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November, 2011

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Fathi Habashi

Available at: https://works.bepress.com/fathi_habashi/476/
METALLURGY AND SOCIETY

Fathi Habashi
Laval University, Quebec City, Canada
Fathi.Habashi@arul.ulaval.ca

ABSTRACT

Mineral resources of a country represent an important national wealth. Localization and exploitation of this wealth require knowledge of geology, mining, and metallurgy. The eighteenth century was the century of the Industrial Revolution as well as the Chemical Revolution by Lavoisier. It was also the century of the beginning of mining and metallurgical education when Schools of Mines were created to give instruction for future miners, metallurgists, geologists, and other technicians needed for the industry. Education was for a long time in the hands of the clergy and there was general apathy for introducing engineering disciplines in universities. Military activities especially after the introduction of gunpowder necessitated the distinction between a military and a civil engineer. The education of the civil engineer grew slowly from an apprentice system to a highly specialized academic discipline. Architects became a distinct group from civil engineers in the Middle Ages during the construction of the great cathedrals.

When the steam engine was introduced in the 18th century, mechanical engineers were organized in a separate group. When mechanical engineers drained water from coal mines and the exploitation of these mines started, the profession of mining engineers was created followed by that of the metallurgical engineers who transformed the coal into coke for iron production in blast furnaces, and iron into steel. The processing of coal tar, produced as a by-product of the coke industry, created the profession of the chemical engineer in the nineteenth century. This was later developed further, particularly in North America, when the petroleum industry was founded. At nearly the same epoch electrical engineers became organized to deal effectively with the numerous power stations generating electricity to serve industry as well as other human needs.

INTRODUCTION

The eighteenth century was the century of systematization. In Sweden, Carl Linnaeus (Figure 1) proposed a system for flora and fauna, Axel Fredrik Cronstedt (Figure 2) classified minerals according to their chemical composition, and in France Denis Diderot and Jean d’Alembert (Figure 3) published the Encyclopedia between 1751 and 1777 documenting the technology of his time. Important books dealing with economic problems were also published, e.g., The Wealth of Nations by Adam Smith in 1776 (Figure 4). In this work, Adam Smith argued in favor of free trade, among other things. All this led to the Industrial Revolution which took place in England.

Figure 1 - Carl Linnaeus (1707-1778) and his book *Systema Naturae*

Figure 2 - Axel Fredrik Cronstedt (1722-1765) the first to classify minerals according to their chemical composition

Figure 3 - Denis Diderot (1713–1784) and Jean d’Alembert (1717-1783) compiled the *Encyclopédie* in ten volumes between 1751 and 1777
EIGHTEENTH CENTURY METALS

In the eighteenth century, mineralogists, travellers, and analysts played an important role in the discovery of new metals. Mineral specimens from different localities were continuously supplied to laboratories where they were analyzed. As a result, 14 new metals were discovered in addition to the seven metals of antiquity and the three metalloids of the Middle Ages (Figure 5). These are in order of their discovery: cobalt, platinum, zinc, nickel, manganese, molybdenum, tellurium, tungsten, uranium, zirconium, titanium, yttrium, beryllium, and chromium. None of these new metals, however, played any major role at that time as compared to the ancient metals.

Nonferrous metals

The alchemists had endeavored to manufacture gold by transmutation of base metals. It was not until the end of the eighteenth century that the concept was finally rejected. However, these endeavors led to a better understanding of chemical processes and the birth of the natural sciences. Although the conquistadors found a highly developed mining industry in Central America, their efforts to increase gold production were largely unsuccessful. Most of the finds consisted of silver. It was not until the discovery of deposits in Brazil in 1693 and on the eastern slopes of the Ural Mountains in 1750 that gold

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2 Platinum was already used by the Amerindians in what is now Colombia before being brought to Europe in the eighteenth century. Zinc was known in India in the thirteenth century and in China in the seventeenth century before it became known in Europe in the eighteenth century.
production increased significantly.

Apart from its use for a great variety of vessels and utensils, copper was also used in very large quantity to make brass - - an alloy of copper and zinc much prized for its resemblance to gold. A high proportion of copper sheet was also used for sheathing the bottom of ships. Mercury was needed for the recovery of gold and silver by amalgamation, the only method then available, hence its importance because both metals were needed to mint coins. Tin was used in large quantities for the production of bronze, bell metal, solder, tinplate, tin foil, and in form of tin amalgam to make mirrors. Lead sheet was used for roofing, piping, and for the new lead chambers process for making sulfuric acid, invented in 1741 by John Roebuck in England.

It was profitable to extract silver present in lead and copper ores because of the high value of the metal. Silver in lead was removed by cupellation, while that in copper by first fusing the copper-silver alloy with a large excess of lead at a temperature below the melting point of copper. The lead flowed off carrying with it most of the silver - - a process known as “liquation”. The lead was then removed by cupellation. Silver was removed from low grade ores by amalgamation. Both gold and silver recovered were impure and required refining by melting again with lead followed by cupellation.

Ferrous metals

The reduction of iron ore to produce metallic iron took place in ancient times in a small furnace 2 to 3 meters high, charged with lumps of iron ore mixed with pieces of charcoal prepared from timber. Air required for burning of charcoal to supply the necessary heat for reduction was supplied by small bellows (Figure 6). The ore lumps were reduced to iron but not melted because the air draft was not strong enough to generate the high temperature needed for melting. When the furnace was cooled, the lump of metallic iron mixed with partially melted gangue minerals and slag, was then removed from the furnace, heated and hammered to get a consolidated metallic product known as “wrought iron”. A furnace of this type would produce 1 or 2 kilograms of malleable iron per day, which was enough to supply the need of that time.

Figure 6 - Production of wrought iron in a short charcoal furnace with small air bellows

To increase productivity, larger furnaces were built with larger air bellows mechanically operated by horses (Figure 7) or by large water wheels (Figure 8). As a result, the temperature increased, and the iron produced melted in the furnace. Some iron was tapped directly into moulds in the casting house and the remaining was collected by allowing it to drain into sand moulds (called "pigs") prepared in the immediate vicinity. The product
contained much dissolved carbon and was suitable for casting many items because of its high fluidity. A furnace of this period would be 5 to 10 meters high and would produce 10 or 20 tons of iron per day. The maximum size of the furnace was limited by the mechanical strength of the charcoal.

Figure 7 - Horse gin, a major power source until it was replaced by the steam engine, was the model for the unit of power called horse-power

Figure 8 - Blast furnace bellows powered by a water wheel

To produce a high-quality iron for tools and knives, it was necessary to refine this iron in what was known as a "finery". Small pieces of the iron were re-melted in an oxidizing atmosphere to remove as much as possible of the carbon to produce a malleable product equivalent to wrought iron. Mathias Meysey and William Ellyott in Birmingham invented in 1614 the "cementation process" to make a high-quality product known as "blister steel". In this process bars of wrought iron were embedded in charcoal and sealed in chests which were maintained at red heat for ten days. The iron absorbed carbon, but the steel was more highly carburized near the surface than at the core.
Charcoal

Charcoal, the backbone of the iron and gunpowder industries, was produced in piles (Figure 8). An area of 9-12 m diameter flat surface of the forest floor was cleared on which center a pole about 5.5 m long was erected. Wood then stacked in four layers around the pole to form a cone shaped pile. The pole then removed, wood chips and kindling were placed down the central chimney hole that was formed. The pile was then covered by a layer of leaves and finally a layer of soil. The charring process started by lighting the wood chips and kindling in the chimney from the top of the mound. To allow air into the pile to drive out the moisture and burn the volatile matter without burning the remaining charcoal, holes were poked through the soil layer. The charring process starts from the top down and requires 10-14 days to complete. The soil layer was then slowly raked from the top of the pit to the ground and piled for future use. The remaining charcoal was about one third the original pile of wood. It was allowed to cool then transported to the iron making site.

![Figure 9 - Production of charcoal in piles](image)

Charcoal was later made in brick kilns, either rectangular or conical in shape. These had a manhole on the top for charging the wood, a door at ground level for raking out the finished charcoal, and several holes around the circumference of the kiln to control the air inlet. Operation of kilns was similar to that of the pits. The problem with this technology was, however, that it led to deforestation and gradually increased cost of production. A furnace producing 20 tons /day of pig iron consumed about 200 tons of charcoal which were obtained from 0.8 acres of forest /day, or 292 per year. Once all the local trees were cut down, wood or charcoal would have to be transported from far away, usually by wagons drawn by
horses which meant additional cost.

THE INDUSTRIAL REVOLUTION

The Industrial Revolution started in England in the eighteenth century and took place in two stages: the first when coke replaced charcoal in 1709 and the second when the steam engine became widespread in 1780s. As a result, pig iron was produced in increasing quantities for machinery and constructional purposes. Today, iron production in one year exceeds that of all other metals combined in ten years. It is a huge industry that started from a modest furnace producing 1-2 kilograms metal per day to a gigantic reactor producing 10 000 tons per day.

The use of coke

When coal mining became safe, many unsuccessful attempts were made to replace charcoal by coal until the solution was found by first transforming coal into coke. The industrial revolution started in England in 1709 by Abraham Darby I (1677-1717) of Coalbrookdale near Birmingham (Figure 10) when he substituted charcoal by coke. Coke is produced from coal by baking - it is porous and can withstand high mechanical pressures. Hence larger furnaces could be built which resulted in a further increase in production. Coal cannot be used because it contains appreciable amount of objectionable sulfur impurities and also because it softens during heating and renders the charge impermeable.

![Figure 10- Location map of Coalbrookdale and Forest of Dean](image)

Coal mining was also unsafe because of the natural gas explosions until Humphry Davy (1778-1829) introduced the miner's safety lamp. Further, a great effort was needed to pump out the water flooding the mines. Using coal solved the problem of cutting trees from the forests which were needed to build ships and homes. A view of the Coalbrookdale furnace was painted at night by a contemporary artist shows the flame coming out of the open top of the furnace (Figure 11).
Coke became available at a much lower cost than charcoal, but iron produced using coke was of inferior quality because of the large amount of impurities. Coke was first produced by piling coal in heaps and partially burning it in the open air in the same way charcoal was made (Figure 12). Beehive ovens replaced the open air method in 1763 in which the volatile matter was burned to supply heat for carbonization. The first attempt to recover the volatile matter was in the horizontal retorts system. The gas collected was known as coal-gas and was first used for illumination and later as a fuel. Now large batteries of vertical retorts are used. Volatile matter collected proved to be an important source of chemicals. The distillation of the tar and the separation of its different components became the basis of the organic chemical industry in the nineteenth century. Today, a coke manufacturing plant is a battery of hundreds of vertical retorts assembled together.

**Pig iron**

Pig iron produced in the coke blast furnace contained 3-5% carbon and other impurities which were not present in the iron produced in the charcoal furnace. It was hard and brittle, of inconsistent composition, but cheap and of high fluidity which simplified casting. It was used for making pots and pans, fire grates, some machine parts especially for steam engines, anchors, cannons and cannon balls. This was particularly important in
warfare, because before the arrival of pig iron, cannons were made of bronze or brass which were more expensive. Once the blast furnace technology using coke was established, efforts were made to economize coke consumption and to cope with increased productivity. This took place, however, in the first half of the nineteenth century.

The availability of large deposits of iron ore and coal, and the undesirability of reliance on charcoal for iron smelting, were stimuli for technical development. The production of large amounts of iron made possible the casting of large number of cannons as well as the production of armour plates for battle ships. As well, it permitted the construction in 1779 of the first bridge in the world made of iron across the Severn River near Coalbrookdale (Figure 13). The importance of this bridge lies in the fact that although iron had been used for thousands of years it had not been a major construction material because there was not enough of it. Outside Britain the adoption of coke furnaces proceeded very slowly.

[Figure 13 –First bridge made of iron across the Severn River near Coalbrookdale]

Cast iron

To obtain an iron of better quality that can be cast into shapes of thin thickness, a small shaft furnace known as “cupola” (Figure 14) was invented in 1795 by William Wilkinson. By melting pig iron in the cupola and blending it with other material, he was able to produce “cast iron” of exact composition and of equal quality to the cast iron produced from a charcoal furnace. Consequently, England produced high quality cannons for the navy and this was one of the basis on which the British Empire was founded.
Steel

Pig iron produced from the blast furnace can be readily cast. However, because of the presence of a large amount of carbon and a number of other impurities it is brittle and hence cannot be forged to shape. To render it malleable, the carbon content was lowered by melting the pigs in a “fining” furnace to oxidize the carbon and produce wrought iron containing less than 1% carbon. It was used for the production of nails, small arms, agricultural implements, horseshoes, wire, locks, and bolts. Bars of wrought iron were also transformed into blister steel by the cementation process (Figures 15-17). An improved steel was produced in Sheffield by Benjamin Huntsman (1704-1776) in 1740 by re-melting bars of blister steel in closed crucibles to produce a “cast steel” of uniform carbon content and much better quality.
Henry Cort (1740-1800) in 1784 invented the "puddling process" in which by a careful control of air and time of heating in the puddling furnace, it was possible to transform directly pig iron into cast steel (Figure 18). The aim of this process was to retain a sufficient carbon content in the product to render it hard but not brittle. The correct conditions for this were determined by experience since the role of carbon in steel was not yet known. The process was tedious and expensive; it took 3 to 4 days at high temperature to produce a few hundred kilograms of the product, but this was the price to pay for a high quality steel. But
steel produced by the puddling process was an expensive alloy. It was used for making special tools, knives, springs, etc., but was not a material of construction. Many puddling furnaces were constructed, the process was mechanized, and the material became widely used.

Figure 18 - Puddling furnace

Figure 19 – Working in a puddling furnace

Figure 20 – Removing steel from a puddling furnace
The influence of carbon content of steel upon hardness was not realized before 1750. The first to analyze carbon in iron was the Swedish chemist Torbern Bergman (1735-1784) (Figure 21).

![Figure 21 – Torbern Bergman](image)

**The steam engine**

The steam engine came at a time when wood was the main fuel for industry and household. Wood was also needed for the building industry and for shipbuilding. The steam engine required a huge demand for fuel which could not be satisfied by the shrinking forests. As a result, attention was directed towards the exploitation of coal. Once the safety lamp was invented and coal mining became relatively safe, the industry started to shift from wood burning to coal burning economy. The steam engine was responsible for solving the problems in the iron industry. The growth of the industry suffered from the following:

- Water power was neither abundant nor reliable. Power was needed for operating the pumps to drain water from coal mines, the bellows to blow air in the blast furnace, the hammers for forging, and the rolling mills.
- The use of coke necessitated a more powerful blast than that obtained from water-driven bellows because of its higher ignition temperature.
- A cheap way to transport coal in bulk to the coke making plant which is located near the blast furnace.

The steam engine was invented to fulfill these needs. The idea of using steam for doing work goes back to 1695 when Denis Papin (1647-1712) (Figure 22), a French Huguenot who found refuge in England in 1675, demonstrated this principle in a simple model.
Newcomen's machine invented in 1712 was the first attempt to solve the problems associated with this idea Figure 23. But it used large amounts of coal to boil water to generate steam which was then condensed by cold water spray to create the vacuum needed to operate the machine.

![Figure 22 - Denis Papin (1647-1712)]()

It was James Watt (Figure 24) who in 1770's successfully built a machine that economized greatly on the coal needed, by introducing a separate condensing chamber for the steam so that the cylinder could remain hot throughout every stroke. However, it was not until 1784 that the steam engine became a reality and started to replace the water wheel. The bellows were no longer needed and air could be blown in the furnace through tuyeres (Figure 25).
The steam engine made possible the utilization of ample power. This had tremendous impact on industry and commerce, and was responsible also for the second stage of the Industrial Revolution which can be summarized, as follows:

- Work once performed by hand could now be done on machines powered by steam engines.
• The manufacturers were freed from depending on the water wheel or the windmill for their source of energy.
• Large cotton mills were established in Lancashire where cotton was imported from the colonies and the textile products were exported back to them.
• Steam ships replaced sailing boats which meant faster transportation at sea (Figures 26-27).

Figure 26 – Sailing boat

Figure 27 – Steam ship

• A system of canals was created in England for the cheap transportation of coal by water. This was later replaced by trains moved by steam locomotives. Trains also replaced horse-driven wagons which meant faster transportation on land.
• The food industry greatly benefitted from the steam engine. Improved technique for rolling wrought iron plates favorably affected the manufacture of tin plate for food containers and utensils needed for the navy.
George Stephenson (1781-1848) (Figure 28) in 1820’s solved the problem of coal transportation by inventing the steam locomotive (Figure 29).

The British machine economy incited many foreigners to visit Britain for the purpose of studying the new technology. One of these was the French government official Gabriel Jars (1732-1769) who visited England in 1764-65 and wrote his observations in his book *Voyages Metallurgiques* published in 1774, five years after his early death.

**Further development**

The Industrial Revolution continued further in England when steel was produced in greater amounts, faster, and much cheaper in the nineteenth century when Henry Bessemer (Figure 30) invented the convertor in 1856 (Figure 31). The tedious and expensive "puddling process" could now be replaced by a fast process that did not use a fuel - - heat required to keep the metal molten was generated by the oxidation of the impurities themselves present
in the iron (Figure 31). Tons of pig iron could be transformed in less than half an hour by simply blowing air through the molten metal. The product became known as “mild steel”.

![Figure 30 – Henry Bessemer](image)

![Figure 31 - Bessemer Convertor](image)

![Figure 32 – Bessemer process](image)

Few years later, in 1863, Wilhelm Siemens in England and Pierre Martin in France developed the open hearth furnace that became known as Siemens–Martin process where large tonnage of steel could be produced.

This made England the master of the world (Figure 33). She was at least fifty years in advance to other European powers in iron and steel making. As a consequence of the Industrial Revolution there was an over supply of products and a need for markets as well as for raw materials. Colonization was the solution to this problem. In addition to steelmaking, Britain was the center for copper, zinc, tin, and platinum metals production. Copper matte was shipped from as far away countries as Chile and Montana to be refined in Swansea in Wales. Nehemiah Champion in Bristol was the first in Europe to produce metallic zinc from calamine and zinc blend in 1702. Bristol was also a center for brass
manufacture while Cornwall was a center for the production of tin. Innovation in spinning and weaving also took place in England as part of the Industrial Revolution. England was also a refuge to intellectuals. Karl Marx and Friedrich Engels published the Communist Manifesto in London in 1848. But the Industrial Revolution had its dark side as well. Many workers lost their jobs and the working conditions in many operations were intolerable.

![Figure 33 – The British Empire](image)

**The transition from wood to coal economy**

When wood was used as the basic fuel, as charcoal in blast furnaces, as a major component in gunpowder, and as a basic material for ship building, there was also a chemical industry based on wood by-products. Wood was the source of tar, pitch, and resin needed as a preservative, particularly for timber for ship building. Potash was recovered by leaching the wood ash with water and was used for making soap and glass. Turpentine was used as a solvent and for making lamp black for inks. Acetic acid was also obtained as a by-product of wood distillation in form of calcium acetate from which acetone was made by dry distillation. All these were widely used material.

When coal replaced wood, other industries came into existence, especially when the volatile matter was collected during the carbonization process. Coal gas in the earlier years of the industry was used almost entirely as an illuminant. Later gases became a source of ammonia, elemental sulfur (from H₂S), and gaseous fuel. The coal tar was distilled to produce a variety of organic compounds like benzene, toluene, phenol, naphthalene, anthracene, etc., as well as pitch. This became the basis of the organic industry for manufacturing dyestuffs, explosives, pharmaceuticals, etc.

Gunpowder made from charcoal, sulfur, and saltpeter remained as the only explosive available during the 18th century. It was gradually replaced by nitrocellulose and nitroglycerine and other compounds only at the end of the nineteenth century.
THE CHEMICAL REVOLUTION

Whether wood or coal were used as a fuel, the nature of the flame generated remained a mystery for centuries. A theory was put forward by the German alchemist Georg Ernst Stahl (1660-1734) in 1723 to explain combustion. It was called the “phlogiston theory” from Greek meaning flame. According to this theory everything that can be burned contains a “phlogiston” which escapes in the form of flame during combustion. Phlogiston could be transferred from one body to another, and resorted to the metallic claxes by heating with substances containing phlogiston like charcoal, coal, and oil, when the metal was produced

$$\text{Metal} \rightarrow \text{Calx + Phlogiston}$$

When bodies burn or are calcined, phlogiston escapes and, when the original bodies are recovered by reduction, phlogiston must be replaced. Oil, wax, charcoal, and sulfur, which are all combustible bodies, are rich in phlogiston, and may be used to restore it to a burnt material from which it has escaped. For example, on heating zinc to redness it burns with a brilliant flame, hence phlogiston escapes. The white residue is calx of zinc. If it is heated to redness with charcoal (rich in phlogiston), zinc distills off. Hence

$$\text{Calx of zinc + Phlogiston} \rightarrow \text{Zinc}$$

Similarly, with other metals. If phosphorus is burned, it produces an acid material, and much heat and light are evolved. Hence, phosphorus = acid + phlogiston. If the acid is heated with charcoal, phlogiston is absorbed and phosphorus is reproduced. Of importance to metallurgy is the understanding of the smelting process. It was believed that when an ore was heated with charcoal or coal it takes up the escaping phlogiston in the fire to form the metal, that is

$$\text{Ore (oxide) + Phlogiston (from coal)} \rightarrow \text{Metal}$$

It was the French chemist Antoine Laurent Lavoisier (Figure 34) who in 1772 finally directed the fatal blow to the theory, when a few years earlier oxygen was discovered, and he interpreted the phenomenon of combustion as an oxidation process. This opened the way for the reform in chemistry and its application in processes for metal extraction.

![Figure 34 - Antoine Laurent Lavoisier (1743-1794)](image)
SCHOOLS OF MINES

The first Schools of Mines were established at the beginning of the eighteenth century, usually in mining districts, as private vocational schools (Figure 35). Mining Councils appointed by the rulers played an important role in recommending subsidizing such schools and founding new ones supported by the state. As time went by, these schools were elevated to Mining Academies. The sciences of forestry and salines are closely related to the mining and metallurgical industries and formed part of the curricula in some Schools of Mines. Forests supplied wood for the mines and fuel for smelters while salines supplied salt for the chemical industry.

Figure 35 – The first Schools of Mines in Europe

Some of these schools started by private individuals, others were created by the ruler or by the State. Gradually, there became the need to have qualified administrators for the mines and smelters, and for teachers for these schools. As a result, some schools were elevated to academies or became later technical universities, some were closed due to exhaustion of the mines or other reasons, some were moved to other developing regions, while others remained as vocational mining schools.

Methods of analysis for precious metals were well established in what was known as “fire assaying”. One of the basic courses taught at the first Schools of Mines was “Metallurgical Chemistry”. Fire assaying, the predecessor of analytical chemistry, was a major component of this course. It dealt with the determination of precious metals in ores, the use of fluxes, and the formation of slags. It included furnaces, combustion,
balances, and numerous chemical manipulations. Students had laboratory training in this discipline. These laboratories were the first chemical laboratories known and were copied by French chemists in their schools. This concept was developed further in Germany by Justus von Liebig who studied in France in one of these laboratories. Fire assaying was also the cornerstone in mints to control the quantity of precious metals in coins. Important literature dating from the Middle Ages is available on this subject.

With increased knowledge in metallurgy and chemistry at the end of the eighteenth century, it became necessary to split “metallurgical chemistry” course into two: chemistry and metallurgy. This took place for the first time in Freiberg in 1795. Amalgamation process dominated the 18th century metallurgy. Mercury at that time had the importance of petroleum today, because of its use in extracting gold and silver from ores needed for minting coins and itself for making mirrors. The toxicity of mercury and other metals, e.g., arsenic and lead were known and many metallurgists alerted those responsible for exploiting the mines to their danger. The teaching staff at the Schools of Mines contributed greatly to the advancement of mining, geology, chemistry, and metallurgy.

EPILOGUE

The 18th century was the century of the Industrial Revolution in England and the Chemical Revolution in France. It was also the century of the beginning of mining and metallurgical education when the first Schools of Mines were created to give instruction for future miners, metallurgists, geologists, and other technicians needed for the industry. The Industrial Revolution was responsible for the shift from wood burning to coal burning economy, for the replacement of coal by coke in the blast furnace, and for the tremendous increase in iron production - - thanks to the invention of the steam engine. It also marks he beginning of capitalism. The Chemical Revolution explained the process of combustion and smelting and reformed the chemical science. The professors at the Schools of Mines created a voluminous literature on geology, mining, and metallurgy which was a valuable guide for generations to come.

Ferrous metallurgists have been leaders in all sectors of the metallurgical industry. For example, the copper industry adopted many technologies used first in iron and steel production. Thus, when Bessemer invented the converter in 1856 it was adopted in the copper industry ten years later, and when high grade massive copper sulfide ores were exhausted and metallurgists were obliged to treat low-grade ores, the puddling furnace was adapted in form of a reverberatory furnace to treat the flotation concentrates. Continuous casting started first in steel plants and was adopted later in the nonferrous industry. In general, the copper industry was in the footsteps of the iron industry although the two chemistries are far apart. It is also remarkable that the pioneers of the Industrial Revolution in England did not have any academic training and the first school of mines in England was founded in 1851, nearly a century after similar schools on the continent.

The beginning of capitalism was a direct result of the Industrial Revolution which took place in England and was based on coal and iron. Iron continued to be the core of industry, but once petroleum was discovered in North America, the center of gravity of imperialism shifted from Britain to USA. The shift became complete after World War II and the New Industrial Revolution became based on petroleum and aluminum. Changes come and progress cannot be stopped, but in the change, many suffer whose old skills and occupation
are gone.

SUGGESTED READINGS

