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Sciences sans conscience?

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Il n'y a pas de formation complète en sciences et génie sans enseignement de l'histoire des technologies.

Depuis des milliers d'années, les métallurgistes ont pourvu aux besoins matériels des gens. Aujourd'hui, la technologie change tellement rapidement qu'à première vue l'histoire du passé semble offrir peu de valeurs professionnelles pour remplir les besoins du présent. L'attitude des individus face à l'histoire peut se résumer dans la phrase: «Sa connaissance n'est pas bénéfique et son ignorance ne fait pas de mal». Mais l'histoire offre plusieurs leçons de valeur, en plus de satisfaire notre curiosité naturelle quant aux découvertes et traditions de cette profession.

Un étudiant qui apprend la métallurgie sans apprécier sa vitesse de croissance, son changement technologique rapide et les forces économiques qui influencent l'industrie n'est pas proprement formé. En plus, la science et l'ingénierie sont faites par des personnes et il est pratiquement impossible d'enseigner une discipline sans mentionner les noms des scientifiques ou des inventeurs. C'est pourquoi il est essentiel d'inclure systématiquement ces noms dans l'étude de la métallurgie. Le sens de l'histoire peut donner à l'étudiant une idée du mouvement, du progrès et du changement continu dans la science. L'intégration de l'histoire dans l'étude de la métallurgie peut sensibiliser les étudiants aux interrelations entre les événements en physique, chimie, métallurgie et autres technologies. De plus, cela remet les grandes découvertes à leur vraie place pour qu'elles ne soient pas vues par l'étudiant comme des événements isolés créés par de grands hommes ou de grandes femmes. En 1983, la Société des chimistes américains a recommandé aux enseignants d'inclure une perspective historique dans l'enseignement de la chimie. C'est pourquoi les livres de chimie d'aujourd'hui comprennent des biographies de grands chimistes et quelques fois des photos. Malheureusement, la Société des métallurgistes du Canada et des États-Unis n'a pas fait de recommandation semblable pour les études de métallurgie. Un vecteur important de la science

Le distingué poète allemand Johann Wolfgang von Goethe, qui s'intéressait à la science, a montré l'importance de l'histoire de la science quand il a écrit: «L'histoire de la science, c'est l'histoire elle-même». Le chimiste allemand Wilhelm Ostwald a reconnu en 1889 l'importance de l'histoire. Il a réimprimé des centaines de travaux originaux de chimistes dans une série qu'il a appelée Les travaux classiques dans les sciences pour rendre disponibles à ses collègues chimistes des travaux obscurs ou non facilement disponibles, ainsi que des travaux qu'il pensait que les chimistes devaient lire.

L'ingénieur minier Herbert Hoover, qui a été président des États -Unis de 1929 à 1933, a aussi reconnu l'importance de l'histoire. Avec son épouse, il a produit en 1912 la première version anglaise du livre *De Re Metallica* de Georgius Agricola, publié en 1556 en latin, un ouvrage de référence pour les étudiants de mines et métallurgie pour au moins 200 ans. Récemment, le distingué professeur de métallurgie du Massachusetts Institute of Technology, Cyril Stanley Smith (1903 -1992), en collaboration avec d'autres chercheurs, a traduit en anglais plusieurs travaux classiques de métallurgie publiés originalement en latin, allemand, italien, français, polonais et japonais.

Les chimistes, plus prolifiques

Alors que plusieurs chimistes consacraient du temps pour écrire sur l'histoire de la chimie, peu de métallurgistes ont fait des efforts semblables. C'est pourquoi l'histoire de la chimie est plus avancée que l'histoire de la métallurgie. Le chimiste anglais J.R. Partington (1886-1965) a publié non pas seulement ses travaux gigantesques sur la chimie physique, mais aussi quatre grands volumes sur l'histoire de la chimie; les volumes sont bien documentés et font autorité sur ce sujet. Avant lui, le chimiste français Marcellin Berthelot (1827-1907), qui a fait plusieurs découvertes en chimie organique et thermodynamique chimique, a écrit quatre livres sur différents aspects de l'histoire de la chimie et un volume intitulé Archéologie et Histoire des Sciences.

L'histoire de la science peut stimuler les étudiants. Par exemple, l'histoire de Charles Martin Hall (1863-1914) qui, à l'âge de 22 ans, a produit le premier échantillon d'aluminium électrolytique, préparé dans sa remise à l'aide de batteries qu'il avait fabriquées lui-même. C'est le même procédé que l'on utilise aujourd'hui pour la production de quelques dizaines de milliers de tonnes d'aluminium, chaque année, dans le monde. Hall avait été inspiré par son professeur de chimie qui avait étudié en Allemagne avec Friedrich Wöhler (1800-1882) lequel avait travaillé sur ce métal et mentionné la nécessité de trouver un procédé moins dispendieux que celui qui était utilisé.

Encore plus inspirante peut-être, pour nos étudiants, est la biographie de Michael Faraday (1791-1867). Ce garçon de 22 ans a été nommé en 1813 adjoint au grand chimiste britannique, Sir Humphrey Davy (1778-1829), de l'Institut Royal de Grande-Bretagne. Faraday venait d'une famille pauvre et a travaillé comme relieur de volumes dans une imprimerie. En même temps qu'il suivait les conférences sur la chimie de Davy à Londres. Un jour, il a relié ses notes de conférences comme un livre et les a présentées à Davy en lui demandant un emploi. Les contributions de Faraday à l'électrochimie, la métallurgie et la physique sont énormes. Quand on a demandé à Davy quelle était sa plus importante découverte, il a répondu: «Michael Faraday». L'histoire, essentielle à la prospective

Personne ayant suivi le déroulement des progrès scientifiques et technologiques dans les vingt à trente dernières années ne peut nier que la science et la technologie sont des facteurs déterminants pour notre futur. Planification et préparation sont une influence sur ce futur qui est devenu lui-même une science appelée «la prévision technologique». Il devient évident que l'on ne peut pas juger ou prédire sans une connaissance approfondie du développement dans le passé. (...) Comment une idée a-t-elle conduit à une découverte? Est-ce qu'elle origine d'une même discipline ou bien d'autres disciplines? Combien de temps a-t-il fallu entre moment de la découverte et la réalisation de sa signification ou son application pratique? Les réponses à ces questions et à d'autres demandées par les planificateurs du futur sont fournies par les historiens des sciences et de la technologie.

La métallurgie, comme d'autres branches du génie, est une activité humaine faite par des hommes et des femmes. L'histoire de Madame Curie (1867-1934), cette immigrante polonaise à Paris qui a travaillé dans des conditions difficiles à dissoudre des tonnes de résidus de pechblende pour obtenir quelques milligrammes d'un nouvel élément dont le sel brille dans le noir, en a inspiré plusieurs (...) Plusieurs scientifiques ont eu une vie réussie et magnifique, alors que d'autres ont vécu dans la misère ou connu des fins tragiques. Le chimiste suédois Jons Jacob Berzelius (1779-1848) et le chimiste allemand Justus von Liebig (1803-1873) reçurent le titre de baron en reconnaissance de leurs travaux alors que le physicien autrichien Ludwig Boltzmann (1844-1906) et le chimiste français Nicolas Leblanc (1742-1806) ont mis fin à leurs jours. La fin tragique d'Antoine Laurent Lavoisier doit être connue de tous les étudiants des sciences. Lavoisier, jeune chimiste français, a été impliqué dans le système de collection d'impôts qui a frappé cruellement pendant la Révolution française. (...) L'histoire de ce chimiste négligent qui a agité un mélange avec un thermomètre, une opération qui ne doit pas être faite par un

chimiste, est aussi instructive. En effet, ce chimiste a brisé le thermomètre, mais heureusement, le mercure du thermomètre a accéléré la réaction. Quand il a répété la même expérience en utilisant un agitateur mécanique, la réaction n'a pas eu lieu comme prévu. Un étudiant qui entend cette histoire gardera en mémoire le rôle joué par un catalyseur. Par ailleurs, il y a plusieurs histoires de chimistes attentifs. Une de ces histoires raconte l'observation faite par le chimiste allemand Ludwig Mond (1839-1909) qui a établi son entreprise chimique en Angleterre. Un jour, il a observé qu'une valve fabriquée en nickel avait été sévèrement attaquée par les gaz des tuyaux. Après un examen plus minutieux, il en est venu à la conclusion que le nickel réagit avec le CO pour former un gaz. Il a trouvé que ce gaz est de composition $\text{Ni}(\text{CO})_4$ c'est-à-dire le tétracarbonyle de nickel. La facilité avec laquelle ce carbonyle décompose à haute température en nickel et en monoxyde de carbone a donné l'idée à Mond d'utiliser cette réaction pour l'affinage du nickel. Il a construit une usine à cette fin et aujourd'hui ce procédé est utilisé à grande échelle pour l'affinage du nickel à Sudbury. En conclusion, on peut dire qu'il est possible d'enseigner à un technologue en métallurgie sans le sensibiliser sur l'histoire de son domaine, mais il est difficile d'instruire un métallurgiste créatif sans cette connaissance.

TRANSLATION

HISTORY AND METALLURGY

From long before the earliest days of recorded history, metallurgists have provided for man's materials needs and wants. Here, in the 1990's, technology is changing so rapidly that at first sight, the story of the past seems to offer little of professional value in meeting the problems of the present. The attitude towards history so far can be summarized in the phrase "*knowledge of it does not benefit and ignorance of it does not harm*". Yet, history offers many lessons of value in addition to satisfying our natural curiosity about the background and traditions of this profession. A student who learns about metallurgy without appreciating its rate of growth, the rapidly changing technology, and the economic forces affecting the industry has not been properly trained. Furthermore, since science and engineering are made by people, it is practically impossible to teach a discipline without mentioning the names of scientists or inventors. It is therefore essential to include these names systematically in studies of metallurgy.

A sense of history can give a student a feeling for the movement, progress, and continuous change inherent in science. Inclusion of history in the metallurgy curriculum can also provide the student with a feeling for the interrelationships among events in physics, chemistry, metallurgy, and other technologies. Integration of history into the metallurgy course places the nature of discoveries in a true perspective so that they are not seen by the student as isolated and completely independent events created by great men. The American Chemical Society's guidelines for undergraduate education in chemistry (published in 1983) recommend that courses in chemistry should incorporate a historical perspective as well as reference to current developments. Unfortunately, the metallurgical societies of Canada and the USA have not put forward comparable recommendations. As a result, most chemistry textbooks today include biographical notes of noted chemists and sometimes their pictures.

The distinguished German poet Johann Wolfgang von Goethe, who was interested in science and wrote a book on the color, showed his awareness of the importance of the history of science when he wrote that "history of science is science itself". The German physical chemist Wilhelm Ostwald recognized in 1889 the importance of history. He reprinted hundreds of original researches by chemists in a series entitled *Klassiker der exakten Wissenschaften* to make available to his fellow chemists obscure or not easily available publications, and old work that he felt chemists should read. In this way, the chemical thermodynamics of the American physicist Josiah Willard Gibbs became known when Ostwald translated and republished Gibbs' work which had originally appeared in a rather obscure journal entitled *Transactions of the Connecticut Academy*. The mining engineer and financier Herbert C. Hoover, who was president of the United States from 1929 to 1933, also recognized the importance of history. Together with his wife, he made in 1914 the first English translation of Georgius Agricola's book *De re metallica*. This book had originally been published in 1556 in Latin, the language of scholars at that time; the title means "Of Things Metallic". This monumental work was the reference book on mining and metallurgy for at least two centuries.

In more recent times Cyril Stanley Smith, the distinguished emeritus metallurgy professor at the Massachusetts Institute of Technology, in collaboration with others, has

produced English translations of many classics of metallurgy originally written in Latin, German, Italian, French, Polish, and Japanese. For example, he was instrumental in producing in 1942 an English translation of Vannoccio Biringuccio's book *De La Pirotechnia* which first appeared in Italian in 1540. Cyril Smith was also a leader in the application of metallurgy in archeological research.

While many chemists have taken the time to write about the history of their profession, few metallurgists have made similar efforts. That is why many stories are known about chemists but very few about metallurgists. The British chemist J. R. Partington not only published a multi-volume book on physical chemistry but also wrote four volumes on the *History of Chemistry* that are to date the most authoritative and well documented work on this topic. Before him, the French chemist Marcellin Berthelot who made numerous discoveries in organic chemistry and chemical thermodynamics, found time to write four books on the history of chemistry: *Les Origines de l'alchimie* (1885), *Collection des anciens alchimistes grecs* (1888), *Introduction à l'étude de la chimie des Anciens et du Moyen Âge* (1889), and *La Chimie au Moyen Âge* (1895). In addition, he wrote a general book on the history of science entitled *Archéologie et Histoire des sciences* (1906). Berthelot's interest in the history of chemistry arose when he visited Egypt in 1869 to attend the opening of the Suez Canal. From this time on he collected and translated rare manuscripts, analyzed old coins and utensils, and wrote numerous historical articles. Incidentally, Berthelot became a senator in 1881, Minister of Public Instruction 1886–1887, and Minister of Foreign Affairs 1895–1896.

Two distinguished German organic chemists, Albert Ladenburg and Carl Gräbe also wrote extensively on the history of chemistry. Beside publishing his *Handwörterbuch* in thirteen volumes in 1882–1896, Ladenburg wrote *History of Chemistry and Lectures on the Development of Chemistry During the Last 100 Years* (1869). Gräbe wrote *History of Organic Chemistry* (1920). The Scottish chemistry professor Thomas Thomson (1773–1852) wrote *The History of Chemistry* in 2 volumes (1930) as well as his *System of Chemistry* (1807) which contained the first exposition of Dalton's atomic theory. Thomson's was the first book on the history of chemistry in English language. These are only a few examples showing that many distinguished chemists have devoted some of their time to historical studies.

Metallurgy history writers are few and their work is rather modest as compared to chemists. Probably the most noteworthy works were those devoted to metals in antiquity, for examples, the works by Forbes and Tylecote. The history of iron and steel has also received great attention, for example, in works by Beck, Johannsen, Schubert, and Needham. The history of several other metals has also been documented, but the first general survey of the history of metals was the two volumes by Aitchison followed by a small work by Dennis.

The history of science can be inspiring to students. A particularly relevant case is the story of how Charles Martin Hall at the age of 22, produced the first buttons of electrolytic aluminum in an improvised wooden shed with homemade batteries. As a result of the commercial success of the Hall Process the price of aluminum fell from \$3 per pound to 60 cents per pound and made Hall a millionaire. Hall had been inspired to seek a cheap method for producing what was then an expensive curiosity by his chemistry professor at Oberlin College, Frank Fanning Jewett. Jewett, who had worked under the German chemist Friedrich Wöhler told his class of Wöhler's work on aluminum and pointed out the need for a lower cost process. At the time of his death, Hall left 3 million dollars to his alma mater.

When the great chemist Sir Humphrey Davy was asked what was his greatest discovery, he answered: Michael Faraday. Faraday was born in poor circumstances and as a boy he

worked for a bookbinder and attended Davy's lectures. He collected the lecture notes, bound them in a volume, and presented them to Davy together with an application for employment. He was 22 in 1813 when he was appointed at the Royal Institution of Great Britain as an assistant to Davy. A few months later, Davy and his bride left on a two-and-a-half-year combination honeymoon and scientific tour of Europe. Faraday was taken along as a secretary and scientific assistant, and therefore was able to meet the leading scientists of the age as he assisted Davy in his demonstrations and lectures. For many years afterwards, he devoted himself to research. He produced the laws of electrolysis, devised the first continuous mechanical motion produced by the action of an electric current which became the basis of the electric motor, made great discoveries in physics (electric induction, discharge in gases, diamagnetism), in chemistry (discovery of benzene, compounds of chlorine and carbon), and in metallurgy (for example in alloy steels).

No one who has witnessed the scientific and technological developments of the past twenty or thirty years would challenge the statement that science and technology are the determinant factors influencing our future. Planning and preparation for an influence upon this future has become a science in itself called *technological forecasting*. It is becoming increasingly clear that the future development of science and technology cannot be judged or predicted without a profound knowledge of their past development. There is no starting point for such extrapolation other than the path that they have followed to the present date. It is, therefore, essential that we examine how important discoveries were made, and whether they were accidental or the inevitable result of previous knowledge. It is also important to know whether the discovery resulted from "pure" or "applied" research, whether it was conducted in an academic or industrial laboratory. How did the idea leading to the discovery occur — did it emerge from the same branch of science or from another related or entirely separate area? How long a period elapsed between the initial discovery and the recognition of its significance or its practical applications? The answers to these and similar questions required by planners of the future can be provided only by historians of science.

In order to obtain answers to the above questions, profound and comprehensive analysis is required. In many historical studies it has been found that interesting discoveries were made at the borders of adjoining territories of science, or as a "pure" science which later found application. For example, spectral analysis started by a physicist who was studying the emission spectrum of metals, was immediately used by chemists as an analytical tool. Polarography, started as a physico-chemical study of the variation of the surface tension of mercury as a function of applied voltage, turned out to become an invaluable method for trace metal analysis.

An invention in one industry may solve a problem in another. When Henry Bessemer in England invented the steel converter in 1856, it took ten years for it to be adapted to the copper industry by metallurgists in France. When Wilhelm Siemens in England invented the regenerative heat transfer system for glass-making furnaces it was immediately adopted by Pierre Martin in France for the steelmaking process that became known later as the Siemens-Martin Process. The rotary kiln, invented by chemical engineers to manufacture cement, was later borrowed by metallurgists to conduct a variety of reactions (oxidation, reduction, etc.). It can therefore be concluded that research on the past of technology will certainly appear as an important component of the technology of the future.

Metallurgy like any other branch of science is a human enterprise, a human activity carried out by human beings. The story of Madame Curie the young Polish immigrant in Paris who worked under the most difficult conditions, dissolving tons of pitchblende residues in nitric acid to extract a few milligrams of a new element whose salts glow at night has been

inspiring to many. The flights of the British chemist Joseph Priestley the French chemist Éleuthère Irénée du Pont de Nemours and in modern times the Luxemburg metallurgist Wilhelm Kroll and many others to the United States show the human aspect of science.

Scientists may be gifted artists. For example, the chemist Alexander Borodin who was professor at the Saint-Petersburg Medico-surgical Institute, was an amateur musician and composer. Who does not admire his 4-act opera Prince Igor or his symphonic poem on the Steppes of Central Asia? The famous German physicist Max Planck played the piano in his free time, while Albert Einstein played the violin. Both played together to relax after a long discussion on quantum theory. The Russian scientist Mikhail Lomonosov wrote poems and made pictures from colored mosaic. He also wrote a book on Russian language grammar. Sir Ronald Ross, the 19th Century British bacteriologist who discovered the cause of malaria, published numerous poems.

Some famous scientists had wonderful and successful lives; others lived under difficult conditions or had tragic ends. The Swedish chemist Jons Jacob Berzelius and the German chemist Justus von Liebig were decorated with the title baron for their achievements. On the other hand, the Austrian physicist Ludwig Boltzmann and the French chemist Nicolas Leblanc took their lives, to mention only a few. The tragic death of Antoine Laurent Lavoisier should be known to every science student. Lavoisier, the distinguished young French chemist, was involved in tax collecting activity which was hated at the time of the French Revolution.

Wealth played an important role in the history of science. A wealthy intelligent young man could afford to have a laboratory and spend his time experimenting without having to be concerned with earning a living. For example, Robert Boyle spent his time on his estate doing fundamental research on the effect of pressure on the volume of gases; this led to the famous law now known by his name. Similarly, the wealthy English physicist and chemist Henry Cavendish devoted his life-time in his castle doing fundamental research on the composition of the atmosphere and that of water and determining the constant of gravitation. In France, during this epoch also, the wealthy scientist René Antoine de Réaumur wrote a six-volume work on insects, devised a thermometer, studied the process of digestion, and wrote a large volume on the manufacture of steel. In modern times many wealthy German scientists had laboratories in universities which they financed themselves for research work. They were engaged as „Privatdozent“ — receiving no salary but only some fees from students who voluntarily attended their lectures.

Some scientists were ridiculed or ignored for their ideas, while others were considered heretics. For example, when the young Dutch chemist Jacobus Henricus van't Hoff published his paper on the arrangement of the carbon atoms in space, which later became a cornerstone of organic chemistry, he was ridiculed by the top chemist of his time Hermann Kolbe. The German chemist Ida Noddack at 29 was ignored when she suggested that the uranium atom might split into two when bombarded with neutrons, an idea physicists could not imagine until Otto Hahn and Fritz Straßmann confirmed it experimentally five years later. For such an important discovery, Hahn received the Nobel Prize. When the famous Italian astronomer Galileo (1564–1642) confirmed that the sun was the center of the universe he was brought to trial before the Inquisition on charges of heresy.

The story of the careless chemist who agitated his mixture by a thermometer, something one should never do, is also instructive. In doing so, the chemist broke the thermometer but was lucky enough to find out that mercury from the thermometer was responsible for greatly accelerating the reaction. On repeating the experiment but using a mechanical agitator, the

reaction did not proceed as expected. A student told this story will always remember the role played by catalysts. On the other hand, the stories of careful chemists are numerous. One of these is that of the German chemist Ludwig Mond who in the late 1880's established a chemical factory in England. One day he observed that a valve made of nickel was attacked by carbon monoxide. On closer examination it was concluded that nickel reacted with CO to form a gas, nickel tetracarbonyl. The ease with which nickel tetracarbonyl decomposed to nickel and CO at high temperature suggested to Mond that this was a possible method for refining nickel. Together with the Austrian chemist Carl Langer they built a plant at Clydach not far from Swansea in Wales to treat a matte from the Sudbury ore. This process is now used on a large scale to refine nickel.

In conclusion it can be said that it is possible to train a metallurgical technologist without giving him a knowledge of the history of metallurgy but it is difficult to educate a creative metallurgist without such knowledge. While history relates past events, one must not lose sight of the fact that in technology, history is made today. While it is nice to incorporate historical facts when teaching an undergraduate metallurgical subject, it is preferable to have an independent course on history.