Executive Summary

Novel Fixed-Bed Gasifier for Wyoming Coals

Prepared for
University of Wyoming
Clean Coal Technologies Research Program
Project Code: WY49975EMERY

February 8, 2013

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Abstract

The Emery Energy Company has novel gasification technology that has the potential to improve the state of the art technology in fixed bed gasifier configurations. Fixed bed gasification has traditionally had technical limitations including tar and oil carryover and limited to coarse coal feeding (i.e. no fines). Emery's approach aims to maximize the benefits of fixed-bed gasifier technology while mitigating the technical and economic downsides of such systems. This approach leverages two well-known and proven processes: updraft fixed-bed gasification & entrained flow gasification. The potential results will be a new approach to coal gasification enabling greater feedstock flexibility and low rank coal utilization and effective use of higher moisture Wyoming coals and capable of operating at altitude with minimal heat and mass balance penalties.

Objectives

Goal: To demonstrate the Emery Energy Gasification technology on Wyoming Coals at altitude.

Objective 1: Evaluate the overall heat and mass balance to compare relative to existing processes

Objective 2: Determine the extent of benefit and identify opportune applications resulting from the syngas outputs and extrapolated economics for larger systems

The methods to be employed included designing, constructing and operating an Emery FlexFeed™ Gasifier appropriately scaled to test and demonstrate this initial configuration (i.e. partial embodiment of the full Emery FlexFeed™ technology and integrated performance and outputs.

Introduction

With Emery Energy's 2008 Clean Coal Technologies Research Program award we were able to complete a majority of the construction of the Gasification System. Additionally, Emery Energy Company has successfully completed additional extended testing of our proprietary ***FlexFeed***™ Gasification system.

Emery's ability to develop predictability and reliability on the start-up, shut down and steady state conditions represents a significant milestone of the development and technical performance of the ***FlexFeed***™ Gasifier technology. This activity has helped reduce the risk of subsequent and ongoing development activities toward engineering scale up activities and will increase the appeal of the technology to potential licensees.

Changes from Original Proposal

In December 2010, the Clean Coal Technologies Fund awarded Emery an incremental $285,000 due to an increase in construction costs as well as an increase in labor costs related to engineering and installation. There were also several project extensions as construction took longer than anticipated due to weather and some design changes.

Results

Construction was completed in November 2011. Due to limitations when the monies needed to be spent on the 2009 Clean Coal Technologies Award, Emery switched to the 2009 award before completing the 2008 award. Emery was unable to complete the full 300 hours of testing under the 2008 award due to severe weather restrictions. However, a total of 132hours of gasification were completed and due to changes in our operational methods significant improvements were made in our ability to run at steady state for longer periods of time which is described in more detail later in the report.

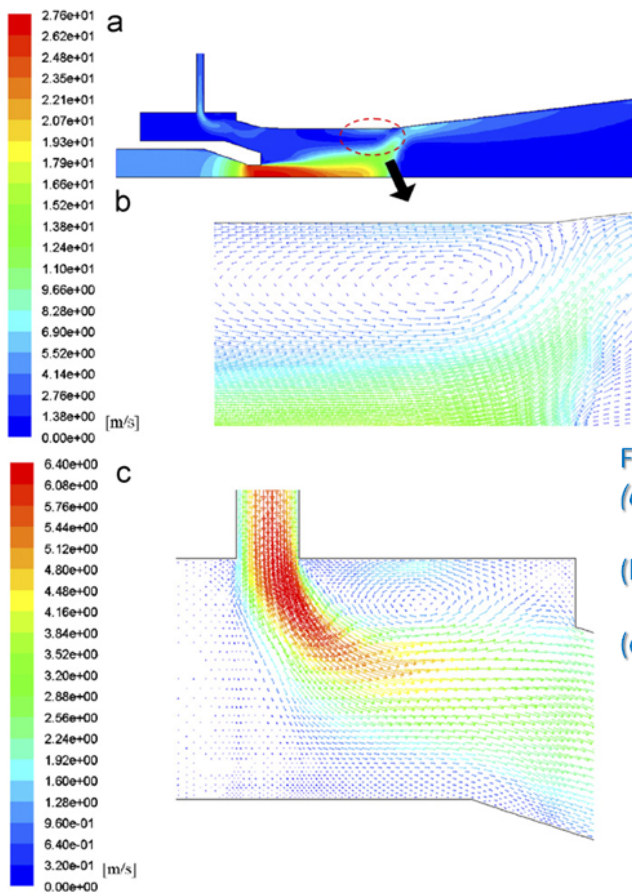
Technical

Construction

Preliminary Design Basis

The initial phase of engineering began in early 2009. Initial 'entrained flow' reactor modeling was performed at at Southern Utah University worked on the E2R reactor modeling. With his data we were able to determine the size and specific details for the E2R reactor. Although was sent out for bid, its relative high cost weighed against the benefit to this specific project, we decided not to go forward with the E2R's. Below is a chart depicting some of the resulting CFD modeling.

Entrained Flow Model Development



Flow patterns
(a) contour of mixture velocity magnitude,

(b) mixture velocity vector of mixing chamber

(c) air velocity vector of suction section.

A Utah-based mechanical engineering firm handled the original engineering and design analysis on the ash grate including the internal and external bearing, shaft calculations, seals and the plates. Drawings were generated that were given to fabricator to begin construction.   A separate Utah-based structural engineering firm handled the calculations for the structural piping and support steel for the gasifier vessel itself. In May 2009, it was decided that a cradle to allow for removal of the bottom head of the gasifier and also to allow for testing the ash grate prior to shipping the unit to Laramie. In addition to outsourcing the design engineering, Dr. Richard Boardman, from Idaho National Lab, also participated in various design review activities prior to fabrication in May 2009.

Design Changes, Fabrication and Installation

After the design basis of the main gasifier reactor was finalized, the balance of the design and design/build efforts went into sizing the balance of plant major systems. During the design of major systems, additional weights and stresses were realized and hence some re-engineering was required to support larger dimension components.

Gasifier Vessel

In November 2009, after the gasifier purchase order was issued, it was determine that we needed to decrease the height of the gasifier. This was to allow for few inches to accommodate the larger 300 lb pressure flanges (vs. the original design of 150 lb flanges) in order to maintain a 'code-stamp' vessel design (at 125 psig), the thicker flanges were required.

The site pad originally specified by the civil contractor that supported the gasifier and flare stack, didn't required rebar detailing. It was determined that with the increase in structural support weight the pad needed additional reinforcement.

Utilizing the gasifier's bottom head cradle, Emery was able to conduct an ash grate test in Salt Lake before it was shipped to Laramie in February 2010. Preliminary results validated good removal rate of the feedstock through the exit, under ambient, non-thermal conditions.

Piping

Downstream of the gasifier, the syngas piping was the next major system that would have to be designed and fabricated to handle the anticipated flows and temperatures of syngas coming from the gasifier. This effort required multiple iterations by the engineering firm to identify where and how all the expansion could occur. They recommended that we use three (3) expansion joints in our piping scheme to deal with the planned expansion and resulting torque. However, the costs of expansion joints were very expensive, hence we elected to only purchase one expansion joint and then extend the length of piping (to overcome expansion) in lieu of the other two expansion joints. This activity then had new impacts on the overall structural steel, which then, again had to be resized and additional structural members added necessary to accommodate the new pipe routing.

In January 2010 it was decided that we needed to line the syngas exit pipes with refractory. This was to accommodate a higher temperature range of the syngas exiting the gasifier.

Steam Boiler

In an effort to reduce costs, we purchased a used steam boiler in December 2009. At the time we didn't know that we needed to also build an enclosure around the boiler and purchase a furnace to keep it operational in colder temperatures.

Flare

The purchase order for the flare was issued in early October 2009 based on the original design. In November 2009 it was determined that the flare stack needed to be made taller to improve destruction efficiency of syngas combustion. This required adjusting stack height, check valves, pressure gauges and manual ball valves, all required incremental costs

In February 2010 we decided to add a small burner in the flare so that purge gas and ventilation gases could be fed to it. This required a new manifold, risers, tips and a 150 lb flange connection to accommodate the 2 new streams.

Feed Pad

For feedstock receiving, handling, and overall infrastructure, we had assumed that much more would be provided by the Western Research Institute. However, the site development ended up being much more like a 'greenfield' development with nothing but land and one natural gas line. Hence we incurred increases costs (and hence time) to complete feedstock receiving area. Additionally, since we didn't have the funds to build solid concrete walls to contain the coal dust we had to design and concrete block system using old freeway barriers and tarps.

Industrial gases

The Oxygen and Nitrogen tanks were much larger than we had originally anticipated. It was required to pour another concrete pad which had to be large enough to allow for the trucks to safely fill the tanks. It was also required to place bollards around the tanks for safety reasons, all per Air Liquide's requirements

Systems Table

Systems Design, Fabricated and Installed through WYO I Award	
Gasifier Ash Grate Plattco's Nozzles Flanges	**Feed Storage** Feed Pad Walls Tarps Storm Water Catch Chamber
Piping Hot Piping Cold Piping Piping to Industrial Gases	**Industrial gases** Bollards Design for feed pad Steam Piping OX
Steam Boiler Boiler Enclosure Furnace	**Safety** LOTO Rattlers Confined Space Monitors
Electrical Junction Boxes Heaters General	**Misc** Tools Solenoids Gauges Nipples Pipe Fittings

HazOps and Design Reviews

There was an initial HazOps/Design Review with WRI conducted in August 2010. Minor design changes were implemented in response to safety concerns resulting in increasing the number of thermocouples, additional pressure relief valves and additional carbon monoxide (CO) monitors.

General Project Timeline

Gasifier Design Began – May 2009

Construction of Gasifier Began–July 2009

Site Preparation Began – November 2009 (gasifier pad poured)

Gasifier Installation – June 2010

Site Construction Completed – November 2011

Operations

Parameters of Run

	Overall	Amount
1	Total coal feed, lbs	30,977
2	Total run time, hrs	131.6
3	Total oxygen, lbs	12,257
4	Total steam feed, lbs	30,834
5	Total syngas produced, scf	5,579,558
	Feed stats	
1	Feedstock	Black Thunder Sub-bituminous coal
2	Maximum feed rate achieved, lbs/h	226
3	Feed size	1/4” to 1”
4	Inert bed material used	3/8” washed crushed gravel
5	Total inert material used, tons	~1.5
6	Density of coal, lbs/ft^3	44.8
8	Proximate analysis of feed	26.3 %M, 5.1% Ash, 8972 BTU/lb, 35.4% fixed C, 33.3% v.matter
	Gasification stats	
1	Average gas composition over the run	8.9% CH_4, 20.2% CO, 28.1% CO_2, 42.7% H_2
2	Average feed rate, lbs/h	226
3	Average steam feed rate, lbs/h	253.5
4	Average oxygen feed rate, scfm	21 (104.7 lbs/h)
5	Average syngas flow rate, scfm	764
6	Average gas heating value, BTU/scf	310.3 (dry basis)
7	Oxygen to coal ratio, lbs/lb	2.16
8	Steam to coal ratio, lbs/lb	1.12
9	Average gasification temperature, F	1387

Mass and Energy Summary Tables

Mass Balance

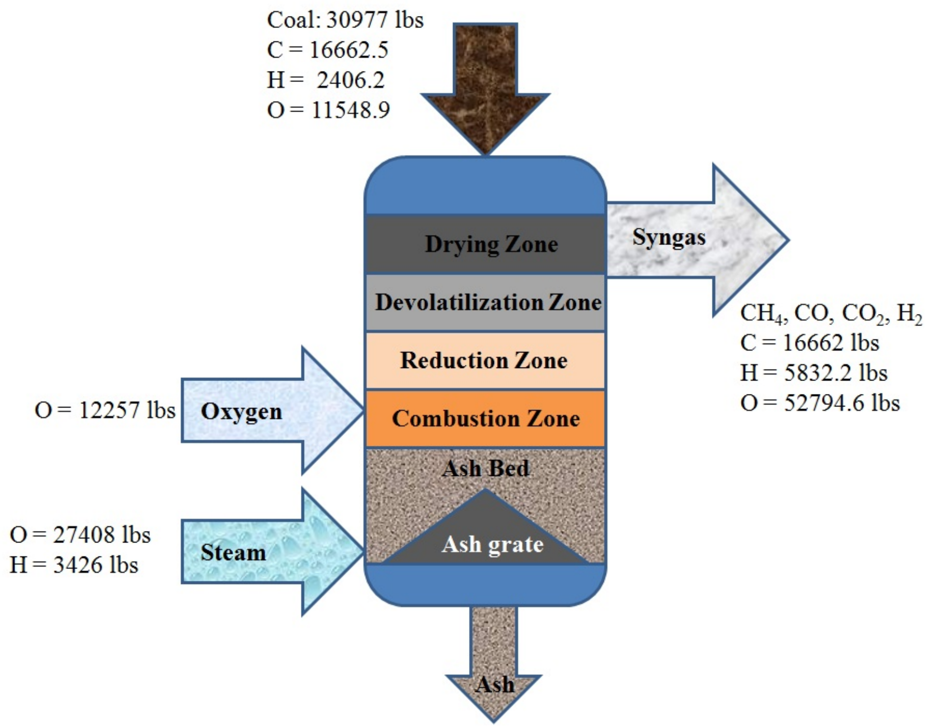
Mass In					
	Coal	Wood	Steam	Oxygen	
lbs	30977.0	0.0	30834.0	12257.0	
C, lbs	16662.5	0.0	0.0	0.0	
H, lbs	2406.2	0.0	3426.0	0.0	
O, lbs	11548.9	0.0	27408.0	12257.0	
Mass Out					
	CH_4	CO	CO_2	H_2	H_2O
lbs	3456.8	13730.1	30013.9	2078.0	26010.6
C total, lbs	16662.5				
H total, lbs	5832.2				
O total, lbs	52794.6				

Energy Balance

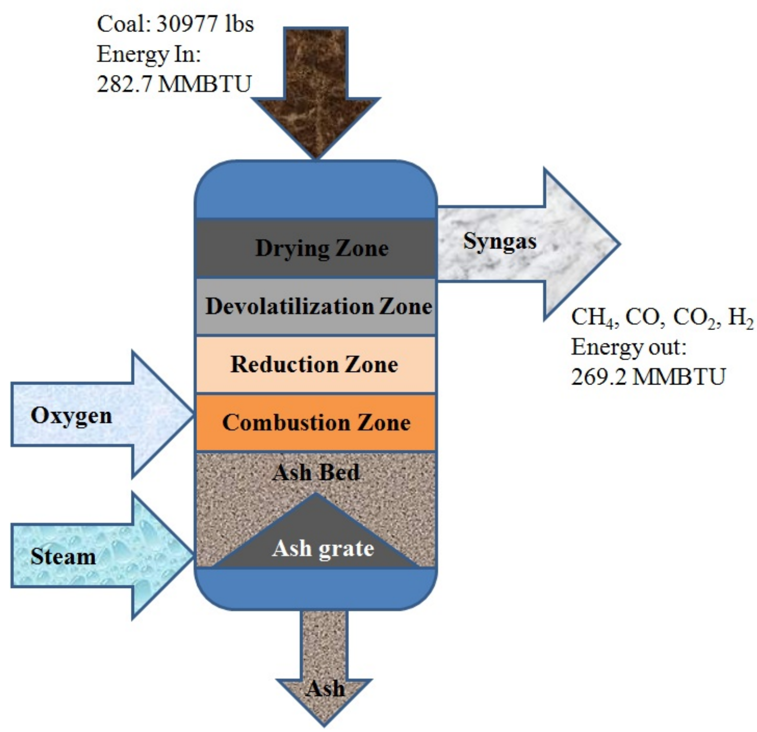
Energy in		Coal	wood	out/in
btu		282706083	0	0.9522713
Total Energy out, syngas				
btu	269212896.4			

Block Diagrams

Mass Diagram



Energy Diagram



Recommendations/Conclusion

Emery Energy successfully designed, installed and commissioned the FlexFeed Gasifier facility over the period January 2009 and December 2011. Although various challenges and delays during design, engineering and construction were encountered, Emery was able to successfully implement the complete functioning gasifier system. This facility, through the subsequent contract, was then able to accrue 1500 hours on Wyoming Powder River Basin feedstocks. During the final operational run at the plant, we achieved a 132 hour continuous run, in which ash was removed at steady state, which represented a significant achievement over prior runs during WYO II operational test runs, where ash removal was still be learned.

Based on this experience, our recommendations for improving operational reliability and maintainability would include the following facility additions:

a. Increase steam capacity to 1500 lbs/hr (vs. the current ~600 lbs/hr) by replacing the current boiler system, so as to increase capacity of gasifier
b. Add a cyclone for particulate removal immediately downstream from the gasifier to prevent coal fines from entraining in the syngas exit lines
c. Increase instrumentation to the HMI in the trailer. Approximately 5% - 10% of the instruments required manual field checking without any feed to the HMI
d. Replace start-up blower (for gasifier burner heat up) with new blower with additional capacity.