MINERALS AND MATERIALS IN THE 20TH CENTURY—A REVIEW

By David E. Morse and Anna N. Glover

The period from 1900 to 2000 was marked by significant changes in the various industries that consume metals and industrial minerals and by major historic events that affected the way minerals are produced and used. This chapter is an overview of some of those changes. The pivotal changes to production and consumption of individual commodities are covered in the annual mineral commodity reviews in this 2000 edition of the U.S. Geological Survey's Minerals Yearbook.

The industrial revolution, which began in the late 1700s, continued through the 20th century, with the pace of technologic discovery and advancement increasing continually. The steam engine that had merely augmented wind, water, and muscle power before the advent of the 20th century gave way to diesel- and gasoline-fueled engines, which for the most part replaced older forms of energy used. The emergence of electric power and its widespread use caused an upsurge in technology that required less manpower and man-hours to complete the same tasks as were previously being done manually. The creation of the computer chip and the subsequent discoveries brought about more inventions the implementation of which facilitated the efficiency of a multitude of applications.

During the century, the Government increased its involvement in consumer protection and legislated various fields in response to activist movements. Legislation enacted by Congress through the century included civil rights, consumer protection, retirement plans, environmental protection, food and drugs, health care, labor/management relations, law enforcement, occupational safety, and social justice, as well as the New Deal, which was created to help the country's economy to grow after the Great Depression.

Experimentation and invention throughout the century in metallurgy, metals production technology, and metals forming and shaping resulted in the ability to produce metals of high purity, some alloys of high strength, others with corrosion resistance, and some with resistance to abrasion and erosion in chemically aggressive and high temperature regimes. Lightweight, low-density metals, such as aluminum and titanium, became important. Furnaces changed, refractories improved, continuous operations replaced batch processes, and electrochemical and hydrochemical processes augmented or replaced pyrometallurgical processes. In steelmaking, the basic oxygen and electric arc furnaces replaced the Bessemer and open-hearth furnaces. Glassmaking technology improvements resulted in tougher, stronger, and more brilliant glasses, and low thermal expansion borosilicate glass had improved shatter resistance. Chemical industry innovations improved mineral acid production; the lead chamber batch process for making sulfuric acid was replaced by the high-volume contact process with associated electric cogeneration plants. Lead oxide and barium/zinc-base lithopone white pigments were replaced by titanium dioxide, which improved whiteness and reduced the health hazard from heavy metal ingestion.

Systems to handle bulk materials improved greatly during the century. Salt and cement, which were routinely shipped in barrels in the early 1900s, were transferred at high rates on conveyor belts and pneumatic pipelines to covered hopper bottom dump railcars, which could haul 90 metric tons (t), and to over-the-road trailers that could move 20 to 30 t. Bulk handling facilities at ports had stacker/reclaimer systems that could move thousands of tons an hour. Open hopper railcars had specially designed couplers that allowed them to be emptied in rotary dumpers without uncoupling; belt and silo systems were used to fill unit trains, which were in continuous motion. Ocean-going bulk carriers capable of hauling hundreds of thousands of tons were in service, most with self-unloaders. Sulfur was shipped molten in special railcars and on uniquely designed barges and ships; bromine was transported in specially designed returnable containers and in unique trucks; one-half ton and one ton bags were in use. Machine power replaced the muscle power that was prevalent at the beginning of the century.

Over the span of the 20th century, the demand for metals and minerals in the United States grew from a little over 160 million tons to about 3.3 billion tons; the ratio of renewable to nonrenewable materials used declined from 40:60 to about 10:90 during the century. Nonfuel minerals accounted for nearly the entire nonrenewable materials demand in 1900, and nonrenewable organic materials accounted for only about 2 million tons. In 2000, consumption of nonrenewable organic materials was equal to the approximately 135 million metric tons of all metals consumed during that year in the United States. However, a significant percentage of nonrenewable organics was attributed to inorganic fillers, extenders, and pigments, which are industrial minerals.

Sectors of the Economy

Agriculture

The 20th century brought developments in the tools used in agricultural processes and in the seed and feed used in the various sectors of agriculture. New machinery, including the gasoline tractor, the grain combine harvester, and the mechanical cotton picker, shifted the emphasis from manpower and horsepower to the faster, more efficient machinery. The development and widespread use of pesticides and fertilizer produced more and better crops, while the creation and increasing use of engineered crops produced better livestock and enhanced agricultural production.

Between 1900 and the end of World War I, the demand for

farm commodities was increasing. The postwar depression, however, severely affected farmers, until technology advancements that started in the 1930s aided in increasing the amount of land used for agricultural purposes. Although the Federal Government tried to help farmers with credit and cooperative management assistance, it was not until the creation of price supports, export subsidies, and soil conservation efforts in 1933 that agriculture received the help it needed. With the implementation of new technologies, the amount of land covered by farms in 1930 reached about 400 million hectares and remained at that level through 1980, and production during the same time period increased dramatically.

Communications

Of the discoveries of the 20th century, the radio, the television, and the telephone have been among the most important. Commercial radio broadcasting was established in 1920, and commercial television broadcasting, after World War II. By 1933, about two-thirds of American households had at least one radio, and about one-third had a telephone. By 1988, 97% of American households had at least one television set. Communications devices have had a profound impact on the culture, economy, lifestyle, and politics of the country. People have been able to watch events as they unfold, keep track of economic trends, and communicate with people half a world away. Media, politics, and entertainment have all benefitted from the advancements in the field of communications, as have emergency services, the economy, and many aspects of cultural life. The gap that time differences and distances had once created were being bridged by the end of the 20th century, bringing people, countries, and businesses closer together.

The metals and minerals industries have found a growing market in the various industries involved in communications, which purchase materials ranging from the metals required for cables and devices to nickel and lithium for batteries to germanium and silicon for semiconductors.

Construction

The 20th century saw the emergence of tall buildings, hydroelectric dams, high bridges, and highways that span the length and breadth of the country. Buildings of great height could be constructed because of steel-frame building techniques and the electric elevator. Skyscrapers, such as the World Trade Center and the Empire State Building in New York City and the Sears Tower in Chicago, which consumed large quantities of cement, ceramic tiles and sanitary ware, copper, glass, and steel, were almost exclusively a feature of the cities of North America for a good part of the 20th century. Late in the century, building of skyscrapers boomed in Asia.

Water power and associated dams, canals, and locks have been used for centuries; dams were used for flood control by maintaining water levels at navigable depths, to store water for drinking and irrigation, and to provide power. The widespread expansion of electric power grids and the constant increase in demand for electricity in the United States and worldwide prompted the construction of dams of unprecedented size during the 20th century.

Suspension bridges are impressive structures that transverse almost unbelievable distances. Although the first suspension bridges were built in the late 1800s, the highest and longest suspension bridges were built in the 20th century.

Another development of the 20th century was the increase in home ownership. Whereas in 1900, less than one-half of the U.S. population owned their own house, about two-thirds owned their house in 1990. Construction techniques and materials have changed drastically in the past 100 years to adapt to consumer, regulatory, and safety requirements and changing lifestyles, as well as those based on new technologies and materials.

Mining and Metal Processing

The technologic advancements that have been incorporated into consumer applications to make everyday living easier also have assisted industry to become more efficient, to produce more with fewer resources.

The mining and metal processing industries were among the first to take advantage of electricity, which was used to power trams and trains, underground and in-pit crushers, and conveyor systems that, combined with employing diesel- and diesel/electric-haulage vehicles, replaced the draft animals. By the end of the 20th century, the mining industry used machines of great size and power that operated at astounding rates and could mine continuously in underground mines and in surface operations. Additionally, innovative materials, such as synthetic greases and lubricants and metal alloys, were employed in critical wear areas to enhance their reliability. The various technologic advancements in mining and related technologies that took place during the century increased the quantity of material produced per employee.

Also during the 20th century, legislation to protect the health and safety of employees and regulations to protect the environment and the mining industry were promulgated. Mining and metal processing waste was regulated in an effort to protect the environment, and laws were enacted that would help miners who were injured on the job or who got sick because of their working conditions.

Innovation was not restricted to mining machinery and mining practices but also to ore processing and mineral separation. Mineral processing can have one or more of several goals depending on the nature of the ore and the desired end product. Early in the century, simple crushing, screening, and washing operations were augmented by such improvements as log washing, jigging, heavy media separation, and tabling that separated mineral species based on density. Later, froth flotation of finely crushed materials produced concentrates from low-grade ore; in-situ solution mining, solvent extraction, and heap leaching proved to be cost-effective ways of producing uranium, copper, and gold, respectively; and the unique Frasch method of underground melting of sulfur was practiced for most of the century. By combining processes, mining companies were able to produce multiple products from a single ore, which meant that they could mine ore bodies that would have been avoided early in the century owing to their leanness and could thus make a profit from the leaner ores.

Consumer Goods

There has been much technologic advancement since the early 19th century. Few fields have benefited more than the one that consists of applications used by consumers everyday. Such appliances as stoves, microwave ovens, refrigerators, and washing machines have made completing everyday tasks easier, and such applications of technology as televisions, telephones, computers, and compact disk (CD) players have provided a greater degree of comfort and entertainment than has been possible for more people than ever before. Some of these same devices have also facilitated the creation and operation of small businesses and self-employment, increasing the Nation's standard of living and helping the country's economy grow.

Health Services

The field of medicine and drugs has changed significantly over the past century. Where only a few drugs were used extensively and medical science was still in its early stages of evolution before 1900, the rate of advances grew drastically during the century and especially after World War II with such advances as genetic mapping, immunosuppressive drugs, magnetic resonance and x-ray imaging, and medical transplantation. One of the contributions of genetic mapping is the production of genetically engineered bacteria designed to break down oil slicks and industrial waste products.

Military

The 20th century was a time of great invention of military and defense applications. The airplane was used in World War I as a military machine for the first time and was enhanced during most of the century. The jet engine made the airplane one of the most widely used forms of commercial transportation, and developments such as breaking the sound barriers and the ability to take off and land vertically have made the airplane valuable to the defense of the Nation.

Other applications that were created by or for the military have found widespread use in consumer applications. One of the biggest developments of the late 20th century, the Internet, was initially developed as a network for the Department of Defense. The laser, which is used in such applications as CD and digital video disk (DVD) players, was created for military applications.

Transportation

At the beginning of the 20th century, the U.S. railroad system connected every major city, town, and hamlet in the Nation. Thousands of trains daily came and went from major cities. Electric streetcars serviced cities, and subways were set up in such cities as Boston and New York. Horses, carriages, mules, and wagons traversed cobble stone streets in the cities and dirt and gravel roads in rural areas. Steam-powered ferries plied the Nation's rivers, bays, inlets, and sounds. The railroads were major consumers of iron and steel for locomotives, rails, and bridges and of aggregates for roadbeds. Trolleys and subways were also consumers of iron and steel, and used copper for motors, switches, and lighting.

The adaptation of the combustion-ignition engine to the carriage led to a significant change in America by the 1920s. From a few "horseless carriages" in 1900 to millions of motorcars in the 1920s, the effects were astounding. Gone were the millions of draft animals, the stables and feed stores, and the mountains of dung. The almost universal adoption of the motorcar resulted in a cry for better roads and bridges, which had a positive effect on the construction industry, which was a major consumer of copper, cement, glass, sand and gravel, steel, and stone. The automobile industry became a major consumer of copper, glass, iron and steel, lead, and zinc. The effect of the automobile was not restricted to draft animals; ferries and railroads keenly felt it. Bridges of unprecedented size replaced ferries at many crossings; passenger rail service became unprofitable by 1930. Diesel-electric traction engines began replacing steam locomotives in the 1930s, and the transition was essentially complete by the early 1950s. By 1940, the Nation had over 3 million miles (about 5 million kilometers) of roads, of which only about one-half were paved.

After World War II, passenger air service greatly expanded, while buses and trucks proved more efficient than rail for service to smaller cities and to towns. Jet engine air passenger service, which was established in the late 1950s, had an additional adverse effect on long distance rail passenger service by shortening the time required for a journey.

The oil embargo of 1973 and adherence to government regulations on emissions and fleet gas mileage altered the automobile such that lighter weight metals and plastics were used to replace iron and steel where possible. Photochemical smog from engine exhaust was a problem in many areas. The automobile was partly responsible for urban sprawl late in the century. The population increase in the last half of the century, which led to urban sprawl and expansion of the suburbs, resulted in a great expansion of water and sewer, electric, telephone, and other public utilities systems, more and bigger roads, larger homes, more schools, more shopping centers, increased emergency services and law enforcement, more hospitals, and larger airports. The expansion placed high demands on the products of the minerals industry.

In 1900, one could cross the continent by rail in about a week; by 2000, one could go the same distance by air in under 8 hours. An ocean voyage to Europe was also about a week's journey; it was only a 10-hour trip by air in 2000. Much rail and most ocean vessel passenger service had been replaced by air service by the end of the 20th century. The movement of goods, however, remained the domain of trains, barges, and ocean vessels. Intermodal containers that could be transferred from rail to ship to truck without unloading were developed to enhance efficiency.

Environmental Considerations

Over the course of the century, the attitude that the Earth was nothing more than resources to be used changed slowly, and by the 1960s, the concept of mankind being stewards of the Earth started becoming more prevalent. In response to growing public demand for a cleaner environment, the government established standards to protect public health and to limit damage to

animals, crops, vegetation, and buildings. Some of the early results were a sharp decline in atmospheric lead and sulfur dioxide (SO_2) emissions.

Control of SO_2 emissions, which help reduce acid rain, affected different parts of the nonfuel minerals industry in opposing directions; recovery of SO_2 at smelters as sulfuric acid was costly and resulted in a byproduct that was not always readily salable. Although recovery of SO_2 at powerplants is also costly, it increased demand for sorbents, primarily lime and limestone, and the building materials needed to construct flue gas desulfurization facilities. The sulfur content of liquid fuels also was regulated and reduced SO_2 emissions from automobiles, trucks, and airplanes.

Since the late 1960s, recycling also became important and contributed to resource conservation, which became another issue of great concern for activists. Recycling is especially important because it removes material from the waste stream so disposal is not needed and it supplies raw materials that can go into new products usually at substantial energy savings compared with products made from virgin materials.

Conclusion

Patterns of consumption per capita of metals and minerals for developed economies have been stable in the latter part of the 20th century, and while there were lower rates of consumption in many developing countries, a number of developing countries had growing consumption per capita. The growth of metals and minerals consumption in developing countries could have a great impact on world mineral consumption.

In the future, satisfying the relatively modest per capita material requirements of these developing countries could strain industrial and financial systems and—potentially—environmental quality. Fostering sustainable development to meet such needs could be key to world peace and stability and could represent one of the major challenges for the physical and social sciences communities and the developed world for the next century.