

TO THE ORIGINS OF FUSES

Jean-Louis GELET

FERRAZ-SHAWMUT, Rue Vaucanson, 69720-St-Bonnet de Mure. France.
Tel. 33 (0)4 72 22 66 30. jean.louis.gelet@fr.ferrazshawmut.com

This paper will open the 8th ICEFA-conference organized by the LAEPT (Laboratoire Arc Electrique et Plasmas Thermiques) and hold in Clermont-Fd from 10th to 12th September 2007. No doubt that many papers of great interest for science and technology of fuses will be presented within the three-days-meetings. No doubt also that every authors and every members will work very conscientiously and very professionally and will make effort for continuing their predecessors' endeavour.

The Organization Committee thought that it could be appreciable for any member to begin the Conference by a general overview upon origin of the fuse and how it was necessarily related with the general history of electricity.

During ICEFA -Conference (International Conference on Electrical Fuses and their Applications) which was hold in Gdansk, in September 2003, Prof. Stokes from University of Sydney introduced his communication as follows :

“Modern electric fuses are marvellous devices for protecting life and equipment from potential power of uncontrolled electricity. Since the coming of electricity in the 1870s, they have been in front line for electrical defence. Indeed, it is fair to say that without the virtually fail-safe protection of the electric fuse there would be no modern electrical industry. Electricity would be regarded as far too dangerous for widespread use.”

Nowadays, the use of electricity and all the devices it makes move is so familiar for us that we are scarcely able to imagine how much difficult was the labour of the inventors who looked for the nature and the effects of electricity.

1. SHALL WE RE-MAKE HISTORY ? :

It is noticeable that between Franklin (1752) and Ampère (1820), seventy years have been necessary to pass from first relevant understandings of the nature of electricity to the formulation of the mathematical equations describing the fundamental laws, especially for that concerns the relationships with magnetism. This is both short and long. Short in comparison with the twenty odd centuries of the occidental civilisation. But long for people who needed improvements from electricity.

In another scope, many English engineers, such as William Murdock, William Symington and Robert Fourness built vapour-powered vehicles at the beginning of the 1780s. But apart from the road-machines manufactured by Trevithick et Vivian between 1802 and 1804, it is necessary to wait up to the middle of the 1820s for new sporadic attempts of vapour-carts or diligences. Wide diffusion of automotive actually started at the end of the 19th century.

Same notices can be drawn for flying machines which were in use in France in the early 1780. French Montgolfier brothers demonstrated their aerostat in 1783 and 1784. But actual progresses only began in the 1890s.

One explanation for these delays may perhaps be found in the French Revolution and the wars and troubles which followed. From 1789 to 1815, Europe permanently faced to instability and lavishly spent money, energy and lives. There was neither place nor time for science and technological development.



King of France Louis XVI and Queen Marie-Antoinette being arrested in Varennes, on 20th June 1791.

Politics fiction novelist could imagine that in 1791, Queen Marie-Antoinette should ask to her husband Louis XVI to leave France and take refuge with her father, King of Austria. In the case Louis XVI accepted, he would be arrested in Varennes and French Revolution would go on. But in the case he refused, he would never be arrested in Varennes and nation would continue to trust him. Maybe France would get a constitution and Revolution would stop.

Then, science and technology would go on with development...

This is a part of French History and also of European History. Anyone knows that King Louis XVI accepted his wife's requirements. And we have now to come back to the reality.

2. TO THE ORIGINS OF ELECTRICITY :

In order to make the things more simple, let say that the history of electricity covers three large periods, even if a 4th period could be mentioned, since the 1950s, with the fantastic possibilities of electronics:

1st period, mainly covering 17th and 18th century : electrostatic phenomena amazed people in the Curiosities Cabinets,

2nd period, from the early beginning of the 19th to the 1870s : chemical generators gave enough energy for carrying out scientific experiments and finding the actual nature and the laws of electricity,

3rd period, since 1870s: thanks to electromagnetic machine, it became possible to turn mechanical energy to electricity and the doors opened for universal uses.

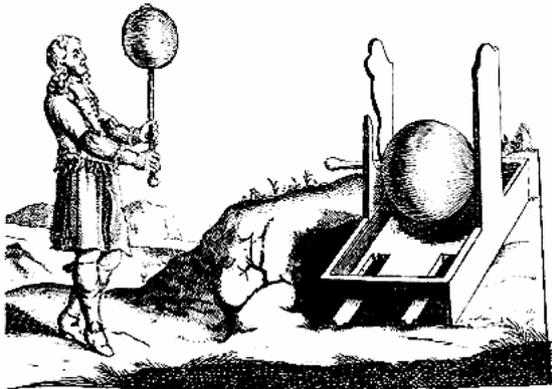
From Amber to Electrostatic, First Discoveries in the Curiosities Cabinets :

In the first times, scientists were captivated by the wonderful manifestations of electrostatic. Around the year 1600, the English Queen Elizabeth 1's own physician, William Gilbert [1] published a treaty about the magnetism of the Earth and proposed the word "*electricity*" to design the action of amber upon some light stuffs (amber is *elektron* in ancient Greek).

It was also the time for Curiosity Cabinets, where well-off people collected minerals, antiques, exotic wares and primitive physical instruments. These miniature museums were an attempt to classify science and civilization while the world was still amorphous. Many of these classifications were a strange hybrid of religion, science and superstition that are now considered obsolete.

Nevertheless, during this period, some interesting discoveries came to light. Around 1650, German Otto von Guericke built a crude friction generator with a sulphur ball that rotated fastly on a shaft. When Guericke held his hand against the ball and turned the shaft quickly, a static electric charge built up. In 1745, another German, Ewald Jürgen Georg von Kleist, found a method of storing this charge. He lined a glass jar with silver foil, and charged the foil with a friction machine. Kleist was convinced that a substantial charge could be collected when he received a significant shock from the device. This invention went on to be known as the Leyden jar because in

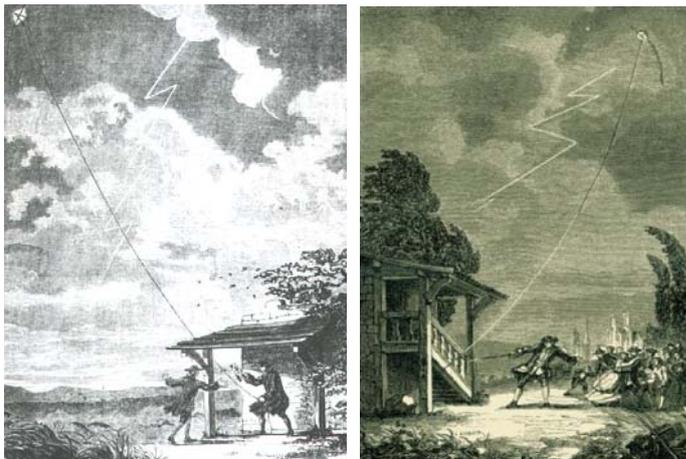
1746, Pieter van Musschenbroek of the University of Leiden, independently made the same discovery and let it know to the scientific world.



Guericke's machine (Germany, 1650).

During the second half of the 18th century, English Edward Nairne patented several electrical machines, including an electrostatic generator consisting of a glass cylinder mounted on glass insulators. The device was intended for medicinal use. Nairne recommended its use for nervous disorders, burns, scales, bloodshot eyes, toothache, sciatica, epilepsy, hysteria, agues and so on.

Also during this epoch, people began to make a parallel between electrostatic and thunder-lights. Most famous are the experiments carried out by American Benjamin Franklin and his son, with a kite in 1752. One year later, without any knowledge about Franklin's discovery, French Jacques de Romas did the same.



Experiments upon thunder :

left : by Benjamin Franklin and his son, in 1752.

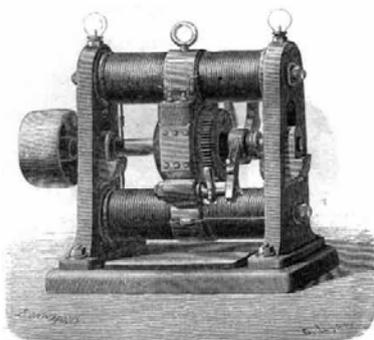
right : by Jacques de Romas in Nérac (France), in 1753

Thanks to Chemical Generators, Nature and Laws of Electricity are Explained :

Then, with the first Volta's batteries, it became possible to better understand the nature of electricity. For examples, Scotchman Prescott Joule found the so called effect and Danish Ørsted observed the magnetic effect of an electrical current. The presentation by the French scientist Arago of Roster's works at the Académie des Sciences, in Paris, on 1820, September, 4th gave to physicist André-Marie Ampère a flash of inspiration. Within one month Ampère formulated the law of electromagnetism (commonly called Ampère's law) that describes mathematically the magnetic force between two electric currents.

Electro-Magnetic Machines Open the Door to Universal Uses:

Lastly, time went for machines able to turn mechanical energy to electricity. Generally, invention of the dynamo is attributed to the Belgian Zenobe Gramme who achieved an efficient machine in 1870. To be honest, he was continuing studies by French Hippolyte Pixii (1832), English Cooke and Wheatstone (1867) and Italian Antonio Pacinotti (1860). Gramme's machine was improved as soon as 1875 by American Charles Francis Brush. From this time, doors were open for multiple applications we know today and for their universal uses.



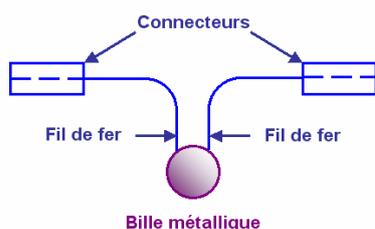
Zénobe Gramme's Machine (1870)

Only from this time started electricity's era.

3. THE FUSE AS A KEY FOR UNIVERSAL USES OF ELECTRICITY :

According to A. Wright and P.G. Newbery [2], earliest references to electrical fuses concern discussions following the presentation of a paper by A.C. Cockburn [2] to the Society of Telegraph Engineers in 1887. In the comments about this, W.H. Preece stated that platinum wires had been used as fuses to protect submarine cables since 1864 and Sir David Salomons referred to the use of fuses in 1874.

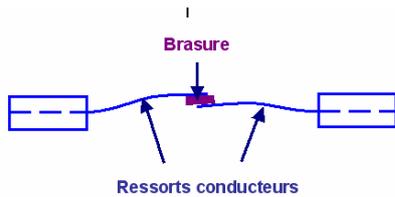
According again to A. Wright et P.G. Newberry, significant quantities of fuses must have been in use since 1879 and even, the simple wire-construction was not adequate enough for some applications because in that year Professor S. P. Thomson produced an "improved" fuse. It consisted of two iron wires connected together by a metallic ball of lead-tin alloy or any other low melting-temperature alloy.



Fuse with lead-tin alloy ball by Prof. S.P. Thompson(1879)

We may assume that action of gravity on the ball at the time it melted, allowed to get a faster and larger opening of the electrical circuit and then a better interruption of the electrical arc. Let us keep in mind that up to about 1890, electricians quite exclusively used direct current, that we know today is more difficult to cut than alternative one.

An evolution to Thompson's fuse occurred and was patented in 1883 by C.V. Boys et H.H. Cunyngham. They soldered two flat conductors having a spring ability. Above a sufficient current, the solder melted and made the conductors free to move in opposite directions.



Fuse patented by Boys and Cunyngham (1883).

Other physical arrangements based on this principle followed, one of them being attributed to Sir W. Thomson.

But, use of fuses actually arrived because of the large interest for electrical lightning in the years 1880-1882. Mentioned by the same A. Wright et P.G. Newbery, J. H. Holmes remembers in a letter to Clothier [4] that earliest lightning installations with incandescent filament lamps were built in 1878, almost simultaneously in England by Swan and in the United States by Edison. In order to protect the lamps against over-running, more than against short-circuit-currents, both Swan and Edison used fuses.



Thomas Edison (1847 - 1931)

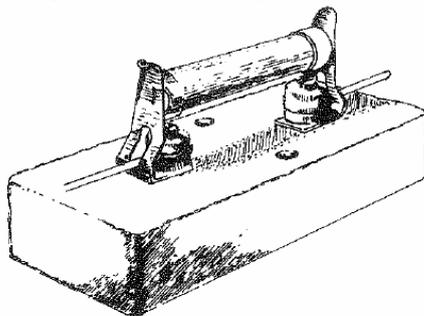
A British patent attributed to Thomas Edison on April 1881 is probably the first official notification of the use of lead-wire as over current protection. It can be read that Edison's disposal is named "safety-guard".

Nevertheless, some information – a lightning installation at Armstrong Works in December 1880 – tend to demonstrate that Swan owns the anteriority of the invention of fuses.

Swan and Edison went to Court in England and in United States, not only for the priority of fuses but also for lamps-patent. In 1883, after legal actions on both sides of the Ocean, Swan and Edison found a commercial solution in a common company : "The Edison & Swan United Electric Light Co". Each lamp produced by this new company were fitted with an additional fuse, consisting in a tin-strips.

Fuse for electrical protection against over-currents was born.

In addition, it is here necessary to bring some information about the invention of the filling of fuses. This is attributed to W.M. Mordey who took a patent in 1890. According to A. Wright et P.G. Newbery, this patent describes a fuse link with a fusible copper conductor enclosed in a glass tube or similar vessel. The tube was completely or partially filled with finely divided, badly conducting materials, preferably incombustible or non-flammable. Mordey suggested dry chalk, marble, sand, mica, emery or asbestos as filling materials. For anyone who experimented fuses, solutions concerning ability to interrupt the arc are as attention-grabbing as conduction and melting. So, W.M. Mordey does merit so much consideration as Edison and others.



Cartridge fuse patented by W.M. Mordey (1890)

4. YES, BUT BEFORE EDISON ? :

The French Electrical Telegraph :

Beside, and also before efforts from engineers working on large electrical installations such as lightning, others have used the same principle consisting on the melting of a conductive wire. According to credible references, fusing-wires have been early used for the protection of telegraphic lines against thunderbolts. The idea is attributed to French Louis-François-Clément Bréguet as soon as 1846.

The story is worth being told.



*Louis-François-Clément
Bréguet (1804-1883)*

In the years 1830-40s, France was equipped with a large net of Chappe's optical telegraphs. For that time, it was an efficient medium, and for example, a message could be transmitted from Paris to Toulouse (ca. 700 kms) within twenty minutes.

At the same time, the English, under Wheastone's leadership, were working on an electrical telegraph.

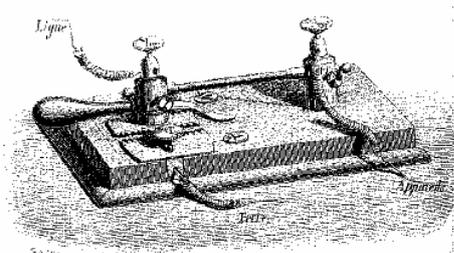
This application of electricity was compliant with the low capacities of the electro-chemical available generators.

The great scientist Arago, who also was a member of the Chamber, succeeded in persuading king Louis-Philippe to install an electrical telegraph line between Paris and Rouen. The Director of the Administration of Telegraphs prescribed that the new system must keep the encoding of the ancient. Operators, wont to read signals of the articulated arms of the Chappe's telegraph would not have to learn a new code. Because of the precision required for the mechanism, the manufacturing of the gear was committed to a famous clock- and scientific device-maker : Louis-François-Clément Bréguet.

This one would write later how came the necessity of the fuse [3]:

“In June 1846, because of a fierce thunderstorm over Saint-Germain village, all the wires of Le Vesinet-station were burnt and the apparatus were destroyed. This accident let us think that we had to protect the operators. We imagine to insert in the electrical circuit a very small and resistant wire, which should burn before the copper-wires of the electro-magnets.”

We called that a "paratonnerre" (Thunder-rod). It consisted as main part of a 0^m,00011 diameter wire, set inside a small wooden or glass-tube in order to preserve it against strokes. This "paratonnerre" was located in the electrical circuit outside the station.”



Bréguet fuse (1846)

About Dangers to be a Scientist:

Another "old story" is related by W. Bussière [4] from Fraunberger [4, 5]:

"On 6 August 1783, in St-Petersburg, Professor Georg Richman and his assistant were struck by lightning while charging capacitors (The Leyde Jar was invented by Ewald Jürgen von Kleist in 1745). The assistant escaped almost unharmed, whereas Richman was dead immediately. The pathologic analysis revealed that "he only had a small hole in his forehead, a burnt left shoe and a blue spot at his foot. [...] the brain being safe, the front part of the lung sane, but the rear being brown and black of blood." The conclusion was that the electric discharge had taken its way through Richman's body. The scientific community was shocked".



Prof. Richman's dramatic accident (Russia, 1783)

W. Bussière also relates that English scientist Edward Nairne [9-11], well-known for having built an electrostatic machine in 1774, is told to have used metallic wires, connected to the potential, in order to make a safety during capacitor-discharge. These wires, because of their electrical resistance and thanks to their adapted lengths were supposed to behave like fuses in case of over currents.



Edward Nairne's machine (England, 1774)

Nairne didn't the commit the same mistake as Prof. Richman. He used fuses!

5.CONCLUSION :

During the all history of electricity, have been the fuses present. Moreover, each time that electricity stepped progress and brought up new dangers, these were cleared by solution including fuses. Edward Nairne used wire-fuses, Louis-François-Clément Bréguet used wire-fuses and also Swan and Edison. Professor Richman who didn't think to protect himself paid with his life.

Beside the evidence of fuses to face the electrical protection-problems, there is the necessity of an adaptation of the fuse to the actual applications. In other words, beside the principle of conductor-melting under Joule's effect, are the adjusted technologies. Our job is there. Perhaps more than Swan or Edison, or Bréguet, or Nairne, the genuine father of our fuse-community is W.M. Mordey who went farther in the understanding of the needs, pointed out the arc-extinguishing and found a technological solution.

Today, because of new applications, because of globalisation, because of environmental regulations, bills of requirements for fuses are changing. And any one of us is asked for improving, and adapting the technologies. Nevertheless always based on the same fundamental principle.

Surely, the 8th ICEFA will demonstrate that the fuse is always able to adapt its simple principle to nowadays environment. The Organization-Committee sincerely hopes that this Conference will bring a better perception of this essential consideration. He will also be very proud to contribute to keep the community which is gathered around the fuse as enthusiastic and dynamic as in the previous time. The words "previous time" are referring to the forerunners of the 19th century as well as engineers who created ICEFA just 30 years ago.

REFERENCES:

- [1] William Gilbert. De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure (On the Magnet and Magnetic Bodies, and on That Great Magnet the Earth) , anno 1600.
- [2] A. Wright, P.G. Newbery. Electric Fuses. *Peter Peregrinus Ltd, on behalf of the Institution of Electrical Engineers. Stevenage, UK, 1982.*
- [3] A.C. Cockburn. On safety fuses for electric light circuits and on the behaviour of the various metals usually employed in their construction. *J. Soc. Teleg. Eng. 16 pp 650-665, anno 1887.*
- [4] H. W. Clothier. Switchgear Stages. *G.F. Laybourne & Unwin Brothers, 1933.*
- [5] L. Bréguet. Manuel de télégraphie électrique, quatrième édition, ornée de 80 gravures sur bois placées dans le texte et de 4 planches gravées sur acier. *Paris, Librairie de L. Hachette et Cie, 1862.*
- [6] W. Bussière, T. Latchimy. Fonctionnement des fusibles MT, Etudes expérimentales et théoriques. *5° Journées du Réseau Plasma Froid. Bonascre. LAEPT Clermont-Fd, 2006.*
- [7]Fritz Fraunberger. Ueber das elektromotorische Verhalten von Metallen, *Buchdruckerei von J. Fuller, München, 1904.*
- [8] Fritz Fraunberger. Elektrizität im Barock. *Aulis Verlag Deubner und Co, s. d. , Köln.*
- [9] Edward Nairne. The description and use of Nairne's patent electrical machine : with the addition of some philosophical experiments and medical observations, 1787.
- [10] E. Nairne, The description and use of Nairne's patent electrical machine [*Document électronique*] : with the addition of some philosophical experiments and medical observations, 1995.
- [11] Caullet de Veumorel. Description de la machine électrique négative et positive de M. Nairne, avec les détails de ses applications à la physique, et principalement à la médecine ; *traduit de l'anglais, 1784.*