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PHASE II CALDERON PROCESS TO PRODUCE
DIRECT REDUCED IRON
RESEARCH AND DEVELOPMENT PROJECT

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QUARTERLY TECHNICAL PROGRESS REPORT
PHASE II CALDERON PROCESS TO PRODUCE DIRECT REDUCED IRON
RESEARCH AND DEVELOPMENT PROJECT

CALDERON ENERGY COMPANY
COOPERATIVE AGREEMENT NO. DE-FC22-95PC92638

Reporting Period: 7-01-01 to 9-30-01

Date of Report: 10-24-01;

Phase II Award Date: 6-23-00; Anticipated Completion Date: 12-03-03

Total Project: \$ 25,814,000.00 Budget II Total DOE Share This Action: \$6,457,000.00

Contracting Officer's Representative (COR): Carl Maronde;

Project Director: Albert Calderon

Assistant Project Director: Reina Calderon

Abstract

This project was initially targeted to the making of coke for blast furnaces by using proprietary technology of Calderon in a phased approach, and Phase I was completed. The project was then re-directed to the making of iron units. U.S. Steel teamed up with Calderon for a joint effort which will last 30 months to produce directly reduced iron with the potential of converting it into molten iron (hot metal) consistent with the Roadmap recommendations of 1998 prepared by the Steel Industry in cooperation with the Department of Energy. The work which is labeled as Phase II will take place at two levels; namely, the bench scale level and the process development unit (PDU) level. The bench scale work is being divided into two parts; the construction and operation of Bench Scale #1 to make hot metal direct as one part and the construction and operation of Bench Scale #2 to make DRI with its conversion to hot metal as the second part. The work at the PDU consists of getting the PDU which exists ready for advancing the activities from bench scale to PDU level.

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Introduction

The commercialization path of the Calderon technology for making a feedstock for steelmaking with assistance from DOE initially focused on making coke and work was done which proved that the Calderon technology is capable of making good coke for hard driving blast furnaces. U.S. Steel which participated in such demonstration felt that the Calderon technology would be more meaningful in lowering the costs of making steel by adapting it to the making of iron - thus obviating the need for coke.

U.S. Steel and Calderon teamed up to jointly work together to demonstrate that the Calderon technology can produce iron units from iron concentrate (ore) and coal quite competitively by eliminating pelletizing, sintering, coking and blast furnace operation. Such demonstration would also prove that, potentially, a significant reduction in pollution would occur including the minimization of greenhouse gases and specifically CO₂ by virtue of Calderon's technology being efficient and closed.

Accomplishments and Discussion

During the past quarter significant progress was made in the following areas:

- Mechanical debugging of Bench Scale #1 for making hot metal direct and start-up its operation.
- Design of Bench Scale #2 for making DRI.
- Completion of the maintenance work at the PDU.

In making hot metal from a mixture of ore concentrate and coal, there are three challenges. The first challenge is the feeding of the solids; the second is the heating of these solids in order to bring them to condition to react; and the third is the reacting of the materials under such conditions as to obtain acceptable metallized iron.

Debugging Bench Scale #1

In operating Bench Scale #1 while cold there were no problems in pushing the mixture of ore and coal through the reactor; however, plugging of the reactor occurred while the reactor was operated hot. When the charger was taken apart it showed that the material had packed solid at the entry of the reactor (see photograph #1). In addition, fines migrated between the pushing ram and the housing (see photograph #2) and these fines packed in such a way that prevented the ram from applying the needed pushing force.

The solution to the solid feeding problems were solved as follows: (i) the reactor was shortened to minimize drag (photograph #3); (ii) the taper was doubled to give more relief; and (iii) the entry to the reactor was made of stainless steel to overcome corrosion problems created by the oxidation properties of the ore concentrate (photograph #4). With these changes, the feeding of the ore and coal has presented no problems except in one instance when the lance was too far into the reactor and operated at a high oxidant input rate. Since that single incident, the pushing of the charges has operated flawless including when operated at a reactor exit temperature exceeding 2400°F (photograph #5).

In heating the charge in the system, initially, the charge is pre-reduced in the reactor and then reduced as it exits into the elbow, thence it is melted in the homogenizer. For a cold start, the reactor is filled with the mix of ore and coal, and an oxy-acetylene torch is used to ignite the coal in the charge. Once ignition of the coal takes place, the oxidant is introduced through a lance to begin combusting the coal and the operation of heating the charge begins. The oxy-acetylene torch is withdrawn and turned off. From here on the only fuel used is the coal which is introduced with the mix. The conversion of the coal into thermal energy in the process is efficient enough to cause the heating and the melting of the charge using the

carbon and some of the gases of the coal acting as reductants. The release of energy becomes intensive to cause the charge to melt and flow out of the bottom of the homogenizer.

In developing a procedure for operations, initially, the molten product was discharged into a pool of water (photograph #6); about two weeks later, the pool of water was replaced by a holding tank sealed to the bottom of the homogenizer; the tank was provided with two ports, one for sampling the “product” and the other for the exhaust of gases (photograph #7). To control emissions, a flexible metallic duct was connected to a drum which was modified internally to serve as a simple cyclone for particulate removal. This cyclone was vented by means of a vertical pipe through a hole in the roof of the building, and a by-pass equipped with a rupture disk was also provided to discharge into the vertical pipe in an emergency (see photograph #8).

Material produced from the process was tested; there is evidence that the coal did convert to a coke, united with the ore and did melt to form a bound “product”. In one of the tests a portion of the “product” was metallized to 80% with energy solely derived from coal.

Design of Bench Scale #2

Progress was made in the preliminary concept design of Bench Scale #2 with respect to length of reactor, its lining, flues configuration, and manner of heating. There is an agreement between U.S. Steel and Calderon to locate Bench Scale #2 in one of the buildings at Calderon’s PDU site in Alliance.

Completion of Work at the PDU

Other than painting, all of the maintenance work has been completed.

Conclusion

During the forthcoming quarter the following are the objectives:

Work with Bench Scale #1 will continue with the goal of producing acceptable metallized iron from ore concentrate plus coal (see photograph #9).

Detailed design on Bench Scale #2 to be completed and orders placed for fabrication.

Work at the PDU will be re-started after satisfactory results are obtained at bench scale and the Environmental Assessment is completed by NETL.

Submitted by:

Albert Calderon
Project Director

PHOTOGRAPH #1

PHOTOGRAPH #2

PHOTOGRAPH #3

PHOTOGRAPH #4

PHOTOGRAPH #5

PHOTOGRAPH #6

PHOTOGRAPH #7

PHOTOGRAPH #8

**Iron Ore Concentrate
+
Coal
into Molten Product**

PHOTOGRAPH #9