ALUMINUM PRODUCTION BY CARBOTHERMAL REDUCTION OF ORE TO AL-SI ALLOY USING HIGH-TEMPERATURE SOLAR PROCESS HEAT

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ABSTRACT – The production of aluminum or silicon by reduction of their oxides with carbon is a technical challenge. The temperature required, in the range 2100–2300 °C, is too high for practical process heat addition from a combustion source alone. In industry, an electric arc or plasma arc furnace is used for high-temperature production of metals, but then only a fraction of the energy contained in the fuel used to generate electricity enters the process. Thus the energy cost dominates the cost of the final product. By contrast, highly-concentrated solar energy is capable of supplying large amounts of process heat at very high temperatures, and may have real advantages for metals reduction processes. The gross thermal energy requirements for a direct-reduction aluminum process are comparable to or greater than the current electrolytic Hall-Héroult process. But thermal processes have a higher volumetric efficiency, and thus much lower capital costs than electrolytic processes. It is this potential for savings that drives the industry to continue its search for a thermal route to producing aluminum. However, the very nature of either combustion – or electrothermal – process heat presents serious limitations on the process itself.
The high energy density of an arc introduces too much energy to the reaction zone, causing undesirable carbide production and loss of metal through vaporization. In the case of aluminum, the metal floats on top of the slag, causing further difficulties. The aluminum industry now uses nearly 10% of the electricity generated globally to produce primary aluminum, and about half comes from coal-fired generation stations. A solar-thermal process would drastically reduce the emission of climate-altering gases, reduce the reliance on electricity, and might be a critical factor in making a direct thermal route from the ore to metal possible. The Alcoa direct reduction research of the last half century, with a starting alumina-silica containing ore and either a pure Al or Al-Si product is an excellent demonstration process for a technology near to its pilot plant stage. Using an Alcoa cost analysis for a greenfield aluminum-silicon arc-reduction plant that included a coal-fired generating station, and a recent Weizmann Institute study of costs of solar process heat it is possible to make a preliminary cost comparison of the capital costs for these two forms of process heat. Comparing the capital costs associated with each form of process heat, and adding in the Present Value of coal that would be consumed by the electric generator, the costs for the solar process heat are lower even though no credit has been given for the greatly reduced CO_2 emissions: \$0.43/kWh for the electrothermal process and \$0.33/kWh for the solar process.

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