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Calderon Cokemaking Process/Demonstration Project

Quarterly Report
November 26, 1996 - February 25, 1997

Work Performed Under Contract No.: DE-FC22-95PC92638

For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
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CALDERON COKEMAKING
PROCESS/DEMONSTRATION PROJECT

Quarterly Technical Report

Reporting Period: Start Date: 11/26/1996 End Date:02/25/1997

Aurthor: ALBERT CALDERON

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DE-FC22-95PC92638 --07

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FINAL QUARTERLY TECHNICAL PROGRESS REPORT

CALDERON COKEMAKING PROCESS/DEMONSTRATION PROJECT
CALDERON ENERGY COMPANY

COOPERATIVE AGREEMENT NO. DE-FC22-95PC92638

Reporting Period: 11-25-96 to 2-25-97

Date of Report: 3-24-97; Award Date: 5-25-95; Anticipated Completion Date: 11-25-97

Total Project: $ 7,354,195.00 Total DOE Share: $3,039,389.00

Contracting Officer's Representative (COR): Mr. Michael J. Baird

Project Director: Albert Calderon

Abstract

This project deals with the demonstration of a full size commercial coking reactor (Process Development Unit) using Calderon's proprietary technology for making coke. Originally, the retort was designed to produce two (2) tons of coke/hour. Because of economic reasons, the reactor had to be scaled up to produce eight (8) tons of coke/hour. This scale up necessitated the re-designing of the retort and its components including a revision to the permit. The activities of the past quarter were focused on preparing a comprehensive technology assessment for Bechtel's internal use. A new permit was prepared and it shall be submitted to Ohio EPA after Bechtel reviews it; such review is scheduled to be completed by March 31, 1997.

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Executive Summary

During this reporting period an agreement was entered into with Bechtel Corporation for design and construction of Calderon cokemaking facilities (see enclosed letter of February 28, 1997). A second agreement with Bechtel Enterprises to commercialize the Calderon technology as a worldwide business has progressed; during the forthcoming quarter, it is expected to have in place an agreement with Bechtel Enterprises (see attached letter of February 20, 1997). Thyssen Still Otto Anlagentechnik (TSOA), the world's largest builder of conventional cokemaking facilities indicated that it would be please to join Bechtel and Calderon in the demonstration and implementation of Calderon's cokemaking technology (see attached letter of January, 1997).

Introduction

At the June 1993 American Iron & Steel Institute meeting of the Technical Committee on Coke Oven Practice, Albert Calderon presented his concept for the production of metallurgical coke in a totally enclosed reactor with syngas production.

At that time, Calderon's process included a coking reactor and a hot gas cleanup. A measured amount of coal is pushed into the cold end of the reactor which causes coke to be discharged from the hot end. This coke is quenched by a closed coke quenching system. The gas from the coal is thermally cracked and desulfurized in a Hot Gas Cleanup (HGCU). All operations are carried out from a control room. Several major changes have been made to the process and will be discussed in a more detailed description which will be presented later.

After the 1993 presentation and subsequent visits to the existing Process Development Unit (PDU) in Alliance, Ohio, the committee concluded that the idea had enormous potential and formulated a 1994 Work Plan to establish whether or not the process merits further study as a viable cokemaking alternate. The work plan sub-committee included Gus Mautz (LTV), Brian Hatch (Stelco) and Jack Garzella (Acme). Status of the project is reported at every Coke Oven Committee meeting and the work plan is continuing in 1997.

In January 1994 Calderon presented a proposal to LTV to supply coke and gas at the Cleveland Plant. Since that time, LTV has assisted Calderon in the development of the test project at the PDU with technical support, coal and coke testing and securing financial resources.

In October 1994 Calderon contacted Thyssen Still Otto Anlagentechnik (TSOA) to determine the interest of a coke oven builder in the process. Over the ensuing twelve months, information on the process was disclosed to TSOA.

Results and Discussion

TSOA EVALUATION OF THE PROCESS

TSOA consulted with cokemaking researchers, operators and designers from their company, the University of Aachen, the German Coal & Coke Research Institute (DMT) and Ruhrkohle to come to the following conclusions:

- [Calderon's] new technology to produce blast furnace coke is revolutionary and could have a significant impact on the direction of the future cokemaking industry.[1]

- Taking into consideration all positive aspects of this technology, the consequence follows that the conventional coke plant for green field sites will have no future anymore.[2]

- You are aware of our positive attitude to [the Hot Gas Cleanup] process section. ...we are convinced that the hot gas cleanup process can be marketed independently.[3]

- We are convinced that your conceptional approach to the heating and coking tube as well as to the structure of the coking chamber is the right approach giving good cause to expect the desired results.[4]

- ...we do have substantial doubts and concerns regarding the physical and chemical properties of commercially useable metallic materials. However, we do not want to rule out that there will nevertheless be a design solution with suitable materials which will fulfill both the technical and economic requirements.[5]

In an effort to reduce the effects of the physical and chemical attacks to the alloy, Calderon decided to change the process to coke at low temperatures and calcine the coke in a separate vessel. Low temperature coking tests conducted at the LTV Technology Center confirmed that high quality coke could be produced with the low temperature/calcining method.

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[1] TSOA letter from D. Stalherm and R. Worberg to the TSOA Board of Directors, December 12, 1994
[2] ibid.
[3] TSOA letter from D. Stalherm and R. Worberg to Albert Calderon, July 6, 1995
[4] ibid.
[5] ibid.

As a result of these tests, TSOA again evaluated the process and offered the following:

- We are in agreement with your opinion that a two-stage process will provide coke of acceptable quality and strength.[6]

- We believe, however, that due to the low temperatures utilized in the coking tube, and the resulting significant increase of the coking time, a plant based on this technology loses its economic advantage and competitive edge.[7]

BECHTEL EVALUATION OF THE PROCESS

At the same time TSOA was evaluating the low temperature/calcining method, Calderon approached Bechtel Corporation with the technology. The Bechtel evaluation of the process led to the same conclusion as TSOA; the number of reactors required for the low temperature coking and the price of the alloy made the process economically uncompetitive.

Calderon then changed the design of the reactor by substituting silicon carbide for the alloy as the material for the reactor. The spiral flue around the outside of the alloy was replaced by longitudinal flues cast into the silicon carbide tiles. Most importantly, silicon carbide is not susceptible to chemical attack of the coke gas and can be operated at temperatures up to 3000^{o}F. At the selected operating temperature of 2300^{o}F and with the addition of dry coal feed, the coking time was reduced to approximately nine hours. This combination reduced the number of reactors by 75%.

Bechtel revaluated the process and concluded that the redesigned reactor, producing 8.5 tons of coke per hour is economically viable in a facility of 1.0 mtpa or more. Calderon and Bechtel have signed a Memorandum of Understanding and are jointly developing plans for the first commercial reactor followed by the first commercial plant. An add-on Directly Reduced Iron (DRI) or Hot Briquetted Iron (HBI) facility to utilize the hydrogen rich syngas makes the project even more attractive.

DESCRIPTION OF THE PROCESS

The Calderon process is completely closed producing metallurgical coke in a Calderon Coking Reactor (CCR) and cracking and desulfurizing the raw coke oven gas in a Hot Gas Cleanup (HGC). There are no oven doors, no offtakes, no charging lids and no atmospheric charging, pushing or quenching. There are no oven machines, no quenching station, no by products plant, no waste water treatment plant and no separate desulfurization plant. This greatly reduces the cost of both operations and maintenance.

[6] TSOA letter from D. Stalherm and R. Worberg to Albert Calderon, October 11, 1995
[7] ibid.

The only products from the plant are coke, clean, desulfurized syngas and sulfur. There are no liquid or solid wastes.

Heating the coal charge in the CCR is indirect, similar to a conventional coke oven but with several significant advantages. For example, the Calderon coking reactor is much more efficient with continuous and uninterrupted heating through silicon carbide rather than silica refractory and an external burner rather than individual flues with direct flame impingement.

When coke at the hot end of the CCR reaches the proper temperature the pushing/quenching cycle of the Calderon process is executed and consists of the following:

1. A measured amount of coal dried and preheated to 250^{o}F is pushed into the cold end of the CCR and an equal volume of coke is pushed out the hot end of the CCR into the Quencher, a barometric U-seal filled with water.

2. At the same time the push is started, a water flow is initiated in the U-seal with the overflow exiting the atmospheric leg. Full water flow is established while the coal is being compacted and before the coke moves.

3. Hot coke pushed from the reactor falls into the water and is carried out of the U-seal by the flow. Quenching time and thus, coke moisture is controlled by regulating the water flow.

4. Quenched coke is separated from the water immediately after discharge from the U-seal and is screened before discharge to separate conveyor belts for metallurgical coke and breeze.

The major components of the Hot Gas Cleanup are a Thermal Cracker for raw gas, a Guard Bed for flue gas, an Adsorbent Regenerator and a Sulfur Condenser.

Raw gas from the CCR flows to the bottom of the cracker which is filled with hot lime pebbles moving countercurrent to the gas. As the gas travels up through the cracker nearly all the hydrocarbons, including the tar, benzene, toluene, xylene, naphthalene, etc. are cracked to hydrogen and carbon monoxide. The only hydrocarbon remaining is a small amount (<5%) of methane. Similarly, the other contaminants such as ammonia and cyanide compounds are cracked to hydrogen and nitrogen gases and to elemental carbon. The inherent water from the coal and the water formed by the oxygen in the coal are reacted to H_2 and CO in the cracker by the water gas reaction. At the same time, the gas is desulfurized as the lime reacts with the sulfur to form CaS. Clean, desulfurized syngas at high temperature is passed through the waste heat boilers to cool the syngas and produce steam. The gas is delivered at pressure without exhausters.

The reacted sorbent leaves the bottom of the cracker and is transported to a surge bin which feeds the cracker, guard bed and regenerator by gravity. The feed rate to the cracker, guard bed and regenerator is controlled by the discharge rate from each vessel. Through a series of reactions in the regenerator the spent sorbent is reacted back to lime and the sulfur is liberated as a vapor. The vapors pass through a condenser and the sulfur is collected as a liquid for sale.

The clean desulfurized syngas leaving the cracker is nearly moisture free at 1800^{o}F. The composition of the syngas is 70% hydrogen, 22% carbon monoxide and less than 5% methane. The balance of the syngas is nitrogen and carbon dioxide.

The most valuable end uses of the clean syngas are as a fuel or a reducing gas for the production of DRI or HBI. Economically, DRI or HBI production is preferred with the syngas being used in place of the hot reformed syngas in the Midrex or HYL process. Use of this syngas eliminates the need for a reformer or heater and reduces the capital cost of the Midrex or HYL installation by 50%. Use of the well proven Midrex or HYL technology removes the risk of developing a second technology in conjunction with Calderon cokemaking.

STATUS OF THE DEMONSTRATION PROJECT

Calderon plan calls for the installation of one full sized commercial reactor assembly (8.5 tons of coke/hr) to demonstrate the production of high quality metallurgical coke at economical and commercial production rates. Plans for the demonstration are to modify the Calderon Process Development Unit (PDU) in Alliance, Ohio, which was constructed and operated at a cost of approximately $17 million, to develop high sulfur coal gasification for the power industry. Design, procurement and construction of the demonstration project is scheduled to be accomplished in ten months. The operating period for the test is expected to be an additional six months.

Calderon has signed a Memorandum of Understanding with Bechtel to develop the process. The cost of the design, installation and operation of the Initial Reactor Unit (IRU) which is commercially-sized and its related facilities is $30 million. At the present time Calderon has $3.0 million committed by U.S. DOE. Additional funding will be requested from U.S. DOE. Calderon/Bechtel are currently in discussions with several other sources to complete the financing package for the demonstration.

After procurement of funding for the IRU, Calderon/Bechtel plan to begin detailed engineering. Given that permits are granted, construction will begin in January 1998 with cold testing in July 1998 and first coke in August 1998. Based on successful testing, first coke in the commercial plant, one (1) mtpa coke and one (1) mpta DRI or HBI, is scheduled for October 2001.

Conclusion

LTV has evaluated the process in great detail from a technical perspective during the last three years. The present design is the result of response to questions raised by reputable engineering firms after close examination.

Since the Calderon process is completely closed by virtue of the elimination of doors, lids, offtakes, atmospheric charging, pushing or quenching, the environmental advantages of the process are obvious. Preliminary discussions with Region V of the U.S. EPA indicate that permitting of the Calderon plant will be much easier than for conventional batteries.

In summary, LTV believes that Calderon process will produce high quality coke at a lower cost in an environmentally clean operation and has issued a Letter of Intent to purchase the first 500,000 tons of coke per year for a period of 20 years from the first commercial facility.

Submitted by:

Albert Calderon
Project Director