4.3.4 ALUMINUM INDUSTRY: PERFLUOROCARBON EMISSIONS

Technology Description

Primary aluminum production is the largest source of emissions of perfluorocarbons in the United States. Mitigation technologies and measures cannot only reduce emissions, but they also can improve process efficiency. (Reprinted with permission of Greenleaf Publishing.)

Aluminum is produced through the electrolytic reduction of alumina (AL_2O_3). The electrolytic Hall-Héroult process was adopted in the late 19th century, and continues as the process in commercial use today. Producing aluminum by the conventional electrolytic cell process requires a large amount of energy and produces significant emissions of greenhouse gases. The Hall-Héroult process results in direct emissions of CO_2, due to the consumption of the carbon anode, and also perfluorocarbon emissions. Within the electrolytic bath, the alumina is dissolved in a mixture of molten cryolite (Na_3AlF) and aluminum fluoride (AlF_3). Perfluorocarbon emissions are formed as intermittent byproducts within the aluminum smelting pot as the result of operational disturbances called anode effects. Anode effects occur when there is an over-voltage disturbance of the smelting process and are triggered when alumina levels in the pot decline below a critical level. During these events, the fluorine from the cryolite bath reacts with the carbon anode to form tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6). Primary aluminum production is the largest source of emissions of perfluorocarbons in the United States. Greenhouse gas emission reduction measures not only reduce perfluorocarbon and other greenhouse gas emissions, but they also can improve process efficiency. The United States is one of the largest global producers of primary aluminum and, as of 2000, there were 11 U.S. companies that produced primary aluminum.

System Concepts

- Current efforts to reduce perfluorocarbon emissions from primary aluminum production focus on using the most efficient smelting processes to reduce the frequency and duration of anode effects. Perfluorocarbon reduction potential varies by smelter technology with point-feed technology the most efficient – and Søderberg technology the least efficient. Another concept, now in the research and development phase, involves replacing the carbon anode with an inert anode. Doing so would completely eliminate process-related perfluorocarbon and CO_2 emissions.

Representative Technologies

- Currently available perfluorocarbon mitigation technologies and practices include computerized controls and point-feeder systems, as well as improved operating practices that minimize the frequency and duration of anode effects and associated emissions. When using the Hall-Héroult process, perfluorocarbon emission reductions could be achieved through retrofitting existing cells, converting older technologies, and using advanced technologies. Emerging technologies include use of the inert anode mentioned above.

Technology Status/Application

- Computerized controls, point-feeder systems, and improved operator practices vary in their cost-effectiveness and ability to reduce emissions. Further research regarding anode effects could yield additional cost-effective emissions reductions. The Department of Energy, through its Industries of the Future strategy, supports research and development of the inert anode. Being noncarbon, the inert anode would eliminate PFC emissions. Laboratory, pilot-scale, and commercial-scale testing of inert anodes is currently underway.

A commercially viable design is expected by 2005. Commercialization can be expected by 2010-2015. Use of the inert anode technology will most likely be in conjunction with wetted cathode technology as part of an advanced technology cell. The advance technology cell is a combination of an inert anode, which would not be consumed during electrolysis, and a cathode with a stable surface, which would reduce electricity requirements.

Current Research, Development, and Demonstration

RD&D Goals

- If successful, the nonconsumable, inert anode technology would have clear advantages over conventional carbon anode technology, including energy efficiency increases, operating cost reductions, elimination of perfluorocarbon emissions, and productivity gains.

RD&D Challenges

- A number of critical technology barriers prevent the aluminum industry from the targets it has identified for inert anode technology. These challenges represent the difference between present-day carbon anode technology and the current state of nonconsumable anode technology. Challenges include:
  - Demonstration of "viable" inert materials for use in fabricating the anodes, including fabricating candidate materials in large sizes, and the means for scaling up the fabrication processes.
  - Basic knowledge of the operation of nonconsumable anodes.
  - Validation of the potential for full-scale process improvement.
  - Computer modeling to address retrofitting issues.

RD&D Activities

- DOE is leading the effort in producing inert anode technologies.

Recent Progress

- Use of the most efficient aluminum processing technologies, such as point-feed technology, has resulted in reducing perfluorocarbon emissions from U.S. primary aluminum production by more than 40% since 1990.

Commercialization and Deployment Activities

- High-efficiency smelting technologies (e.g., point-feed technology) and options for retrofitting the Hall-Héroult process are commercially available. A commercially viable inert anode design is not expected to be available until 2005.

Market Context

- Retrofit capability is a key issue with inert anode technology. If the new technology is technically and economically successful – but, ultimately, cannot be retrofitted to existing cells – it will still be considered a success. However, the ability to retrofit would be considered a major benefit, and would improve the technology's economics.