Report Title:

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

Report Type:

QUARTERLY

Reporting Period Start Date: 07/01/2003 End Date: 09/30/2003

Principal Author(s): **ALBERT CALDERON**

Report Issue Date: 10/22/2003

DOE Award No.: DE- FC22 - 95PC92638

Submitting
Organization(s)

CALDERON ENERGY COMPANY

500 Lehman Avenue

Name & Address

P.O. Box 126

Bowling Green, OH 43402

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(2)

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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: 7-01-03 to 9-30-03

Date of Report: 10-22-03;

Phase II Award Date: 6-23-00; Anticipated Completion Date: 12-03-04

Total Project: \$ 14,732,316.00 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 successfully completed. The project was then re-directed to the making of iron units. In 2000, U.S. Steel teamed up with Calderon for a joint effort which will last 42 months to produce directly reduced iron with the potential of converting it into molten iron or steel consistent with the Roadmap recommendations of 1998 prepared by the Steel Industry in cooperation with the Department of Energy by using iron ore concentrate and coal as raw materials, both materials being appreciably lower in cost than using iron pellets and coke.

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Executive Summary

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.

The fact that U.S. Steel and Calderon teamed up to jointly work together to demonstrate that the Calderon technology will produce in a closed system iron units from iron concentrate (ore) and coal competitively by eliminating pelletizing, sintering, coking, blast furnace operation and possibly doing away with the BOF and the EAF by making steel directly, a huge reduction in CO₂ generation relating to steelmaking would ensue. Such reduction will restructure the steel industry away from the very energy-intensive steelmaking steps currently practiced and drastically reduce costs.

As the tariffs imposed on steel imports will cease by 2005, the development of a technology to lower U.S. steelmaking costs and become globally competitive is a priority of major importance. Therefore, the development work which Calderon is conducting presently under this Agreement with the U.S. Department of Energy becomes more crucial than ever. To demonstrate feasibility of the Calderon process U.S. Steel set a target for metallization of 80%. Calderon met 90% of the 80% target (72.3% metallization). Steps were taken during the past quarter to make changes to the equipment to overcome the impediment which prevented the attainment of 80% or better metallization of the iron ore concentrate.

Experimental

It has been discovered that drum changes during the test runs, penalize the steady state operation of the system by virtue of cooling the exit end of the reactor. After attaining the 90% target of the set goal, it was decided to take the necessary steps to eliminate the feed of the produced material from the reactor into drums, and feed it directly into a refractory lined vibrating feeder whose operation will not disrupt the steady state. Such feeder was ordered. During the fabrication of the feeder a layout was prepared showing the assembly of the existing equipment and its integration with the feeder (see Drawing No. DRI-C7 attached). Also preparations to receive the feeder were made. The manpower crew was divided into two parts. One part of the personnel which was qualified to do construction work was assigned to make physical changes to the facility and the other part was assigned to do work relating to coal gasification which was outside the scope of the contract with NETL; the costs for the gasification work were not charged to the contract. It is for this reason that the monthly billings to NETL were reduced. Because of the design, fabrication and construction work to replace the drums, no experimental work was performed on making iron during the period that this report covers.

Results and Discussion

During the entire quarter the activities centered on the changes that needed to be made to the existing equipment to accommodate the installation of the feeder. The feeder which weights 9,500 lbs was delivered on time; see photograph 1. To accommodate it the following works was performed:

- ! Track wheel assemblies (see photographs 2 and 3) adapted to be raised and lowered were designed, fabricated and installed to the feeder to enable the entire feeder to be rolled away from the material receiving position of the reactor in order to make possible the inspection, cleanup and repair of the bottom of the reactor elbow, and also be out of the way during preheat at start-up.
- ! A new structural steel support was designed, fabricated and installed (see photograph 4) in order to accommodate the feeder whose height exceeded the height of the drums previously used.
- ! A sectionalized cover for the top of the feeder (see photograph 5) was designed, fabricated and installed having special features to enable the sealing of the feeder's pan with the cover wherein the feeder pan vibrates during operation and the cover remains fixed.
- ! Two supporting carriages rolling on tracks, one for the reactor (see photographs 6 and 7) and one for the charger (see photographs 8 and 9) were designed, fabricated and installed on top of the support structure to enable the movement of the reactor and/or the charger for maintenance.
- ! A new off-gas discharge spool was designed, fabricated and lined (see photographs 10 and 11) for attachment to the bottom of the elbow.
- ! A transition was designed and fabricated for interconnecting the spool to the feeder cover (see photographs 12 and 13) for disengagement from the spool when the feeder is rolled away from the material receiving position of the reactor.
- ! Other miscellaneous work consisted of refractory repair to the discharge end of the elbow; re-routing the exhaust for the off-gas; re-routing the hoses for the

cooling water to and from the oxygen lances; and lining various components with insulation and refractories.

Several challenging issues arose in trying to integrate the feeder to the other components to obtain the desired operation:

1. The feeder must rest on the concrete floor when vibrating and must be off the floor when being moved.
2. The cover over the vibrating pan of the feeder being made of metal and being lined adds considerable weight to the vibrating pan. It was decided for the pan to vibrate and for the cover to remain fixed.
3. How is the pan sealed to the cover to prevent emissions when the pan vibrates and the cover does not.
4. How is the hot material entry port in the cover interconnected with the elbow so that the cover can disengage from the spool below the elbow when the feeder is moved from under the elbow, and still remain sealed when the feeder is operational under the elbow.

These challenging issues were addressed as follows:

The main components of the equipment to practice the Calderon process for making iron/steel direct consists of the materials charger, the reactor, the elbow, the oxygen lances, the off-gas spool, the transition, the vibrating pan cover and the vibrating pan itself.

In past reports, the charger, the reactor, the elbow and the lances were described in detail and no changes were made to these components. The off-gas spool which is fixed and rigidly connected at the top to the bottom of the elbow possesses a recess which is provided with a sealing ceramic rope imbedded in a special groove at the bottom of the spool. The

transition which is adapted to be raised and lowered mechanically and is refractory lined, possesses a rim at the top (see photograph 13) that when it is raised this rim presses against the rope that is imbedded in the bottom of the off-gas spool to form a tight connection between the spool and the transition and prevent gas leakage. The bottom end of the transition penetrates the hot material entry port. The transition is adapted to be raised towards the spool and lowered away from the spool by mechanical means in order to interconnect and disconnect the hot material entry port in the cover of the pan, to and from the fixed off-gas spool. A recess for the containment of a ceramic rope (see photograph 14) for circumferencial sealing of the transition shell is provided in the cover. Thus the transition is the interconnection which seals the cover to the off-gas spool via the transition. In sealing the cover to the vibrating pan of the feeder, a ceramic rope is imbedded in the walls of the cover (see photograph 15) to provide a longitudinal seal.

In lining the vibrating pan of the feeder and its cover it was decided to divide the vibrating pan and its cover into two sections:- a lined section which is under the drop point beneath the elbow of the reactor where the +2500°F material drops, and an unlined section downstream of the drop area. The drop point was intentionally made depressed (see photograph 16) so as to accommodate room for the thickness of the lining at the drop point. A screen was also added to the unlined section (see photograph 17) in order to remove fines while the material is cascading along the vibrating pan. To minimize heat loss at the drop point of the vibrating pan, a composite lining was provided. An insulating compound good for 2600°F was first applied (see photograph 18) and next a chrome-alumina refractory called “ruby” which is good for +3200°F was vibrated in place (see photograph 19).

In lining the cover of the vibrating pan it was decided to only line that section which is above the drop point of the vibrating pan in order to minimize heat loss at that location. For this reason the cover was made into two parts (see photograph 5). The lined part was provided with stainless steel anchors which were welded to the steel shell of the cover (see photograph 16). An insulating board good for 2600°F was installed, with the anchors positioning the board and flat nuts securing them in order to prevent them from falling down from the cover (see photograph 20) when the insulation in the cover is in suspension. A thick coat of ruby (refractory) was applied to the surface of the insulating board to give it strength and also to cover the flat nuts that secure the board to prevent them from melting (see photograph 21). Once the lining and insulation of both the hot section of the feeder and its cover were completed, they were assembled and gradually heated (see photograph 22) for 24 hours to slowly drive the moisture out of the lining to minimize cracking of the lining.

Conclusion

The main components of the equipment have been assembled. It is planned to resume testing next quarter with the goal of achieving 80% minimum metallization of ore concentrate with coal in a 72 hour run at a reasonable steady state as agreed with U.S. Steel.

Submitted by:

Albert Calderon
Project Director

References - Not Applicable

The work performed in this quarter which the report covers, was original work. No reference material was relied upon for the work

CALDERON ENERGY CO.
 1000 W. 10TH ST., CHICAGO, ILL. 60607

CONTRACT NO. _____ PROPOSAL NO. _____
SUPPORT STRUCTURE GENERAL ARRANGEMENT

DRAWN BY LA CHECKED BY LA APPROVED BY LA
SCALE 3/4" = 1' SURT DATE 9-15-03 DRAWING NO. DRI C7

**Hot Material
Drop Point**

1.

Vibrating Feeder as Received

2.

Rear Mechanism for Raising & Lowering
Vibrating Feeder

**Flanged
Wheel**

**Hoisting Worm
Drive**

3.

**Front Mechanism for Raising & Lowering
Vibrating Feeder**

Elbow

4.

Supporting Structure

**Hot Material
Entry Point**

**Insulated
Section**

**Uninsulated
Section**

5.

Vibrating Pan Cover over Feeder

**Supporting
Structure**

Reactor Carriage

6.

Reactor Carriage on Structure

7.

Reactor on Carriage at Assembly

**Carriage
Track**

**Supporting
Structure**

8.

Charger Carriage on Structure

9.

Charger, Reactor & Elbow Mounting

10.

Off-Gas Spool

Off-Gas Exit Port

**Ruby
Lining**

11.

Off-Gas Spool

12.

Transition

Sealing Rim

13.

Interconnecting Transition

Sealing Rope

14.

Feeder Cover Entry Port for Transition

Ceramic Rope Seal

15.

Insulated Cover (turned upside down)
Showing Longitudinal Sealing

**Cover above Drop
Point to be Insulated**

**Cover downstream from Drop
Point to Remain Uninsulated**

**Depressed
Drop Point
Insulated
and Lined
with Ruby**

**Stainless
Steel Pins
to Secure
Insulation**

16.

**Vibrating Pan of Feeder with Cover
Prior to Lining**

**Depressed Section
for Lining**

Screen

Unlined Section

17.

Part of Vibrating Pan

Insulating Compound

18.

Hot Material Drop Point
Of Vibrating Pan

Ruby Lining

19.

Hot Material Drop Point
Of Vibrating Pan

Entry Port

**Securing
Washers**

**Insulated
Board**

**Stainless
Steel Pins**

20.

Insulating the Pan Cover

**Ceramic
Rope**

**Insulation
Board
Covered
With a
Coat of
Ruby**

21.

Insulated Cover (turned upside down)
Showing Circumferential Sealing

Vibrating Feeder

22.

Slow Drying of Insulation & Refractory