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Early **Aluminum** Production in the **Pacific Northwest**

Bob Voller, Guest Author

Aluminum is the most common metal in the Earth's crust, and various natural oxides of aluminum are found in many forms. Pure aluminum metal is produced by reducing the oxide in an electrolytic reduction cell. So while the raw material component of the final cost of metallic aluminum is quite low, the cost of energy to produce the metal can be significant. Hence, the aluminum smelting industry tends to locate in areas where the cost of electrical energy is low.

In 1940, an aluminum-rich red clay called bauxite was mined and refined in the southern part of the United States. The resulting aluminum oxide was a coarse white powder referred to as alumina. It was shipped in bulk by boxcar or tank car as feedstock for the smelters. Approximately 2 lb of alumina was required for each pound of aluminum produced.

The Process

In an electrolytic cell, carbon anodes conduct dc current through a molten salt containing aluminum oxide, housed in a carbon-lined cell (cathode). Molten aluminum forms in the bottom of the cell, where it can be tapped off to cast ingots. These cells are referred to in the industry as pots, and complete installations called pot lines are housed in pot rooms. During 1940, these pots were approximately 7-ft wide by 23-ft long. A typical pot line consisted of 130 pots connected in series, with a current rating of about 40,000 A. In 1940, this configuration required approximately 8 kWh of electrical energy to produce 1 lb of molten aluminum.

PURE ALUMINUM METAL IS PRODUCED BY REDUCING THE OXIDE IN AN ELECTROLYTIC REDUCTION CELL.

The Invitation

In an effort to provide employment during a severe depression, the U.S. government started two huge projects on the Columbia River: 1) the Grand Coulee Dam in north central Washington State and 2) the Bonneville Dam on the river between Washington and Oregon about 80 mi upstream from Vancouver, Washington. Construction of the Bonneville Dam began in June 1934, and its commercial operation was achieved in 1938. The initial wholesale cost of power was US$17.50/kW year (0.2 cents/kWh), a rate that was maintained for the next 28 years.

President Roosevelt invited the Aluminum Company of America (now ALCOA) and Reynolds Metals to build aluminum smelters in the northwest to utilize this electrical power and provide employment in the region. ALCOA purchased property in Vancouver, Washington, in December 1939 and poured the first ingot on 23 September 1940.

Reynolds Metals purchased the property for a smelter in Longview, Washington, in 1940. By this time, with war raging in Europe, the U.S. government saw a strategic need to increase aluminum production for the impending defense effort and agreed to underwrite the construction of the Longview facility. The smelter went into production in September 1941.

The War Expansion—1942

As part of the buildup in aluminum capacity required for the war effort, the federally funded Defense Plant Corporation (DPC) subsequently built additional aluminum-reduction plants in Troutdale, Oregon; Mead, near Spokane; and Tacoma, Washington. To save precious time, the engineering design from the Vancouver plant was duplicated, and the facilities were operated by ALCOA and other contract personnel. Besides these reduction facilities, the DPC also built the Trentwood rolling mill near Spokane to supply aluminum sheet and plate to Boeing and other west coast airplane manufacturers.

After the war, the government disposed of the DPC aluminum facilities

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to foster competitive conditions within the primary aluminum industry. Having had a virtual monopoly on aluminum production, ALCOA was excluded from acquiring any of these plants. The Mead, Tacoma, and Trentwood facilities were leased to and eventually purchased by Kaiser Aluminum and Chemical Corporation. The Troutdale smelter was sold to Reynolds Metals.

The Rectifier Station

Earlier installations of large, 12-phase rectifiers systems in Tennessee resulted in a significant production of 11th and 13th harmonics that caused serious communication problems on the telephone network in the southern part of the United States. These rectifiers had to be shut down until the design could be converted to a higher-phase order that minimized harmonic generation. So the designers of the facilities in the northwest knew at the beginning that they needed to employ a 36-phase design to avoid this problem.

The pot lines were constructed in a U shape, with the substation and rectifiers station located at the top of the U. A typical pot line was supplied by 72 rectifiers arranged in six groups of 12. Each group was supplied by a rectifier transformer, rated at 7,500 kVA and 13.8 kV/600 V.

The rectifier transformers had dual-wye secondaries connected in a star configuration. Three transformers had wye-connected primaries, and the other three transformer primaries were connected in delta to provide a 30° phase shift. The addition of four 10°, phase-shifting autotransformers, two lead and two lag, completed the installation (see Figure 1). This resulted in a 36-phase ac supply to the rectifiers, reducing the ripple in the dc current and minimizing telephone system interference. The six rectifier transformers were supplied by one 13.8 kV, 40,000 kVA load tap changing autotransformer to control pot line voltage.

Ignitrons

At the time of these developments, the best available technology for high-current rectification was the mercury arc rectifier or ignitron.

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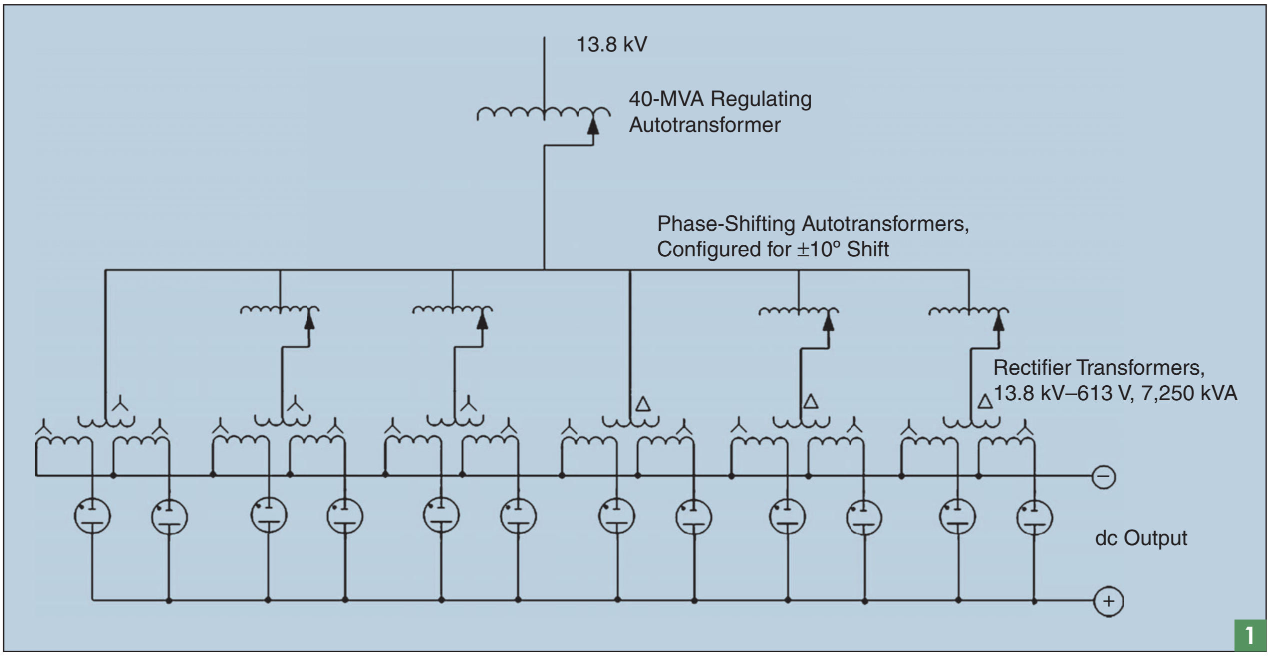
Ignitron rectifiers were introduced a number of years earlier, but it was not until 1940 that the first large installation of single-anode rectifiers was completed at the ALCOA Vancouver Plant (Figure 2). Ignitrons consisted of steel tanks, approximately 2 ft in diameter and 3 ft high, containing the mercury pool, ignitor, and water-cooling jacket. A single-graphite anode was suspended by an insulator bushing in the top. A 1-μm vacuum was maintained by continuously running vacuum pumps. Application of 100 V and 10 A to the ignitor produced a mercury cloud that initiated the conduction of each cycle. Ignitrons were rated at about 95% efficiency.

Voltage control was obtained by phase control of the ignitor signal. The practical limit for single-anode ignitrons was 15%, before an undesirable increase in the number of arc-backs. The addition of a load tap changing the transformers in the supply circuit to a group of paralleled rectifiers provided a means of voltage control, without the power factor penalty associated with retarded rectifier phase control.



Electrical arrangement of the rectifier station.

An arc-back is an occurrence where the ignitron passes current in both directions, causing a short circuit on both the ac and dc systems. This results in the tripping of the anode circuit breaker. No permanent damage is done, and the circuit can be reenergized in a matter of seconds. However, the arc-back is accompanied by a loud report, which can be compared to the discharging of a shot gun in a large steel barrel. This was very disconcerting to the station operators. Early work at the Vancouver plant determined that arc-backs were caused by manufacturer-specific manufacturing defects. One cause was contamination of the mercury by porcelain dust. Another cause was mercury splashing on the anodes because of poorly baffled vacuum openings. Satisfactory operation of all the ignitrons was finally attained by 1945. It was interesting to note that the electrical maintenance personnel also purified 13,000 lb of mercury by distillation in addition to their other duties that year.

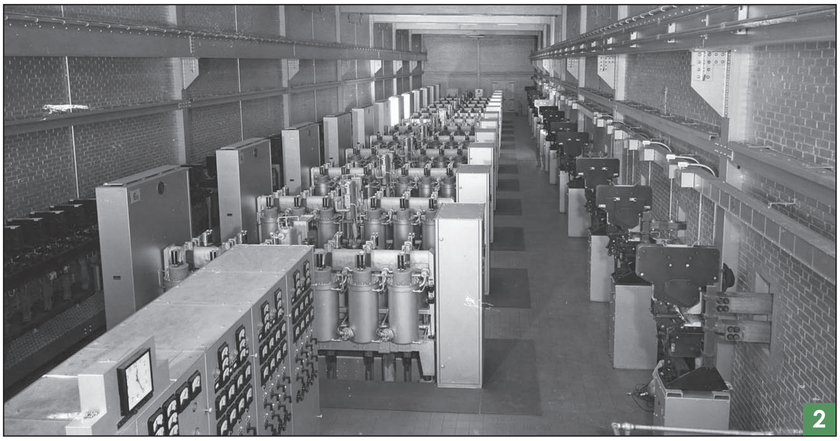
By 1960, the ignitron was virtually obsolete as a source of dc for industrial processes. Silicone diodes with a forward drop of 2–3 V replaced the ignitrons with their 15–20-V drop.

Several companies manufactured diode assemblies in a mechanical configuration suitable for direct bolt-on replacement of the ignitrons.

Epilogue

With the increase of electrical energy costs in the 1990s, all of the 1940 vintage aluminum reduction plants fell on hard times. In spite of the incremental improvements to process control and equipment, all the plants eventually closed. By 2009, all of these plant sites have been razed and are being marketed as new industrial sites.

Between 1955 and 1971, five additional aluminum reduction plants were constructed in Washington, Oregon, and Montana. At the end of 2009, only the ALCOA facilities at Wenatchee and Ferndale, Washington, were in operation.



Ignitron room at the Vancouver, Washington, aluminum smelting facility in 1941. (Photo courtesy of Schenectady Museum/Hall of Electrical History.)

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