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IITRI - 4.2.9 - Design, Engineering, and Evaluation
of Refractory Liners for Slagging Gasifiers

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INTRODUCTION

The objectives of this program under Department of Energy Contract No. DE-AC05-78ET13410, "Design, Engineering, and Evaluation of Refractory Liners for Slagging Gasifiers," are to design, construct, and operate a Refractory Test Facility for the evaluation of refractory liners under slagging gasifier conditions.

The program is composed of six tasks which can be grouped into three parts. The first part includes only Task A, Conceptual Liner Designs, which summarizes the state-of-the-art of the design of refractory liners for slagging coal gasifiers. The second part includes Task B, Design and Construction of Test System; Task C, Refractory Liner Tests; and Task D, Liner Design Evaluation. The test system constructed in Task B is used to test refractories under simulated slagging gasifier operating conditions. In the third part, the results of Tasks B, C, and D are to be used to prepare refractory liner design models and develop recommended design practices, which can then be incorporated into a handbook for gasifier designers and refractory suppliers.

RESULTS FROM PRIOR QUARTERS

The contract for this program was awarded at the end of September 1978. Work was started on 1 October 1978, on Tasks A, B, and E. Task A, Conceptual Liner Design, has been completed; Task B, Test System Design and Construction, is in progress. Task C, Liner Tests, and Task D, Liner Design Evaluation, will begin upon completion of Task B. Task E, Liner Model Development, is now inactive after an initial data compilation and theoretical model development effort. It will be activated as soon as

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data are available from Task D. Task F, Liner Design Handbook, was active along with Task A since the report of both tasks will use the same format. It is now inactive until the completion of Tasks D and E. The principal efforts on this program during all prior quarters have been to design and construct the test facility, Task B.

Construction of the test unit was completed by 31 July 1981. A two-phase plan for integrated check-out and shakedown of the completed system was established and agreed to by DOE, Oak Ridge National Laboratory, and IITRI personnel. Phase I consists of the following tasks:

- a) rework control circuits
- b) put in a remote start/stop switch for slag tap torch
- c) install piping and valves for gas analyzer
- d) install gas detector
- e) wire optical pyrometer
- f) wire generator gas detector
- g) extend thermocouple wiring to data logger
- h) install data logger operating cable.

Phase II consists of the following tasks:

- Task 1) Run cold at atmospheric conditions (compressors, pumps, generator, and slag injection and removal system all run at same time to check entire system and familiarize ourselves with operation).
- Task 2) Run cold, but at a pressure of 100 psi.
- Task 3) Assemble auxiliary nozzle and equipment for low temperature heat-up of unit and dry-out of refractories.
- Task 4) Run through entire system with all burner systems to be fired at atmospheric conditions.
- Task 5) Go through complete start-up procedure with Davy McKee and burner people present.

This is considered to be a minimum shakedown schedule.

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The work was to be completed by 30 October 1981. However, because of the need to conserve (requested by the ORO) funds, the work crew was cut in half, and because of the usual unanticipated equipment malfunction which always occurs when new equipment of this size (pilot plant scale) is first operated, only parts of Phase I and II were completed during the time period 1 July to 30 September 1981. The problems and work completed were discussed in the quarterly report ending 30 September 1981.

PROJECT STATUS

During this report period, 1 October to 31 December 1981, the Phase I tasks were completed, all systems were checked out and found to be operational. Task 1, cold running at atmospheric pressure and Task 2, cold running at 100 psi pressure, of Phase II shakedown of the test unit were completed during the previous quarter. The remaining tasks of Phase II--Task 3) assemble auxiliary nozzle, Task 4) fire all burner systems at atmospheric temperature and heat up unit to 1500°F to dry out refractories and fire in castable refractories, and Task 5) fire up all burner systems at pressure (90 psi) and heat up the unit to 2700°-3000°F and run slag through system--were attempted during this quarter.

The report from Hercules on the Hazard Analysis of the test equipment and its operation was received during the first week in December. A preliminary analysis of the report was given on 15 October 1981 by C. A. Angoli of Hercules Incorporated Allegany Ballistics Laboratory, Cumberland, Maryland. In their opinion, the test vessel construction and operation procedure were satisfactory. However, there were a few items in the analysis that they thought should be done which would be of benefit to the project. These are listed below:

- 1) Install audible and visual alarms from gas detector outside of compressor enclosure and on the control panel - done.
- 2) Move gas compressor switch to outside of gas compressor enclosure - done.

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- 3) Control room and gas compressor room exhaust fans should have flow switches - not to be done.
 - 4) Both fans to start automatically - not to be done.
 - 5) Overhead roof fan to start automatically - not to be done.
 - 6) Additional gas alarms to be put on burner pipe rack - in process of being installed.
 - 7) Platform on top vessel - will be done at a later date.
 - 8) Face shields and breathing apparatus - purchased.
 - 9) Flow switch for N₂ purge - not to be done.
 - 10) Insulation around scrubber - done.
 - 11) Level controls for slag tap vessel - designed and purchased.
 - 12) Clock for control room - done.
 - 13) Install limit switch on main burner gas and oxygen for gas lance purge valves and light on panel to indicate they are closed - not to be done.
 - 14) Install controls on panel for slag tap vessel drain - done.

Phase II - Task 3, Heat-up burner installation

The main burner supplies too much heat even at low firing to safely heat up the test unit at approximately 100°-150°F per hour. In order to bring the unit up to a safe temperature (1500°F) to light the main burner, a North American "Aardvark 4492A" burner (Figure 1), a compact, high-velocity air heater was purchased and installed in the test unit. With suitably sized gas accessories, the Aardvark can deliver air at any temperature from 300° to 1600°F. Even higher temperatures are possible with suitably constructed hot air delivery piping and heating enclosures. Air temperature of the discharge of the Aardvark must be high enough to

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overcome radiation losses in the distribution piping, and piping must be compatible with these temperatures. Insulation can be applied to the distribution piping as long as this does not cause excessive temperature buildup in the piping. A stainless steel smoke pipe (Figure 2) was used as the distribution pipe to bring the hot air through the slag tap vessel to the main test vessel. The original design consisted of a standard stainless steel smoke pipe without water cooling fitted through the flange cover of the lower manhole of the slag tap vessel (Figure 3).

A test run on 6 November 1981 heated up the flange cover rapidly to above 300°F. The system was rechecked, and an asbestos insulation was put in the smoke pipe to insulate it from the Aardvark mounting flange. On 10 November 1981, the unit was tested again. The flange cover did not heat excessively, but the pipe was hot. The slag tap vessel began to heat up, and the stove pipe was at red heat. Water was introduced into the bottom of the slag tap vessel, and the slag tap vessel water sprays were turned on. The water in the vessel was allowed to drain, and cold make-up water was continually introduced. This system appeared to keep the stove pipe from overheating. During the next two weeks all systems (control wiring, gas analyzer, thermocouples, igniters, flame sensors, pumps, and compressors) were rechecked, and the unit was made ready to attempt Task 4 of Phase II (heat up unit and fire all burner systems at atmospheric conditions).

Phase II - Task 4, Heat up test vessel and start main burner
and auxiliary torches at atmospheric conditions

Test was started on 2 December 1981. After six hours running time, the flange to which the Aardvark heater was fastened began to overheat. The heater was turned off, and the unit was shut down. It was discovered that the stove pipe had burned through just past the asbestos-lined section. The rest of the stove pipe had collapsed, and hot air was heating up the slag tap vessel. A decision was made to make a double pipe, of 7-in. OD section and 5-in. ID section with space between filled with Harbison-Walker castable 26. The new insulated smoke pipe was installed in the slag tap vessel. The castable in the notch was repaired before installation of the pipe. Damage was due to the water spray on the uncured castable.

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A second test attempt was started on 8 December 1981. Again heat-up was done slowly, approximately 100°F per hour. After 5 hours of running time, the smoke pipe again heated up and the sprays were again turned on. After 9 hours running time, the temperature in test vessel approached 1000°F, but it was impossible to keep the smoke pipe cool and slag tap flange cover was beginning to heat up excessively. The heatup was kept on low heat until 8:45 a.m. on 10 December 1981 when the decision was made to shut down the run. The smoke pipe failed at the joint in the manway cover plate. The inner pipe had collapsed, the castable refractory eroded away, and the outer sheel burned through.

After this run, a new concept was devised for transmitting the hot gas from the Aardvark burner to the test vessel. A ceramic inner liner (zirconia) (5-in. ID with a 1/8-in. wall) was used, and a 7-in OD with a 1/8-in. thick 310 stainless pipe was used for the outer support. The space between the ceramic and the stainless was packed with Fiberfrax insulation. In order to avoid heating up the manway flange, a hanger was installed inside the slag tap vessel to hold the smoke pipe in place. The Aardvark burner was fitted to the end of the smoke pipe, Figure 4. To further insure cold running, the smoke pipe was water-cooled (Figure 5), and the ends of the distribution pipe were sealed with plastic refractory to hold the insulation in place, as shown in the figure.

Another test run was attempted on 29 December 1981 with the new distribution pipe (smoke pipe). No problems were encountered during heat up. The test-section refractories were heated to 1200°F, and the decision was made to turn on the main burner. The Aardvark unit was turned off, and an attempt to light the main burner was made at 10:00 on 29 December 1981. The burner started with a pop on the first try and ran for about 10 seconds. The flame scanner was very unstable, and the gas compressor shut off. There was difficulty in getting the gas compressor started, and the refractories were cooling rapidly. It was decided to start the Aardvark burner again. It would not start, and it appeared that the hot gas distribution pipe was plugged with debris from the explosive start of the main burner. After the run was terminated, it was determined that the debris was from the slag placed in the bottom of hearth section and old

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bits of refractory left from previous runs. The pieces of refractory that blocked the flame scanner view of the Aardvark were cleaned out and at the next try, the unit start up explosively which cleaned out the distribution pipe. After this occurred, the distribution pipe was heating excessively (1200°F), and it was decided to abort the run without trying to light the main burner again. After cool-down and removal of the distribution pipe, the ceramic tube was found to be cracked and broken in several places. The ceramic tube was replaced with a spare tube, and a decision was made to change the operation of the Aardvark so that it could be operated with the main burner. The hot air distribution pipe was modified with the necessary change in piping and additional cooling coils before the end of the report period. The new design for the distribution pipe appears to work well, and the pipe can be heated to 1150°F without damage to the system. Another test run was scheduled for 4 January 1982.

Figure 6 is a view of the control room and data being taken from the data logger. Figure 7 is a view taken from IITRI's Tower Building during the 22 December 1981 run showing the water cooling tower in operation, and Figure 8 is a close-up of the tower during the same run. All systems tested appear to work satisfactory.

During the report period, the operating crew has worked well together, and learned a great deal about the operation of the test unit and how to handle emergency situations.

Figure 1. 4492A Aardvark burner used to heat up and dry out the test unit.

Figure 2. Stainless steel smoke pipe to bring hot air through the slag tap vessel to the test vessel.

Figure 4. Aardvark burner fitted to smoke
pipe in manway of slag tap vessel.

Figure 5. Water cooling jackets
on smoke pipe.

Figure 6. Control room.

Figure 7. View of water cooling tower in operation.

Figure 8. Close-up view of water cooling tower in operation.