Chapter 4

Patent wars and vertical integration

Before the Pittsburgh Reduction Co., which became the Aluminum Company of America in 1907, could take full advantage of Charles Martin Hall's discovery, it had to clear a hurdle of patent cases. In the end, the company lost in court but closed a financial settlement that ensured Alcoa a virtual monopoly on aluminum production in the U.S. until the end of World War II.

The Pittsburgh Reduction Co.'s patent problems could be traced back to Feb. 23, 1883, when Charles Schenck Bradley applied for a U.S. patent for an aluminum reduction process. The patent involved using electrical current both to fuse, or melt, the materials by electrical-resistance heating and for electrolysis of the dissolved ore. After several tries, the patent was granted on Feb. 2, 1892, as U.S. patent No. 468,148. Bradley's method dispensed with the need for a crucible and simply used a heap of ore. As the ore fused inside, the outer crusts of the heap served as a container. This avoided the problem of the steel or iron walls of a crucible being destroyed in the reduction process. Bradley was following on the heels of numerous attempts around the world to utilize electrical current to produce metals from nonconducting ores. The compounds of aluminum, for example, were nonconducting at room temperature. If nonconducting ores were fused by external heat, provided by coal or natural gas, an electrical current could be passed through the molten material. The significance Bradley's idea lay in using electrical current to both heat the material for fusing and for electrolysis – a key component to the modern reduction process. The Bradley patent was not confined to cryolite or alumina but related to all ores of aluminum and to refractory ores of a similar nature. [1]

Bradley assigned his patents to his agent, Grosvenor P. Lowrey, who intended to use Paul Heroult's aluminum alloy process at an experimental aluminum plant in Boonton, N.J., operating under the name U.S. Aluminum Metals Co. The plant carried on some experiments but never operated commercially. [2] But Bradley's ideas were already being used by the Cowles Electric Smelting & Aluminum Co., which learned about a possible patent interference from the U.S. Patent Office in the spring of 1885. Bradley's initial patent application, No. 85,957, had lain dormant for more than two years. The Cowles brothers immediately contacted Bradley and his attorney and arranged to pay $5,000 for all of Bradley's inventions that were in conflict with those owned by the Cowles brothers. The ownership of these patent rights by the Cowles was established in court by Judge Henry Severens on Feb. 15, 1897. [3] Bradley sold other patents to the Cowles in

1885, and the Cowles laid claim to the new patents as well under the old contract. The dispute went to federal court where Judge William Howard Taft, who later became the 27th president of the United States and 10th Chief Justice of the U.S. Supreme Court, ruled in favor of Lowrey over Cowles in the Circuit Court of the Northern District of Ohio. The case was appealed, and Cowles won on Feb. 15, 1897. [4]

Pure aluminum patent process

In January 1891, the Cowles Electric Smelting Co. began to produce pure aluminum metal at their Lockport, N.Y., plant using a method similar to that used by the Pittsburgh Reduction Co. Cowles advertised the aluminum at a lower price than Pittsburgh Reduction Co.'s and based their claim to the process through a furnace technology patent they had obtained in 1885. [5] On Nov. 14, 1888, The American Engineer reported that the Cowles Electric Smelting and Aluminum Co. had published a 70-page pamphlet describing the properties and uses of some of the alloys of aluminum and silicon that the company produced. "The uses to which these bronzes are applied and their strength adaptability and durability are presented as information which should be appreciated by all interested in the use of such materials," the journal reported. [6] Pure aluminum prices had fallen ever since the Pittsburgh Reduction Co. went into production, and by 1890 Cowles felt threatened since it was a producer of only aluminum alloys. At the same time, the Pittsburgh Reduction Co. was infringing on the Bradley patent right for internal heating by electrical resistance, which had been acquired by Cowles. [7]

After Cowles unsuccessfully attempted to merge the two patent rights during negotiations with George Clapp at the Pittsburgh Reduction Co., Cowles hired away one of the Pittsburgh Reduction Co.'s furnace operators, a man named John Hobbs who had previously worked for Cowles in Lockport. Sometime in early 1891, Arthur Vining Davis found a way to get onto the island where Cowles's plant was located and spied on their equipment. He felt sure their reduction process was identical to the Hall electrolytic process. [8] Using the process patented by Charles Martin Hall, the Pittsburgh Reduction Co. sold pure aluminum for $1.50 per pound, but Cowles offered the metal for as little as $1. Within two months, the Pittsburgh Reduction Co. sued for infringement of the Hall patents, seeking a preliminary injunction. U.S. Judge Augustus J. Ricks, of Ohio, denied a complete injunction but restrained Cowles from increasing the output of their plant during the trial of the suit, or from selling aluminum below a price to be set by the Pittsburgh Reduction Co. The complainant named $1.50 per pound, which fixed the market price for several months while metallurgical experts were hired by both parties and voluminous testimony was taken. In the meantime, European producers began to offer aluminum for as low as 56 cents per pound, and imported aluminum appeared in the US market. Pittsburgh Reduction Co. notified the court that for the duration of the trial, it would sell aluminum for 50 cents per pound, which was close to the actual cost of production. [9]

On Jan. 29, 1893, Judge Taft ruled in favor of Hall for the Pittsburgh Reduction Co. and ordered Cowles to pay $292,000 in damages. Cowles was able to delay payment and won the right to reopen the case using the argument that the Pittsburgh Reduction Co. infringed on Bradley's patent right, which they had acquired. [10] In his ruling, Judge Taft said Hobbs had provided the Cowles brothers with important information about improvements in the smelting process that had been discovered by the Pittsburgh Reduction Co. since it began operating – particularly the idea of abandoning the use of external heat. The initial industrial application of Hall's laboratory discovery called for a steel or iron crucible lined with carbon to be heated in a furnace and then filled with cryolite, which melted. Over time, Hall and his crew discovered that the electrical current running through the crucible provided sufficient heat to keep the bath and aluminum molten, eliminating the need for an external heat source. This also addressed the problem of how thick the crucible's carbon lining needed to be. If it was too thin, the fluoride in the bath would attack the steel walls of the crucible; if it was too thick, the external heat couldn't penetrate efficiently. Judge Taft ruled that the use of electrical-resistance heating was an improvement to the Hall process and did not constitute a new discovery altogether. The court ruled in favor of the Pittsburgh Reduction Co. and assigned the case to a master to ascertain damages. [11] It was determined that Cowles owed the Pittsburgh Reduction Co. $195,000 in damages. [12]

Having lost their initial patent defense, Cowles filed a new suit against the Pittsburgh Reduction Co. in 1897. The basis of Cowles' new claim was that both the electrical fusion of the cryolite bath and the electrolysis of the dissolved alumina were necessary to the process, and that Hall's patent in fact described an external source of heat. Hall's lawyers defended his patent right by noting that electrical fusion experiments could be dated back to Sir Humphry Davy. Cowles also argued that Bradley had never pursued his discovery, that he worked on the discovery for only two or three days and never realized its commercial potential. The ruling went again in favor of the Pittsburgh Reduction Co. as the court narrowly interpreted Bradley's discovery. [13] On Oct. 22, 1901, Judge John R. Hazel ruled that, assuming the Bradley patents were valid, the Hall reduction process did not infringe upon them. Hazel believed that Bradley's patent had never been put into practical application and had enough technical faults to make it no more than a "paper patent." Cowles appealed Hazel's ruling. [14]

On appeal, Judge Alfred Coxe ruled in favor of Cowles in October 1903. To some looking back at the case, the ruling was not fair – the use of internal electrical heating in Hall's electrolytic process was "inevitable and inextricable" when the process was applied to a large industrial scale. Hall had never realized the importance of internal heating when he was experimenting with small laboratory equipment or with the small pots the Pittsburgh Reduction Co. used in its early years. The Bradley patent claim was upheld, and the Pittsburgh Reduction Co. was ordered to pay Cowles $3 million in damages. [15] But during the intervening 10 years prior to this decision, an injunction issued against Cowles had prevented the company from producing pure aluminum, and Cowles had fallen onto hard times fighting its case against the Pittsburgh Reduction Co. [16]

The patent settlement

The judgment created immediate turmoil, as the Pittsburgh Reduction Co. stopped all capital expansion plans and both sides tried to figure out how to stay in the aluminum business without infringing upon each other’s patents. Within a matter of days, the two companies reached an accord under the following conditions: 1) the Pittsburgh Reduction Co. was given a license to produce aluminum under the Bradley patent; 2) the Pittsburgh Reduction Co. paid Cowles $250,000 in back damages; 3) the Pittsburgh Reduction Co. paid Cowles $120,000 per year until the Bradley patent expired; 4) the Pittsburgh Reduction Co. paid a one-cent royalty to Cowles for each pound of aluminum over 8 million pounds that it produced; 5) the Pittsburgh Reduction Co. agreed to sell Cowles 146,000 pounds of aluminum at a 10% discount each year until the Bradley patent expired; and 6) all companies controlled by Cowles were forbidden to produce pure aluminum but were allowed to trade in it. [17]

In the following years, the Cowles Electric Smelting & Aluminum Co. stayed out of the aluminum smelting business, and eventually a friendly relationship developed between the two companies, as Cowles took advantage of its discounted prices to trade in aluminum. By the time the Bradley patent expired on Feb. 2, 1909, Cowles had earned $1.13 million and developed a prosperous aluminum jobbing business. [18] But until Bradley’s patent expired, the Pittsburgh Reduction Co. had a virtual monopoly over the production of ingot aluminum through exclusive rights to the most commercially competitive process. [19] Cowles was also embroiled in a patent dispute in England, where they ran a plant at Stoke-upon-Trent that later was acquired by British Aluminium in the late 1880s. Cowles also won the case against a carborundum company in 1900, in which the judge awarded the Cowles $300,000 for developing a method “for reducing ores and other substances by the incandescent method.” [20]

The U.S. Patent Office never adjudicated priority between the Cowles brothers and Bradley, but in 1927 the Patent Commissioner suggested that Bradley himself had either conceded priority to the Cowles brothers or else had been defeated by them in an interference proceeding. When the Cowles brothers brought their lawsuit against the

Pittsburgh Reduction Co. for infringing on their patent rights to using electric furnaces to make aluminum, they used their ownership of the Bradley patents as proof, even though good evidence existed suggesting that their own patents and discoveries made a stronger case. The irony of the situation was that the Cowles brothers won their lawsuit against the Pittsburgh Reduction Co. as owners of an invention by a comparatively obscure inventor who had never put his ideas into practice. There were complex legal arguments behind the importance of the Bradley patent in the case against the Pittsburgh Reduction Co., but there were also two simple business facts – the Cowles patents would expire on June 9, 1902, while the Bradley patents would not expire until Feb. 2, 1909, and the Bradley patents carried broader claims over the process. [21] With the patent wars settled, the Pittsburgh Reduction Co. could move ahead in creating an aluminum industry.

The metal monopoly

From 1870 to World War I, American industry underwent what could be called a second industrial revolution. The first industrial revolution, between 1820 and 1840, saw the economy in the U.S. and other parts of the world transition from hand production to machinery, improved water power and more steam power, advances in chemical manufacturing and the development of machine tools. It also saw the rise of the factory system for the mass market, especially in the textile industry. The changes introduced by the second industrial revolution were fostered by new capital-intensive and technology-based industries operating under modern managerial corporations, including railroads, telegraph and telephone, electrical utilities, oil and steel. Larger businesses trended toward horizontal integration, absorbing competing companies by forming trusts or holding companies. Between 1898 and 1904, some 4,227 U.S. firms merged into 257 corporations, leaving 318 trusts in control of two-fifths of U.S. manufacturing assets. [22]

Alcoa followed a different path, relying on internal growth and vertical integration rather than merger and acquisition to remain competitive. A detailed accounting of this corporate development can be found in George David Smith's 1988 book "From Monopoly to Competition, The Transformations of Alcoa, 1888-1986." Smith had good access to Alcoa records in writing his history. Whether expanding horizontally or vertically, growing corporations during this time period relied on large capital investments, and large-scale financial services were another new development. In the case of Alcoa, according to Smith, the Mellons became partners exercising restraint rather than replacing the original managers. The benefits gained from economies of scale were also important to these new large corporations. Andrew Carnegie summed it up by stating that "the larger the scale of operation, the cheaper the product." [23]

Economies of scale were well suited to continuous-processing industries, such as oil refining, glass manufacturing and metals reduction. Besides offering lower costs through physical size, large firms could commit part of their plant capacity and labor to production and set aside a reserve to protect against economic fluctuations. Carnegie noted a paradox created by economies of scale – a large firm could benefit in the long run by producing at a small loss rather than shut down and wait out a temporary drop in market demand. The high fixed-investment costs of capital-intensive enterprises such as the aluminum smelting industry made them more susceptible to downturns in the market than traditional smaller manufacturing companies. Those risks drove many capital-intensive companies toward horizontal integration, but some degree of vertical integration was also necessary – early meatpacking companies needed to promote refrigeration to their customers, and electrical equipment manufacturers needed to provide credit to customers as well as install and service necessary equipment. [24]

Alcoa's move into bauxite mining, alumina refining and power generation followed the pattern established by Carnegie's steel companies, but the move required complex organized managerial systems to direct the flow and quality of raw materials. According to Smith, Alcoa's slow transition from an owner-based company to a formally structured corporation was inevitable. Research and development were also important, as Alcoa improved reduction processes and created a market for its products. Over time, the company established an industrial research laboratory to address more difficult technical issues. The board of directors of the Pittsburgh Reduction Co. recognized the need to vertically integrate the company's operations by 1895. Fabrication facilities were making aluminum products at the New Kensington site, but the company saw a need to control the supply of raw materials – bauxite, alumina, cryolite, carbon and electrical power. The need arose from several concerns: 1) to ensure the lowest cost and the highest quality for these raw materials; 2) to be in a good business position once Hall's patent expired; and 3) to be prepared for a change in protective tariffs for new industries such as aluminum smelting. The overall goal was to maintain a monopoly position over aluminum production. [25]

By 1928, Alcoa held interests in 32 aluminum operations in 11 different countries. At the same time, the company had vertically integrated and grown to dominate and even control the U.S. aluminum industry. As Alcoa CEO Charles W. Parry explained in 1985, "For more than half our life, we were the most successful business monopoly in American history. We had the power to make decisions about aluminum that were largely independent of direct competitive pressures. We acquired bauxite reserves and hydroelectric sites to strengthen our solitary role. Alcoa expanded rapidly, achieving economies of scale that made it difficult as well as less attractive for potential competitors to enter the aluminum business. And we were financially successful." [26]

The race for bauxite

Evidence of Alcoa's growing share of the U.S. economy can be seen by its consumption of raw materials and energy. From 1935 through 1939, at the eve of World War II, the average annual consumption of raw materials for the refining of alumina by the U.S. aluminum industry – which was mostly comprised of Alcoa – included 500,000 tons of bauxite, 15,000 to 22,500 tons of quicklime, 17,500 to 25,000 tons of soda ash, and 2,000 to 2,500 billion BTUs of coal, oil, gas or electricity. The average annual consumption of raw materials for the reduction of alumina into aluminum by the U.S. aluminum industry during that same time period included 250,000 tons of alumina, 50,750 to 56,875 tons of petroleum coke, 21,750 to 24,375 tons of pitch, 5,500 to 7,000 tons of natural cryolite, and 3,000 to 4,500 tons of synthetic aluminum fluoride. In 1940, the U.S. aluminum industry consumed more than 4.5 million megawatt-hours of electrical power, making it the largest consumer of electrical power in the nation. Electrical use climbed steeply after that. It was estimated that in 1943, during the height of war-time production, the U.S. aluminum industry consumed about 22 million megawatt-hours. [27]

Aluminum production begins with bauxite. Two tons of bauxite will produce about one ton of alumina, the raw ingredient placed in Hall-Heroult reduction pots. [28] At one time, the U.S. produced about one-fourth of the world's supply of bauxite, but over time the major suppliers became South America, Jamaica, Australia and Guinea. [29] A modest deposit of bauxite was discovered in Rome County, Ga., in 1883. The ore was shipped to independent refineries that sold alumina for use in the chemical and abrasives industry. In 1891 and 1899, more substantial deposits of bauxite were discovered in Alabama and Arkansas. [30] The Pittsburgh Reduction Co. first acquired bauxite deposits in Georgia in 1894 and set up the Georgia Bauxite Co., a joint venture under the management of George Gibbons. [31]

By 1899, Pittsburgh Reduction recognized that the Georgian deposits were running out, and Alfred Hunt conducted an inspection tour of newly discovered bauxite deposits in Arkansas. Based on his investigation, the Pittsburgh Reduction Co. spent $60,000 securing significant acreage of Arkansas bauxite reserves. The company next acquired the General Bauxite Co. in Arkansas in 1906, which held an additional 15,000 acres of bauxite reserves. In 1909, as the Hall patent expired, the company purchased the Republic Mining & Manufacturing Co. and began mining bauxite in Arkansas. At that point, Alcoa became a net seller of bauxite. Surplus bauxite was sold to alumina refineries, such as the Pennsylvania Salt Co., the Norton Co. and General Chemical Co. [32]

By 1909, according to U.S. government estimates, the Pittsburgh Reduction Co. owned 90% of all the economically viable bauxite deposits in the U.S. [33] In 1917, Joseph Uihlein made a superficial investigation into the size of the bauxite reserves in the U.S. He found little or none outside of Arkansas, and all 7 million tons of that was owned by Alcoa. [34] Joseph and Robert Uihlein ran the Schlitz brewery in Milwaukee, Wis., and were interested in breaking into the fledgling aluminum industry. They initially bought the Republic Carbon Co. to gain a hold on carbon anode production and later were advised by former Alcoa employee Lloyd Emory to look into bauxite mining. The Uihleins invested in bauxite properties along the Demerara River in British Guiana and considered investing in a hydropower project on the Saguenay River in Quebec. [35] John Casper Branner, the state geologist for Arkansas from 1923 through 1940, estimated that Alcoa owned nearly 5 million tons of aluminum-grade bauxite in Arkansas and another 5 million tons was owned by others. In 1941, Lawrence Litchfield, Alcoa's head of bauxite operations, provided nearly the same figures as Branner, but he estimated that Alcoa owned about 52% of the bauxite in Arkansas. At the rate of consumption estimated in 1939, the Arkansas bauxite deposits were expected to last only eight more years. [36]

The limited supply of domestic bauxite sent Alcoa abroad searching for reserves in tropical locations. In 1912, the company began acquiring bauxite fields in British Guiana (today's Guyana) through the Demerara Bauxite Co. Ltd. and in Dutch Guiana (today's Suriname) through the Surinaamsche Bauxite Maatschappij Co. [37] In order to conduct business inside the British Empire, Alcoa had to concede to an agreement with the British government which stated that any bauxite mined from the British Empire must be at the British government's disposal. Alcoa eventually constructed an alumina refinery in Canada in the 1930s in order to meet that requirement, thereby enabling the British government to seize the alumina during an emergency. The policy was put to use during World War II, when aluminum from Alcan smelters in Canada was directed to the war effort. [38]

According to one account of early explorations in British Guiana, a Scottish geologist named George Mackenzie bought land 60 miles up the Demerara River in 1913 where bauxite had been discovered in the late 1800s. Mackenzie told locals he planned to grow oranges, but he died two years later and the land went to Winthrop Nelson. In 1916, a technical paper was presented in London on the occurrence of bauxite in British Guiana that influenced Alcoa to incorporate the Demerara Bauxite Co. to purchase the bauxite lands. Mining under the Demerara Bauxite Co. began in 1916 at Akyma on the Demerara River and was expanded in 1922 with processing and shipping facilities for ocean-going ships. [39]

In 1928, Alcoa sold the Demerara Bauxite Co. to its offshoot company Aluminium Ltd. of Canada. Production continued to grow at a steady rate, and by 1939 British Guiana was the world's third largest bauxite producer. A slump in the global bauxite business took place in 1930-1936, but business picked up in 1939 and continued to be important during World War II. The Berbice Bauxite Co., a subsidiary of American Cyanamid, began producing chemical-grade bauxite at Kwakwani in 1942. Demerara Bauxite expanded operations to Ituni in 1943. British Guiana was the second largest producer of bauxite by 1953, accounting for about 17% of the world's bauxite production. The Reynolds Metals Co. acquired Berbice Bauxite in 1952 and started producing metallurgical bauxite at Kwakwani. Expansion of operations had taken place during World War II, and by 1957 British Guiana was producing 2.2 million tons of bauxite per year. In 1956, the Demerara Bauxite Co. began construction of an alumina refinery that started operating in 1961. Most of British Guiana bauxite had been shipped raw to alumina refineries in the U.S. and Canada, but once the alumina refinery began operating, the British Guiana government received very modest royalties. [40]

Alcoa also developed bauxite deposits in Dutch Guiana. According to legend, in 1898 a convict escaped from a French penal colony in French Guiana and fled west into Dutch territory, where he found reddish colored rocks. The convict was from Les Baux, France, and the rocks resembled bauxite ore he had seen there. As the story of his find got around, mining companies sent men to investigate the area. When Alcoa began operations in Dutch Guiana in 1916, the company found "an almost forgotten and impoverished Dutch colony... which had to look forward to a future without a glimmer of hope," according to an in-house magazine Alcoa produced in late 2014. Dutch Guiana was a land of subsistence farms and wild rubber factories, along with colonial plantations that produced cocoa, coffee and sugar. In Alcoa's first half-century there, the company mined bauxite to the east and south of the capital and sent it abroad, by boat, for processing. [41] The company acquired the mining rights on several plantations and incorporated the Surinaamsche subsidiary to mine the deposits in 1916. The first shipment of raw ore left by sailing schooner in 1922. [42] During World War II, more than 75% of U.S. bauxite imports came from Dutch Guiana. [43]

Surinaamache was a wholly-owned subsidiary of Alcoa solely engaged in mining and exporting bauxite until 1958, when the Suriname government and Alcoa signed the Brokopondo Agreement to develop hydroelectric power and bring a fully integrated aluminum company to the nation called the Suriname Aluminum Co. or Suralco. [44] Alcoa, the Dutch Guiana minister-president and the Dutch governor signed the Brokopondo Agreement, named for a town located just north of the proposed Afobakka Dam. The plan was to build an alumina refinery and a hydroelectric dam to power a smelter all at one nearby location. The plans were drafted at Alcoa's Engineering

Department at its offices in Pittsburgh, Pa. Construction of the 1.2-mile long 189-megawatt dam lasted from 1959 to 1965 and created a 618-square-mile reservoir that displaced about 6,000 people in 43 villages. The Brokopondo Agreement left it up to the Dutch Guianese government to “remove the population, the buildings and other property from the reservoir area.” The Brokopondo Agreement provided a small portion of the dam’s electrical output to the Dutch Guianese government at 0.4 cents per kilowatt-hour, and electrical power from the dam also was used to light and power Paramaribo, the country’s largest city. [45] Alcoa also began mining at Moengo, 120 miles from Paramaribo on the Cottica River. By 1963, Moengo had grown to a sizeable town, with schools, a hospital and power lines, and another town grew up at Paranam on the Suriname River. The $150 million Brokopondo Agreement called for connecting the Afobakka hydroelectric dam to Paranam with a 50-mile road. Plans also called for an alumina refinery and a 60,000 ton-per-year aluminum smelter. [46] The new industrial complex’s first ingots of aluminum metal were poured in 1965, and the first alumina exports were sent to Vancouver, B.C. that same year. [47]

Alcoa also purchased rights to bauxite deposits in southern France in 1912, operating as Bauxites du Midi, and it purchased rights to bauxite deposits in Yugoslavia and Italy in 1921. [48] The company also gained access to bauxite deposits in British Guiana and Dutch Guiana held by the Republic Carbon Co. when Alcoa purchased one-third of Republic Carbon’s stock in December 1924. At the time, Republic Carbon produced large carbon electrodes for use in smelting aluminum at its plant near Niagara Falls. [49]

Transporting bauxite ore from South America to Alcoa’s facilities in the U.S. presented another set of problems for the company. By 1936, the U.S. merchant fleet was becoming obsolete and declining in numbers, partly a result of the Great Depression. Only two ocean-going dry-cargo freighters were built in the U.S. between 1922 and 1937, and only 10 shipyards in the U.S. were capable of building a ship more than 400 feet long. A large number of ships had been built at the start of World War I, but many of them were two decades old by 1936 when President Roosevelt signed the Merchant Marine Act, creating the U.S. Maritime Commission. The independent agency was tasked with establishing new shipyards capable of building over a 10-year period a fleet of 500 modern and fast merchant cargo ships that could be sold, chartered or leased to American companies for overseas shipping. The ships would also serve as a reserve U.S. Naval auxiliary fleet in event of war. The Act also called for training both shipyard workers and merchant marine personnel. [50]

Once World War II broke out in Europe, Alcoa lost access to foreign-flag ships to transport bauxite from South America. In 1939, the War Shipping Administration provided Alcoa with 14 World War I vintage cargo ships to maintain the flow of bauxite.

These 14 ships were prone to German U-boat attack and four were sunk. In 1940, Alcoa consolidated the three bauxite-shipping companies operating in the Gulf of Mexico into the Alcoa Steamship Co. Several ships operated by the new steamship company also sank during the war, including the City of Birmingham and the Robert E. Lee. In 1941, Alcoa ordered three ships from the Moore Dry Dock Co. in Oakland, California – the Alcoa Courier, Alcoa Corsair and Alcoa Cruiser. In addition to carrying bauxite, the ships were designed to carry up to 102 passengers with luxury first-class accommodations – a swimming pool along with beach, sports and sun decks, glass-enclosed promenades, a cocktail lounge, a library and staterooms with private baths and showers. Alcoa wanted the passenger revenue to help offset the cost of shipping bauxite. The ships could also carry 313,000 cubic feet of cargo, including refrigerated goods. [51]

But none of the new ships were delivered to Alcoa after the Japanese attacked Pearl Harbor. Instead, the three ships were reconfigured for the U.S. Navy for use as medical facilities and troop transport. The Alcoa Courier was renamed the USS Tryon after a former Naval Surgeon General. [52] The Alcoa Steamship Co. was re-organized in 1950 and later established a subsidiary, the Lib-Ore Steamship Co. of Liberia. Over time, the company expanded operations and began leasing its ships to other aluminum-related companies around the world. The passenger-cargo liners were discontinued in the 1960s due to growing expenses and competition. [53]

In 1949, during remedy proceedings in the federal anti-trust case against Alcoa, Richard S. Reynolds, president of Reynolds Metals, spoke highly of a new type of ship specially designed for transporting bauxite. A few days later, Alcoa President Irving Wilson testified that his company had looked into the ships and concluded, “We do not believe there will be any economy utilizing an ore carrier. They are very expensive pieces of equipment and as such cannot be used for any other purpose than just hauling ore.” Shortly afterward, Reynolds commissioned an English firm to build the SS Carl Schmedemen, the first self-loading bauxite carrier. The ship got good reviews as it was estimated to reduce shipping costs by one-third. Not long afterward, Alcoa ordered two of the ships. [54]

Building alumina refineries

Alcoa’s movement into alumina processing came late, and its early alumina refining operations were inefficient and expensive. The company was slow to recognize the importance of Karl Bayer’s alumina refining process and put it to use. Charles Martin Hall had understood the importance of alumina production in the Pittsburgh Reduction Co.’s early years – bauxite was too impure to be used in his electrolytic process. But the cost of alumina accounted for about one-half the cost of producing aluminum, and Hall experimented unsuccessfully to find a way to use bauxite directly in reduction pots. He tried feeding finely-ground and calcined high-grade bauxite directly into the molten cryolite, but no way could be found to remove the silicon, iron and titanium present in even the best bauxite ore. Through the 1890s, the Pittsburgh Reduction Co. bought nearly all its alumina from the Pennsylvania Salt Manufacturing Co., an undesirable arrangement for the aluminum company. In 1899, the Pittsburgh Reduction Co. established an experimental plant at New Kensington to find a way to refine bauxite. [55]

The Pittsburgh Reduction Co. soon realized it needed a dedicated facility to serve as its first alumina refinery. On March 10, 1902, the company purchased about 400 acres of land in East St. Louis, Ill., for construction of an alumina refinery. Much of the property included the upper end of Pittsburg Lake, a large oxbow lake created by the Mississippi River. The East St. Louis area offered a ready supply of raw materials, including coal, limestone and fluorspar, transportation by rail and barge, and labor. The site also was advantageously located between the company's bauxite mines in Arkansas and its aluminum reduction plants in New York. Construction of the East St. Louis Works began on April 5, 1902, and the plant began operating the next year. [56]

The new alumina refinery started out using a batch process to refine bauxite from the company's Arkansas mines. The calcined alumina was shipped to the company's reduction plants at Niagara Falls and Massena. Refining bauxite into alumina was a relatively simple process, and the technology evolved substantially during the life of the East St. Louis Works. Initially, Alcoa purchased aluminum hydrate, a key intermediate ingredient in the refining of bauxite to alumina, but suppliers were unable to keep up with the rising demand. Whereas modern alumina refineries purchase sodium hydroxide for the digesters, the East St. Louis Works made the caustic by reacting quicklime with soda ash. The soda ash was purchased, but the quicklime was made by burning powdered limestone in a kiln to drive off the carbon dioxide. The kilns initially were heated by coal and later by natural gas, and a coal gasification plant operated at the site in its early years. [57]

The first year's production was 5,500 tons of alumina. By 1907, the waste product from alumina refining, called red mud, was hauled to residue disposal areas on site by light rail rather than mule-drawn carts. Bauxite was shipped to the plant by rail, where it was unloaded, crushed and passed through a sieve. Barge shipments of bauxite from Arkansas began unloading at the Fox Terminal Dock on the Mississippi River in 1916 and continued until 1925, by which time all raw materials were shipped to the plant by rail. [58] In 1910, the Alton & Southern Railway was formed, absorbing the Denverside Connecting Railway in 1913. A subsidiary of the Aluminum Ore Co., in turn a subsidiary of Alcoa, the new railway existed to transport raw materials to the East St. Louis Works. Alcoa sold the railway in 1968. [59]

The Pittsburgh Reduction Co. used a version of the 1855 LeChatelier process to make alumina until 1911, when it switched to the more economical Bayer process. [60] Karl Bayer had patented his process in 1894, and the U.S. patent for his process expired in 1911. [61] The Pittsburgh Reduction Co. obtained the rights to the Bayer process in 1905, the first time the company adopted borrowed technology, but it didn't switch over the East St. Louis Works to the Bayer process until 1911. By that time, Hall had taken out four patents for what he called a "dry process," which used electrothermal heating of a mixture of bauxite and coke to produce alumina. During its first two decades, the Pittsburgh Reduction Co. depended on the Pennsylvania Salt Co. for much of its alumina supply – even after alumina production had begun at the East St. Louis Works. [62]

By 1909, after the company changed its name to Alcoa, Hall admitted the company's mistake in not adopting the Bayer process sooner. "I do not want to see us make again the mistake which we did before – i.e. of underestimating the advantages of the process which our (European) competitors were using," Hall said. "We really ought to have known all about the Bayer process… five or six years ago, and not have gone along working our own process with the idea that it was superior, without really knowing." He called the process used in East St. Louis a "hybrid" between the Bayer process and Alcoa's methods. [63]

In the aluminum industry's early years, companies employing the Bayer process typically used 2.33 tons of coal to process one ton of bauxite into alumina. As a result, bauxite was typically transported to areas near coal deposits for refining into alumina. That figure dropped to 0.15 tons of coal per ton of bauxite over the following century. Energy improvements came from use of heat exchangers and flash tanks for energy recovery and the use of large autoclaves – the larger the reactor, the less heat was needed per unit of production. Precipitation tanks also increased in size to 10 times the size of the autoclave. Steam was utilized for heating and agitation, and autoclaves were connected in series to permit continuous operation, decreasing the need for manpower. [64]

By July 1911, after switching to the Bayer process, Alcoa recognized that the East St. Louis Works produced all the alumina the company needed at a cheaper cost and of better quality than it could obtain from the Pennsylvania Salt Co. The plant superintendent, Charles B. Fox, suggested that Alcoa "would be money in the pocket if the reduction plants were to depend entirely on the East St. Louis Works, because we are now making alumina at a lower price than what we are paying the Pennsylvania Salt Co." Fox noted that the Alcoa alumina was also higher quality. By 1915, the East St. Louis refinery was producing 350 tons per day on the same amount of land where it had produced 15 tons per day. It was several decades later that the significance of economies of scale for alumina refining were recognized. One large modern alumina refinery typically supplies alumina for two or more smelters. [65]

The high demand for alumina in World War I and the use of bauxite from South America resulted in construction of a second alumina refinery at the East St. Louis Works in 1918. Shortly after Plant 2 went into operation, production reached approximately 500 tons of alumina per day. A temporary shutdown of Plant 2 occurred in the early 1930s as a result of the Great Depression, but by 1937, with an improved economy, the facility began producing approximately 1,000 tons of alumina per day. [66] Competition by other alumina producers dwindled as Alcoa's production capacity grew. In 1903, the Merrimac Chemical Co. of Woburn, Mass., held rights to use the Bayer process. The company made alumina until 1917, at which time it entered into a contract to purchase alumina from Alcoa through 1927. [67]

By 1920, several modifications to the Bayer process for converting bauxite to alumina were developed by Alcoa. The improvements included the continuous digestion process, the lime and soda process, and the starch process. Improvements continued after that. By World War II, the Bayer process recovered on average about 95% of the alumina in bauxite ores. By 1962, the recovery rate was 97%. [68] Between 1928 and 1937, Alcoa produced 66% of all the alumina refined in the U.S., and the Pennsylvania Salt Co. produced the rest. Of all the alumina Alcoa produced in the U.S. during this time period, Alcoa used 78% and sold the remainder to other aluminum producers and chemical companies. By 1941, Alcoa produced all the alumina in the U.S. used to smelt aluminum – because it was the only company in the U.S. making aluminum from alumina. [69]

Alcoa continued to experiment with the dry process, also called the Hoopes process, from 1904 through 1928. In the latter years, the experiments were conducted at the company's Arvida aluminum smelter in Quebec. In 1928, the dry process experiments became the property of Alcoa's spinoff company Aluminium Ltd., but the process never proved successful. [70] In 1912, Alcoa entered into a contract with a French company to develop a new type of alumina refining called the Serpek process that would simultaneously produce alumina and ammonia and be cheaper than the Bayer process. The Serpek process never proved practical and the contract was cancelled in 1920. [71] On Aug. 20, 1912, the Det Norske Nitridaktienselskab aluminum company was formed in Norway. The company aimed to take advantage of the Serpek process, which theoretically would produce alumina and nitrogen compounds at the same time. The Serpek process, however, did not work, and by 1913 DNN had turned to aluminum production. [72]

In 1938, Alcoa built another alumina refinery at Mobile, Ala., where it processed bauxite shipped from Dutch Guiana. Alumina refining required bulk quantities of bauxite ore, soda ash, lime, and coal or natural gas, all of which were readily available in the southeastern part of the U.S. since the turn of the century. Bauxite deposits in Arkansas were playing out, and new sources were being developed in Jamaica, Dutch Guiana and British Guiana. [73] The Mobile refinery could produce 600 million tons of alumina per year. [74] Alumina from the Mobile refinery was sold to the Japanese until the start of World War II. By 1942, alumina from Mobile was being used to make aluminum for aircraft flown against Japan and Germany. The Mobile refinery produced about 34% of the alumina used by the U.S. wartime aluminum industry in 1943. [75]

Cryolite and carbon

Alcoa also expanded into fluoride chemical production, including cryolite – sodium hexafluoroaluminate, a colorless compound forming cube-shaped crystals. The aluminum content of cryolite is about 13%, while the aluminum content of bauxite is about 50%, so while cryolite was initially considered a source for making aluminum, the focus of early scientists turned to bauxite once the Hall-Heroult process was discovered in 1886. Cryolite is also extremely rare – it is possibly the only mineral on Earth to be mined to extinction. The Ivigtut mine in Greenland was depleted by 1987. But cryolite provided the key to separating aluminum atoms from oxygen atoms in alumina. Melting alumina into a liquid requires a temperature of 2,072 degrees Celsius, which is prohibitively expensive. Cryolite melts at 1,012 degrees Celsius, and dissolving alumina in cryolite provided a cost-efficient electrolytic industrial process. [76]

The annual production of cryolite from 1925 to 1934, mostly from Greenland, amounted to 10,000 to 35,000 tons, with about a third going to the Pennsylvania Salt Co. of Philadelphia. Most of the cryolite went to aluminum smelting, but it was also used as a flux in metallurgical applications, in the ceramic industry, as a flux and opacity agent in enamels, as an opacity agent in the glass industry, as a solvent and opacity agent in glazes, as a binder for abrasive materials and as an insecticide. By 1934, the entire world production of cryolite came to 170,000 tons, but the monopoly held by the Pennsylvania Salt Co. and the Oresund Co. of Copenhagen drove interest in finding a way to produce synthetic cryolite, sodium aluminum fluoride, in a cost-efficient industrial process. In 1936, for example, higher prices for cryolite, graphite electrodes and electrical power forced the Japanese Electrochemical AG company to operate at a loss. [77]

The source for fluorine to make synthetic cryolite included two commonly found and distributed minerals – fluorapatite, made of calcium, fluoride and phosphate, and fluorspar, the mineral form of calcium fluoride. The global manufacture of synthetic superphosphate using fluorapatite created about 20,000 tons of fluorine as a byproduct. Fluorspar was used to make hydrofluoric acid and its derivates. The commercial production of synthetic cryolite likely began in France and Germany, and those products were shipped to the U.S. By 1938, Japan was manufacturing one-half of its cryolite needs. The Soviet Union projected a production of 25,000 tons per year by 1936. Alcoa and the Grasselli Chemical Co. held American patents for the production of synthetic cryolite, and Alcoa produced synthetic cryolite at its East St. Louis plant using fluorspar. The two most commonly used methods for making synthetic cryolite included the silicofluoride method, by combining silicofluoride with alumina and sodium carbonate, and the hydrofluoric acid method, by combining alumina or an aluminum salt in the presence of sodium ions with hydrofluoric acid. Japan was likely the only country using the silicofluoride method as a byproduct of the phosphate industry, while the rest of the world likely used fluorspar. [78]

Alcoa began operating a fluoride acid plant at its East St. Louis Works in 1907. The primary product was aluminum fluoride, which was used for smelting aluminum. Production reached 30,000 tons per year. At the plant, aluminum trihydrate was reacted with hydrofluoric acid or hydrofluoric gas and then calcined to anhydrous aluminum fluoride, a white powder. The generation of hydrofluoric acid/fluorine gas took place in "acid plants." Fluorspar ore mined in southeastern Illinois or Kentucky was reacted with sulfuric acid in a still, liberating hydrofluoric gas that was used to fluorinate aluminum trihydrate or as a source of fluoride for other fluoride products. During the reaction, calcium sulfate, the mineral gypsum, precipitated out in the still. The gypsum was chipped out and hauled away by narrow gage rail car and clamshell bucket. [79]

In 1929, Alcoa turned to a dry process, where fluorspar was reacted with sulfuric acid in a rotating heated kiln with a breaker. The process was exothermic so minimal external heat was needed. The gypsum left the kiln in dry powdered form. Fluorine gas was liberated, which was then reacted with dry alumina hydrate, producing an anhydrous aluminum fluoride. This gypsum waste was used to build up the dikes built to hold back the red mud waste ponds for the adjacent alumina refinery. From 1930 to 1937, a portion of the gypsum waste was reprocessed into plaster products, but that process was discontinued as it was not profitable. The East St. Louis Works also produced cryolite, as much as 20,000 tons in a year during high demand. In addition to aluminum smelting, cryolite was used as an insecticide by fruit, vegetable and ornamental plant farmers. [80]

Alcoa also moved into the carbon industry. Carbon paste is the material used to make anodes and cathodes for aluminum reduction pots. Usually the carbon lining of a metal cathode pot remains intact through the life of the pot, but the anode is consumed as alumina loses its oxygen atoms and becomes aluminum. The oxygen combines with the carbon in the anode to form carbon monoxide, and the anode continuously burns away. This process takes place in continuously-fed Soderberg anodes or with prebake anodes that must be replaced one block at a time. Carbon paste is the industrial name for a mixture of petroleum coke and coal tar pitch in the rough proportion of 70 parts coke to 30 parts pitch. The ratio of the coke varies with the quality. Petroleum coke is a by-product of petroleum refining and consists of the residue left after the top gasolines, fuel oil and other products have been removed from crude oil. [81]

The Pittsburgh Reduction Co. began carbon production at New Kensington before 1894. Those facilities were moved to Niagara Falls when the company began operating an aluminum smelter there. [82] In 1905, the company built one of the largest electrode factories in the world at Niagara Falls. [83] But they weren't alone there. In October 1918, the Republic Carbon Co. broke ground for construction of a new carbon electrode manufacturing plant near Niagara Falls to meet the growing demand by the steel, ferroalloy and aluminum industries. Raw materials used at the new facility included anthracite coal, coke, petroleum coke, retort carbon, hard and soft pitch, tar and oil. Crushed coal or coke was calcined in an electrical furnace at very high temperatures to reduce the material as far as possible into carbon. The calcined coal or coke was then finely crushed and stored in bins for later mixing. Carefully weighed portions of each needed ingredient was mixed in large machines and then molded into "cheeses," or lumps, using binding material. The cheeses were then placed in a 3,000-ton hydraulic press with specially designed dies to create desired electrode shapes. [84]

The Republic Carbon Co. facility could create round electrodes with 8, 9, 10, 12, 14, 16, 17, 20 and 24 inch diameters, and 16 or 20 inch square electrodes. The green electrodes were packed in sand and placed in one of 28 special furnaces for baking and annealing. Heat was provided using gas from an onsite gas-producer plant, which converted coal to gas. The baked and annealed electrodes were then machined with accurate faces and threaded ends so one electrode could screw into another. The final products were shipped out in crates. Electric power was provided by the Niagara Falls Power Co. as 12,000 volt 3-phase 25 cycle power. The facility also had its own research laboratory for quality control and new processes. [85] On Nov. 20, 1920, the U.S. granted a patent to Frank Kemmer as the assignor of the Republic Carbon Co. for a new method to make carbon electrodes. By passing electricity through the green unbaked electrodes, high temperatures were created that helped convert the amorphous carbon into graphitic carbon. The patent was later cited by numerous companies over the years in their patent applications, including Pechiney in 1960 and 1970 and Sumitomo Chemical in 1975. [86] In December 1924, Alcoa purchased one-third of the stock of the Republic Carbon Co. [87]

In 1924, Alcoa acquired a little over half interest in Det Norske Aktieselskab to gain control of Electrokemisk Industri, a Norwegian company that owned the patent rights to the Soderberg aluminum reduction processing design. [88] The Soderberg patent involved a continually-fed anode that reduced the amount of labor needed in pot rooms. Carbon paste was formed into briquettes that were fed into the top of the open anode shell. The briquettes melted inside the anode shell and were baked into hard carbon by the heat of the reduction pot. The Soderberg design became the most common one used in aluminum smelters until the 1940s when prebake anodes became available. The Anaconda Company opted to install Soderberg-type reduction pots in its smelter in Columbia Falls, Mont., and they were operating until the plant shut down in 2009.

Holding onto hydropower

Alcoa's foray into electrical generation was probably its most expensive investment toward establishing a monopoly in the aluminum industry. Electrical power is one of the most costly factors in the smelting of alumina into aluminum. Electrical current efficiencies in the electrolytic smelting process run about 85% to 92%, and total energy efficiencies run about 40%. A typical electrical power consumption of 6 to 8 kilowatt-hours per pound of aluminum produced includes buss bar, transformer and rectifier losses. [89]

Hydroelectric facilities can require enormous capital investments to build, with the need for large land purchases for reservoirs and watersheds, and construction of massive concrete dams, generating plants and transmission lines. In the case of the Pittsburgh Reduction Co., the initial investments at Niagara Falls and Massena were made by utility companies that the Pittsburgh Reduction Co. initially contracted with for power. On June 28, 1893, the company signed its first contract with the Niagara Falls Power Co., calling for 1,500 horsepower of electrical power with an option for 1,000 horsepower more (one horsepower equals 746 watts). A new aluminum reduction plant was designed and put into operation near Niagara Falls on Aug. 26, 1895. A second plant was put into operation nearby on Nov. 21, 1895. Over the next few years, capacity was added to these plants. [90] In 1906, the Pittsburgh Reduction Co. built a power plant on the American side of Niagara Falls to power a third smelter plant at that location. That same year, the company acquired the St. Lawrence Power Co., the utility which had provided power for the Massena smelter since 1903, and then made plans for a new hydroelectric reservoir in the Long Sault section of the St. Lawrence River. The Long Sault plan, however, was thwarted by a powerful coalition of conservationists. [91]

The Pittsburgh Reduction Co. also turned to establishing power-generating facilities at Shawinigan Falls on the St. Maurice River in Quebec and acquired potential hydroelectric power sites in 1899. According to the company's board of directors, the purpose was in part to prevent other companies from establishing major aluminum smelting operations in Canada. [92] The Pittsburgh Reduction Co. signed a power sales agreement with the Shawinigan Water and Power Co. on Aug. 14, 1899. [93] The Pittsburgh Reduction Co. hired Edwin S. Fickes, a civil engineer, in the winter of 1899-1900 to design the Shawinigan Falls smelter. Fickes' job was made more difficult by the company's high level of secrecy. In order to protect the Hall process from corporate theft, Fickes was refused entrance to the Pittsburgh Reduction Co.'s smelter plant at Niagara Falls by order of Charles Hall himself. Eventually Fickes gained the company's trust and became head of the company's engineering department, helping to site and design the company's far-flung empire of mines, refineries, power-generating plants and smelters. [94]

The Shawinigan Falls smelter was the largest in the British Empire. [95] It was constructed in about seven months and poured its first aluminum ingot on Oct. 22, 1901. Most of the ingots were shipped to British and Japanese markets, with some going to making aluminum conductors for transmitting power to Montreal. In 1902, the Pittsburgh Reduction Co.'s Canadian assets were renamed the Northern Aluminium Co. [96] The name was changed to the Aluminium Co. of Canada Ltd. in 1925. [97]

Alcoa next turned to plans for a large alumina refinery on the Saguenay River in Quebec, using ore shipped from British Guiana. The company entered into negotiations with U.S. tobacco magnate James Buchanan Duke, who along with several Canadian partners had already begun to develop the Saguenay River for hydroelectric power at Isle Maligne and Chute-a-Caron. The negotiations limped along until 1924, at which point Arthur Vining Davis brought in Andrew Mellon and his influence as U.S. Treasury Secretary to push development through. [98] In April 1925, Alcoa paid $17 million in stock for the undeveloped hydroelectric site on the Saguenay River. Called the Lower Development, the site was capable of producing 780,000 horsepower in electrical power. [99] In July 1925, a merger was made between Alcoa and Duke interests just three months before Duke passed away. Much of Duke's estate passed into a charitable trust, and Alcoa effectively took control over his Canadian developments. [100]

The Saguenay hydroelectric facilities were sited on the river near the outlet of Lake St. John, which contained the runoff from more than 30,000 square miles of land. By 1930, plans were in place for generating 500,000 horsepower at Isle Maligne with a future 500,000 horsepower to be generated at a nearby location. [101] Alcoa soon made plans for an aluminum smelter at the new town of Arvida, which is now part of the city of Jonquiere, to use this additional hydroelectric power. [102] The name of the new smelter town was derived from the Northern Aluminium Co. president's name – AR thur VI ning

DA vis. [103] Arvida was located 24 miles by rail from the harbor at Port Alfred, where large ships could dock and unload raw materials from around the world. [104] Alcoa located the deep-water port five miles from Jonquiere and Chicoutimi near Ha! Ha! Bay. By 1927, a 27,000 ton-per-year smelter was in operation. Soon after that, an alumina refinery was in operation using the “dry process.” By 1928, Alcoa accounted for more than half the world’s primary aluminum smelting capacity, with 90,000 tons per year in the U.S., another 45,000 tons in Canada and 15,000 tons in Europe. [105]

As additional plans for power plants on the St. Lawrence River were stymied by difficulties between the U.S. and Canadian governments, Alcoa turned to Tennessee. [106] The company began purchasing riparian rights along the Little Tennessee River in 1909 with the goal of building a network of dams. Alcoa chose North Maryville in Blount County for an aluminum plant site in 1913. It reincorporated the town with the name Alcoa in 1914, purchased 750 acres and built a smelter. After World War I, Alcoa expanded the facilities by building a rolling mill and a sheet mill and made plans for a 7,500-acre city. [107]

To secure full hydroelectric potential in the region, Alcoa purchased the Knoxville Power Co., Tallassee Power Co., Western Carolina Power and Transportation, Union Development Co., and Union Power and Water Co. and put them together as the Tallassee Power Co., which later became known as Tapoco. A railroad was run into the area in 1916, and the new dams began operating in 1919, 1928, 1930 and 1957. Alcoa was unable to renew its 1955 federal license in 2005 because of concerns about flooding in the Great Smoky Mountains National Park, but the situation was fixed with a land swap. [108]

As the number of workers needed for the plant increased, Alcoa constructed housing, schools and other facilities. The wife of James Rickey, a hydroelectric engineer with Alcoa, came up with the name Alcoa for the new town based on the acronym for the Aluminum Company of America. The company officially changed its name to Alcoa Inc. in 1999. [109] The town of Alcoa was incorporated in 1919, and many of the streets were named for Alcoa executives. In addition to building homes, schools and parks, the company bought and operated a dairy farm with milk sold in Alcoa-labeled jugs. Until the 1950s, the mayor was also the plant manager. [110] The Alcoa, Tenn., smelter was improved during World War II and received additional power from the Tennessee Valley Authority. In 1948, the plant produced nearly 137,000 tons of primary aluminum. [111] By 1998, the plant was producing 210,000 tons of aluminum per year. [112] On Feb. 4, 1952, the last of the original Hall reduction pots still operating at the Alcoa smelter were shut down for the first time. The pots were first put into operation in 1888. [113]

Alcoa also expanded into nearby North Carolina when a French smelter project ran into financial problems during World War I. In 1912, the French company L'Aluminium Francais acquired the assets of the Whitney Co., which had been exploring and developing a power plant on the Yadkin River in North Carolina since 1889. Whitney went bankrupt in 1907. L'Aluminium Francais opted to build a new 200-foot-high hydroelectric dam to power an aluminum smelter, under the direction of its wholly owned subsidiary Southern Aluminum Co. A village for workers was designed and built and named Badin after the president of Southern Aluminum Co., Adrien Badin. The project faltered when most of the French engineers returned to Europe during World War I. [114] The hydroelectric dam was only one-eighth to one-quarter completed when the war broke out, and the French government issued regulations forbidding the Southern Aluminum Co. from sending money to the U.S. for the project. [115]

Alcoa purchased the unfinished project in 1915 for nearly $7 million and by 1917, after making numerous changes and investing large sums of money, the Badin dam and smelter were completed and put into operation. [116] Alcoa built a second dam downstream of Badin in 1919, a third dam upstream of Badin in 1927, and fourth dam between the others in 1962. [117] The smelter was improved during World War II, and by 1948 it was producing 29,500 tons of primary aluminum. [118]

By 1937, Alcoa owned numerous hydroelectric power generating plants across the U.S. totaling 540,000 horsepower in developed capacity. The entire undeveloped capacity of the U.S. at the time was estimated to be 11 million horsepower. Alcoa also owned undeveloped sites in North Carolina at Nantahala, Glenville, Tuckertown and Fontana and in Tennessee at Needmore. [119] Alcoa also acquired hydroelectric power sites in Norway and France in the 1920s. [120]

In the early years in Pittsburgh and New Kensington, the Pittsburgh Reduction Co. had turned to coal-fired boilers driving steam-driven generators for electrical power. After that, the company preferred hydroelectric facilities. One exception to that rule was the Rockdale aluminum plant in Texas. During the 1950s, as the company upgraded older facilities and built new capacity across the U.S., Alcoa recognized that it might be cheaper to purchase electricity from utilities, but it wanted to maintain control over power. [121] The company at the time believed that hydroelectric production had peaked in the U.S., and coal would become a competitive energy source. In the case of Rockdale, the company saw adequate supplies of coal at the nearby Sandow lignite mine. Alcoa completed construction of the Rockdale smelter complex in 1952 as part of the U.S. defense effort and owned and operated the coal mine and the power plant until 1989. The Rockdale facility employed 1,300 workers in 1999, including 800 hourly smelter workers, 260 mine workers at the mine and power plant, and 240 salaried workers. [122]

In addition to building hydroelectric dams, alumina refineries and aluminum smelters in the U.S., Alcoa invested in Europe. During the 1920s, Alcoa bought a one-third interest in Det Norsk Nitrid, a closed plant in Norway owned by French and English businessmen, a one-third interest in Aluminio Espagnol of Spain, and a one-half interest in Societa dell'Alluminio Italiano from its French owners. Altogether, Alcoa purchased 10,500 tons per year in primary aluminum capacity in Europe in the 1920s. [123]

While smelter capacity was being increased every year, another development was taking place that sidestepped the whole aluminum reduction process – recycling. Prior to 1910, scrap aluminum was customarily thrown away. Scrap aluminum is produced at fabricating plants and is generally high-quality aluminum, compared to consumer waste that is recycled. Some metal producers purchased scrap from fabricators for about one cent per pound. Over time, the scrap aluminum market grew in size and complexity. From 1922 through 1937, the production of secondary aluminum in the U.S. averaged 75 million pounds per year. In 1937 it exceeded 125 million pounds. Some manufacturers of cooking utensils in the 1930s relied entirely on secondary aluminum. Generally the price for secondary aluminum was less than the price for primary aluminum, and secondary aluminum competed with virgin ingot aluminum. [124]

The importance of R & D

Through the early years, the Pittsburgh Reduction Co. and Alcoa invested in research and development to further improve aluminum production methods. Edwin S. Fickes was one of the first employees of the company to call for uniform testing and operating methods at the company's far-flung plants. According to George David Smith, fabrication plants reported that metal coming from Alcoa smelters was inconsistent – sometimes of good quality and sometimes not. The smelters blamed the alumina refineries, and the refineries blamed the bauxite coming from the company's mines. In 1909, Fickes called for an independent and competent research organization to work out these problems, but he was turned down by Charles Hall. The company, however, did establish a research laboratory. By 1913, Alcoa's New Kensington laboratory had 20 employees under the direction of Earl Blough, who had a doctorate in chemistry and was the company's chief chemist and metallurgist. He was joined by William Hoopes, the company's chief electrical engineer. One major research focus for the company was finding an inexpensive alternative to the Bayer process. This effort was finally suspended in 1919. Other research efforts were focused on innovations that would improve production methods, from mining to fabrication. [125]

In 1919, Francis Frary, a research chemist who headed up Alcoa's research and development, joined Hoopes to develop a new way to make aluminum that was up to 99.99% pure. The two built an experimental reduction pot at the Badin smelter with a bottom layer of heavier molten aluminum-copper alloy, serving as the anode, a middle layer of molten fluoride electrolyte, and a top layer of pure aluminum, serving as the cathode. The new process improved on the Hall-Heroult process, which was only capable of producing aluminum with up to 97.75% purity. The high-purity aluminum was eventually used in a variety of new alloys for aircraft propulsion and structural components, among other uses. According to Smith's history of Alcoa, Frary and Hoopes had relied on a precise knowledge of the physical and chemical properties of the electrolytic bath, pure aluminum and the aluminum-copper alloy – scientific knowledge that had been determined by research chemists working in a laboratory environment. [126]

The success of the experiment led Alcoa to investing more in laboratory research. By 1920, Alcoa had discovered that aluminum powder could be used as a pigment in paint and discovered new ways to cast and work magnesium, a potential competing metal. Alcoa pioneered efforts in X-ray diffraction and made many fundamental discoveries in the structure of metals. Alcoa's management eventually came to see research as an important part of its business goals and invested more money into its research facilities. By 1928, Alcoa's research budget had reached $700,000, and Arthur Vining Davis was willing to put more money into the company's labs. [127]

Davis ordered a new facility to be built at New Kensington. By 1930, the Aluminum Research Laboratory's new building was ready, complete with marble and aluminum trimmings, sitting on a hill overlooking the New Kensington Works. Research also took place at other Alcoa plants – on forgings in Cleveland, on electrical transmission at Massena and on alumina refining at East St. Louis. Alcoa's research budget fell as low as $445,000 in 1932, during the Great Depression, but important research work continued. During this period, the company developed the Combination Process for refining low-grade high-silica bauxites. In 1929, while designing new blooming and structural mills, a metallurgist at Massena began work on a new way to cast very large ingots of aluminum that eventually came to be called the Direct Chill Process. The semi-continuous casting process involved producing billets, blooms or ingots in a vertical compartment with a small mold mounted on a hydraulic ram. Molten aluminum was poured into the small mold, called a dummy block, which slowly dropped down into the compartment. Water jets cooled the outside of the incoming hot metal, and the hardened metal held the molten metal in place, creating a form for the final product. The new casting method was first tried in December 1934. By mid-1937, about half of all rolling-ingot alloy production was made by the Direct Chill Process. [128]

In 1937, Alcoa installed mercury arc rectifiers, also known as ignitrons, at its aluminum smelter in Massena, N.Y. to replace the rotary converters or motor-generator sets used to convert AC power from the Niagara Falls power plants to the DC needed for the potlines. Large 12-phase rectifier systems using phased-transformers to supply power for mercury arc rectifiers at Alcoa's Tennessee plant, however, caused problems for telephone systems southeast U.S. as they produced 11th and 13th harmonics. These rectifiers had to be shut down until a solution could be found that minimized harmonic generation. Electrical engineers quickly recognized that the 12-phase system needed to be converted to a 36-phase system. Potlines were set up in a U-shape, with the substation and the rectifier stations at the top of the U. A typical potline was supplied with 72 rectifiers arranged in six groups of 12. Each group was supplied by a rectifier transformer rated at 7,500 KVA with 13.8 kilovolts primary and 600 volts secondary. The rectifier transformers had dual-wye secondaries connected in a star configuration. Three transformers had wye-connected primaries, and the other three had delta-connected primaries, resulting in a 36-degree phase shift. Four 10-degree phase-shifting autotransformers, with two set up for lead and two for lag, supplied power to the rectifying transformers. A 40 MVA load-tap regulating autotransformer provided power to the four phase-shifting autotransformers. [129]

This setup resulted in 36-phase AC supply to the mercury arc rectifiers and reduced the ripple in the DC current, while minimizing interference to the regional telephone system. The first major installation of mercury arc rectifiers took place at Alcoa's aluminum smelter in Vancouver, Wash. in 1940. Arc-backs in the ignitrons occurred when plant technicians tried to regulate output voltage, which caused a short circuit in both the AC and the DC systems. A circuit breaker tripped, with no serious damage to the equipment, but a loud noise comparable to a shotgun blast accompanied the arc-back. Alcoa personnel determined that the arc-backs were caused by manufacturer defects, including mercury contaminated by porcelain dust or mercury splashing on the anodes because of poorly installed baffling. Satisfactory operation of Alcoa ignitrons was attained by 1945. Alcoa's electrical maintenance personnel purified 13,000 pounds of mercury by distillation that year. Ignitrons were replaced by silicon diodes by 1960. [130]

Incremental changes in the way reduction pots were operated led to increased yields of up to 250 pounds per day per pot by 1940. In alloys and fabrication, Alcoa moved beyond its version of the Duralumin alloy, 17S, to two new alloys, 25S and 24S. By the end of the 1930s, Alcoa could claim that 23 of 27 basic alloys and 17 of 20 wrought alloys in use by industry had been developed by Alcoa scientists. In 1940, Frary had 220 scientists working under him with advanced technical degrees. He allocated up to 25% of his total research budget to fundamental research by scientists who were prominent in their fields. The company boasted 16 chemical labs, 11 physical testing labs and one motor lab, altogether employing 554 people with a $1.75 million annual operating budget. [131] Alcoa's research and development facilities also helped with the company's drive to create new uses for aluminum as a way to expand the consumer market.

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[2] Junius David Edwards, "The Aluminum Industry in Two Volumes, Aluminum and its Production," 1930 [AL1359]
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