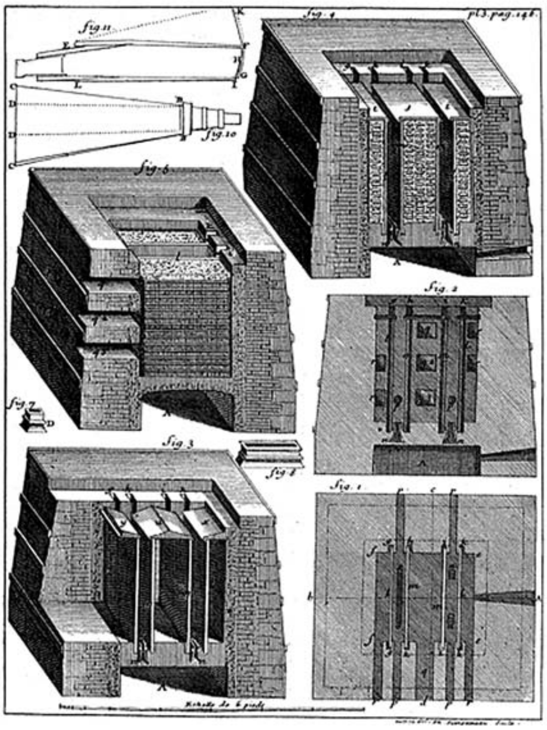

Fig. 2. Blueprints of Reaumur's laboratory furnaces

3) The most effective materials used for the process of cementation (carburization) are: charcoal, ash and carbonized leather.

4) Some salts increase the cementation process efficiency.

For the first time, Reaumur clearly established a fact, that the iron to steel conversion occurs gradually, beginning from the top layer of a sample towards the center part. Reaumur discovered, that fine-grained iron possesses better properties since it contains more vacancies that allow foreign substances to penetrate the sample. Although this is a simplification of the entire process, Reaumur basically described a diffusion process.

He then tried to understand what is there in the iron that turns it into steel. By weighting pieces of iron before and after they turned into steel, Reaumur discovered, that that mass increased by about 0.40 % what proved the accepted "refining" theory wrong (i. e. the theory about mass reduction when carburizing). He then tried to define the cause for that weight increase. Reaumur suggested that the cause for that are sulphurous compounds and volatile salts (at that time, all the combustible materials along with carbon containing materials were considered to be sulphurous). Reaumur's explanation for that fact was that the fire itself contains sulphurous materials and penetrates the iron through blowholes leaving incombustible materials behind. He drew an analogy with ash that accumulated in chimneys that is "mixed with fire but is steel combustible". Hence, after conducting scrupulous investigations, Reaumur stated a fundamental model about the role of carbon at the iron-steel conversion process. Reaumur stated that: "...the base (of the iron alloys) is pure iron substance that is combined with greater or lesser amount of sulphurous and salty matter where pig iron contains most of that matter, and wrought iron contains the least amount of that matter. Steel contains average amount of that matter. By adding that sulphurous and salty matter to soft iron one can first receive steel, and then pig-iron". Reaumur's views were not accepted at first by specialist and scientists. It took over a century to clarify the role of carbon in iron and steel alloys. One of the popular textbook on XIX century iron metallurgy noted that the iron properties in all different metallic compounds depend on a variety of chemical elements among which carbon plays such an important role, that it should be considered and investigated separately from the iron theory. The influence of the other elements is limited to the metal properties change that was already described by carbon".

As it usually happens, Reaumur was not recognized in France, although the results of his work were used in other countries. During the XVIII cincture, French economy was mostly agrarian. Most of the workhouses belonged to landlords that cared mostly about the financial aspects of their business. The technical aspects were left to the craftsmen that worked according with the traditions and resisted any innovations. The charcoal quantity reduction that happened during the XVII–XVIII century in Europe, did not bring new technologies to existence like it happened in England.

On the contrary, because of the energy crisis, it turned out to be impossible to introduce the cementation process that required large amounts of charcoal (Fig. 3). The low-grade steel production and pig-iron castings supplied the needs of the military and domestic market. The economic

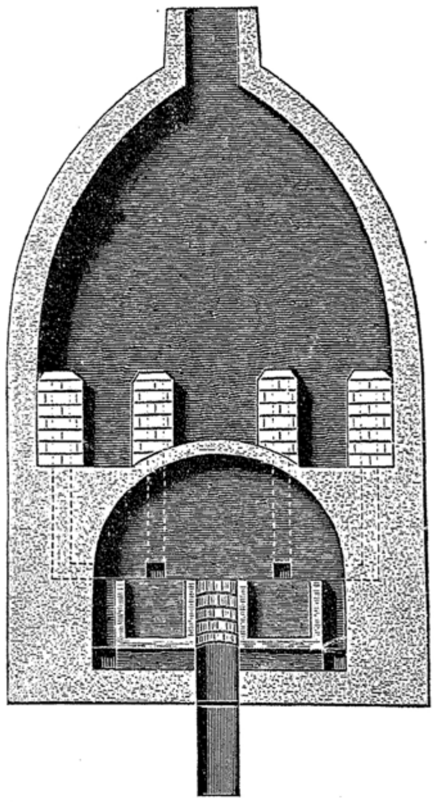

Fig. 3. Industrial cementation furnace

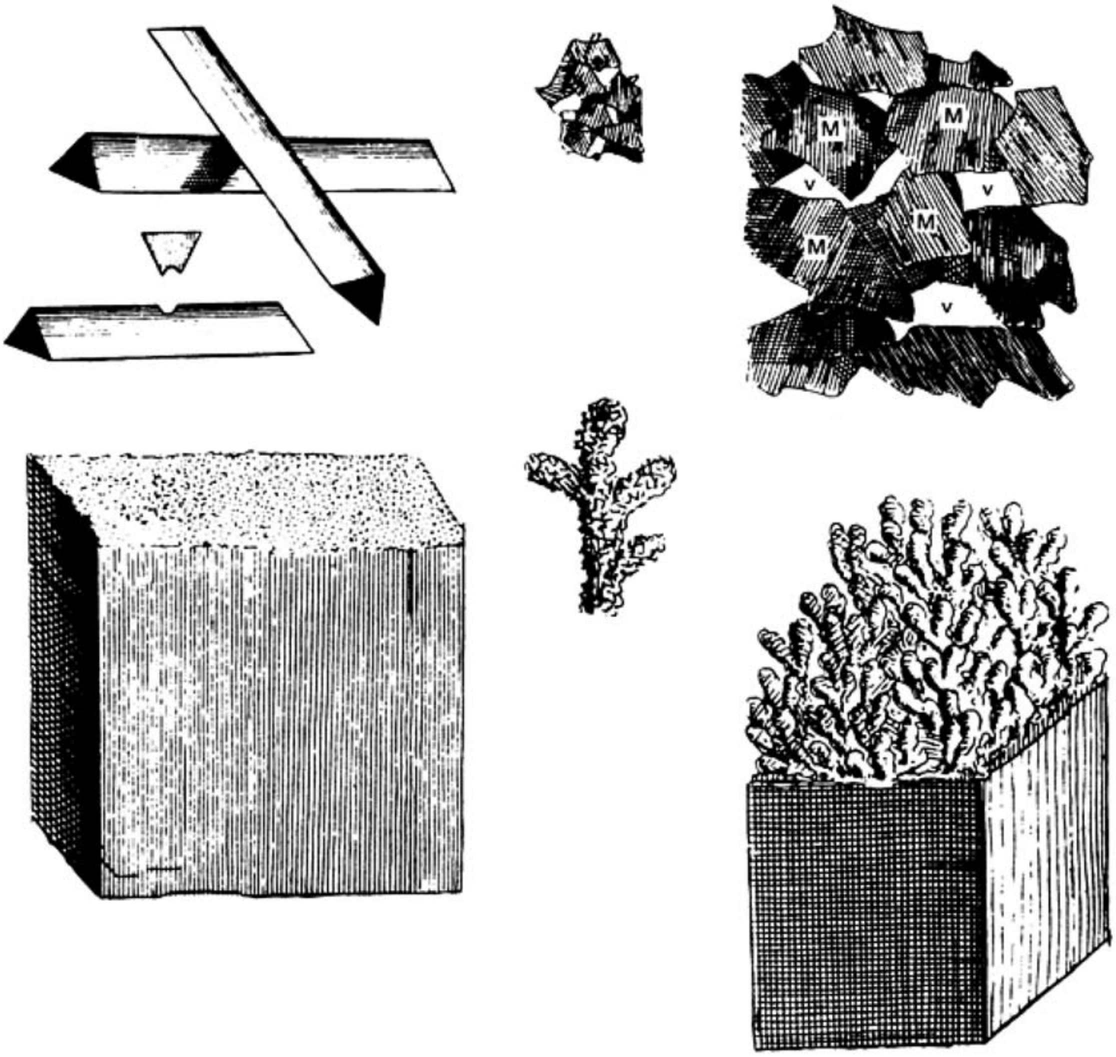

Fig. 4. High magnified details sketches (Reaumur)

condition prohibited the further development of the cement steel production that was widely used for cutting tools, knifes and arm blanche. The credit interest rate was twice higher then in England. That fact limited the investment possibilities. However it allowed to import a cheap steel. Thus, the high-graded steel production in France returned a lesser interest then the commercial steel sale.

Within a few years after Reaumur published his works, the cement steel manufacture became widely known in England and Sweden. His works demonopolized the cement steel manufacture by individual manufacturers that held the cement-steel secret. Newcastle and Sheffield became the centers of cement-steel manufacture. The process was performed in furnaces that were constructed according to Reaumur's principles. Iron blanks (in the shape of long thin bars with a rectangular cross section) were put in chambers made of refractory materials and covered with powdered coal. The heating process was performed outside the chamber by means of combustion gases (coal, firewood).

The iron load was about 10 tons, and the process lasted for 5–6 days since the chamber reached its desired temperature. The steel that comes out of this chamber was called "blister steel" (because of the gaseous impurities on the metal surface).

When studying the "raw" iron and the produced cement-steel, Reaumur drew a conclusion about the quality of iron, steel and cast-iron interrelation with its internal structure, that was determined by fracture mode. For his studies of fracture modes, Reaumur used magnifying glass and a microscope[4]. He studied events that are still of interest for scientists in our days: "blistering", burns, brittle fractures, dendritic fractures etc. (Fig. 4). It should be mentioned, that attempts to classify metals (mostly non-ferrous) were attempted even before Reaumur, however they were all local

[4] A simple double lens microscope with a 3–10x was manufactured in Netherlands in 1590 by Yansen brothers. The optical system improvement helped Anthony van Levenguk (1674) to manufacture lenses with a sufficient magnification to conduct simple scientific observations.

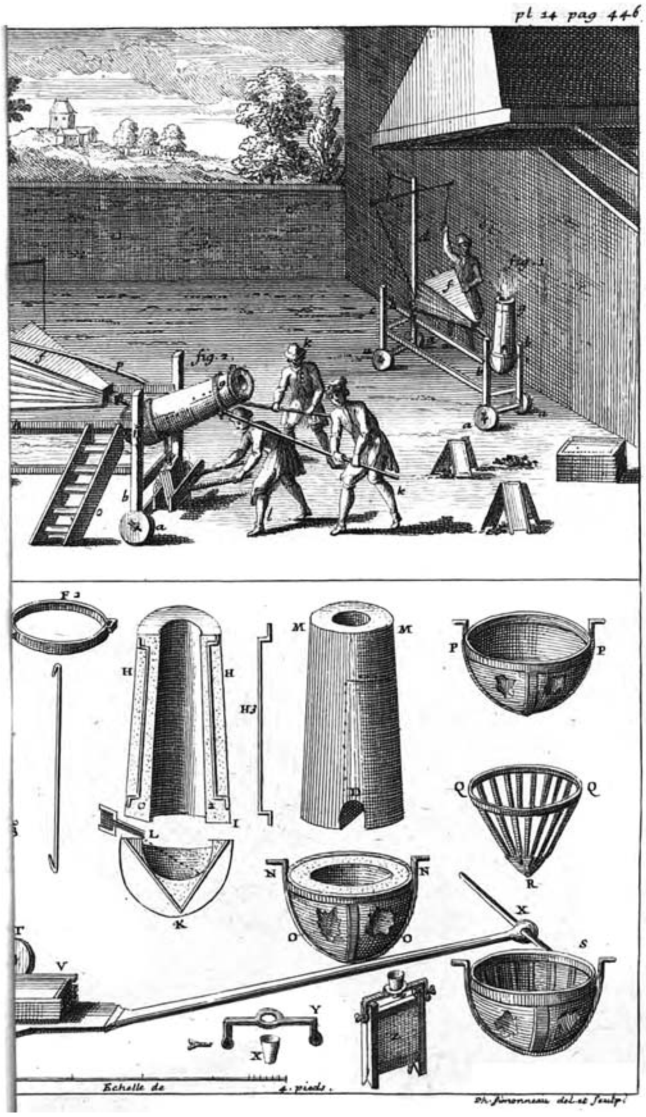

Fig. 5. Reaumur's cupola furnace

and were not recognized. Reaumur was first who attempted to use scientific methods to study iron alloys for complex quality analysis. He was impressed by the fact that a craftsman could only determine the quality of steel by making an instrument and testing it. The scientist held a revolutionary opinion (at that time) to test the quality of small samples and transfer the results on blanks and end products.

When analyzing the differences between "good" and "bad" steel, Reaumur concluded that in order to evaluate the steel quality, one could use the following characteristics:

— Grain fineness;

— After forgery hardness;

— Ductility.

Reaumur suggested to evaluate the grain fineness by the fracture mode appearance using magnifier. To evaluate hardness, Reaumur suggested a test based on standard sample use to scratch the tested sample. The seven steps hardness scale was suggested by Reaumur and outran the ten step Karl Fredrick Moh scale. To evaluate sample ductility, Reaumur developed a special device that allowed to determine to what degree can a sample bend until it breaks. For correct confidence limits, it was necessary to meet the following condition:

- The test samples should be identical in size. That condition was achieved by using the same roll;
- The test samples should be annealed at the same temperature. That as achieved by a simultaneous heat up at a liquid lead bath (antecessor of a salt-bath furnace)

For his pig-iron studies, Reaumur constructed a cupola furnace (Fig. 5). Systematic studies allowed Reaumur to develop a annealing practice with a malleable pig-iron obtainment ("softening"). Unfortunately, that technology was soon forgotten and was rediscovered in the beginning of XIX century. One of the other metallurgical work was description and recommendations for anchor manufacture improvement. That work was presented in a form of a report to the Science Academy by the name of "Anchor manufacture" in 1723. That report was later included in "The description of arts and crafts" and in Diderot's "Encyclopedia".

Finally, by 1725, Reaumur presented the Science Academy his work by the name of "The origins of tinned sheet plate manufacture". Until then, the technology of sheet plate manufacture was unknown in France, and all of the sheet plates were imported from Germany (The sheet plate monopolist manufacturer). German metallurgists strictly protected the secret of tin plating technology.

The main problem was scale removal that covered the top layer of a plate. The scale particles constitute of thin iron oxide plates that prevent melted iron to cover the iron sheet uniformly. Reaumur discovered, that when iron sheets are left in water acidated with wheat middlings then annealed in a furnace until a think layer of rust is formed the scale particles (when sanded) could be easily detached and removed from the iron-sheet surface. For effective tinning, the sheets must me immersed into melted tin covered with a thin layer of grease to prevent the reoxidation process.

Once Reaumur explained the basics of a tip plating process, it was arranged in various regions of the country. However, at the same time, many workhouses for tin plating appeared in England. English tinned iron appeared better looking than German of French, since iron sheets were obtained by rolling and not flattened by hammers (like it was done in Germany and France). Thus the surface was smoother, and British tinned iron won the leading positions on the market.

Reaumur's scientific work in the field of metallurgy was appreciated by some of his coevals and by the following generations of metallurgists. In 1734, Svedenborg, in his widely known tract "De Ferro", completely reproduced part of Reaumur's work (iron to steel conversion). Diderot (at the "Steel" article) specifically mentioned Reaumur's work as a large-scaled and extraordinary in the first part of his encyclopedia (published in 1751).In the beginning of the XIX century, Reaumur's works were appreciated by Assenphratz at his "Siderotechnic" work for his apprehension of the role of carbon and iron classification based on the fracture appearance. By that time all Reaumur's predictions were scientifically proven by means of chemical analysis.

Fig. 6. Full-dress portrait of Rene Anthony Farchault de Reaumur — commodore and indendant of the Saint-Louis Royal military order

Reaumur's works in the field of iron metallurgy initiated his communication with Russia. He sent a copy of his work on metallurgy to Peter the First, whom he met in Paris in 1717. Peter the First was so interested in this work, that he decided to translate in into Russian. Unfortunately, with the death of the emperor this undertaking was forgotten like many others.

Coevals also mentioned Reaumur's humanity. He was good-minded, generous and selfless. While being an indendant of the Saint Louis Royal military order in 1735 until his death, Reaumur donated all of his annual salary to charity. By the way, this position (according to the social status) is equal to Earldom (Fig. 6).

As to his personal life, its was not rich in events. He was not poor, and lived a single life — i. e. he was not distracted from his scientific experiments. Only in 1754, signs of a stroke were diagnosed — dizziness, and a temporary aphasia. For that matter, Reaumur left Paris by buying out a right to live in La Bermondier castle[5] (west France, Men province — today a Mayenn department). He arrived to his castle in 1755. September 6th 1755, Reaumur had a stroke and fell while riding a horse. That fall intensified his illness. Reaumur died a month and a half after that fall October 17th. Reaumur is buried in Saint Julien de Terry at a small village church cemetery.

Being a founder of an applied metallurgical science, Reaumur demonstrated its advantages compared to simple generalization of a handicraft experience. He relatively easy disclosed secrets that were guarded by foreign manufacturers. Being a patriot, he attempted to develop French industry, and make its manufactured articles competitive. It was not his fault, that the economic laws did not allow him to carry out his ideas.

"It is desirable that the discoveries served everybody, and it is a pity, that often they are useless. But there is a way to overcome those difficulties that is unfortunately not widely known. If a method gives good results once, it should be practiced widely. Being frequently repeated, it will not only benefit us but also give us a deeper knowledge"

R. A. F. de Reaumur.
"The art of converting iron into steel" Vol. 6

[5] The facts mentioned in different sources vary. It is unlikely, that this castle was his family estate and most of his scientific experiments were conducted there. The work at the Academy would not allow him to spend much time outside Paris, and the castle is located far enough from Vandey (it was already mentioned that the Farchault family originated from that part of France). However there is another theory that the Reaumur inherited the castle or it was presented to him by his close friend. Most likely, that castle belonged to Thomas Phantel de Lanya — French mathematician and a member of the Science Academy, who could possibly be Reaumur's friend. Phantel de Lanyz died in 1734, therefore it is possible that Reaumur rented the castle from his widow in 1755.