3.1.1.1 Refractory Evaluation

When the gasifier configuration modifications were incorporated, several different types of refractory materials were installed for evaluation in the various sections of the gasifier based on operating conditions in these sections. Figure 1 is a simplified diagram of the gasifier (not an exact representation of the gasifier configuration) included to illustrate the locations of the different refractory types.

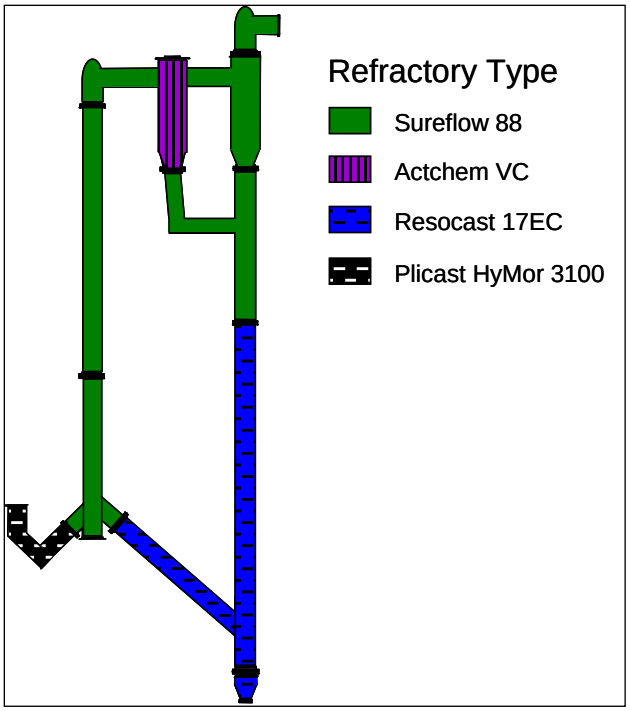


Figure 1. Gasifier Refractory Layout.

The modified gasifier refractory includes an insulating layer throughout using Resco RS-3A material, which was designed for reducing atmospheres. Prior to the modifications, the hot-face refractory used throughout the gasifier was Resco Resocast 17EC, which features an extended working life. The lower standpipe, which was not modified, contains the original Resocast 17EC material. The largest hot-face portion of the gasifier employs Resco Sureflow 88, an erosion resistant material designed for ease of mixing and replacement. Actchem VC from Vesuvius was utilized in the first solids separation device, and this material features a high corrosion resistance and high coefficient of thermal expansion, although it can be susceptible to cracking. The Plibrico Plicast Hymor 3100 material in the burner leg was selected for its low thermal expansion and thermal shock resistance.

Refractory Results. Detailed inspections were performed after test campaigns to evaluate the new and original refractory condition in the gasifier. The new refractory installed was in service for 2,500 hours and experienced 15 thermal cycles. (A full thermal cycle is a temperature increase

from ambient temperature to 1,800°F combined with a decrease in temperature below 200°F at a rate of 100°F/hr. A half thermal cycle designation is a temperature decrease below 1,000°F at a rate of 100°F/hr.) The original refractory in the lower standpipe that was not replaced during the gasifier configuration modifications was in service for 16,500 hours (including both combustion and gasification operation) and experienced over 80 thermal cycles.

In general, the new gasifier refractory was in excellent condition with two exceptions: the inlet of the first separation device and the seal leg. The original refractory was still in acceptable condition with only minor cracking observed. Figure 2 is a photograph taken of the lower standpipe refractory after 70 thermal cycles.

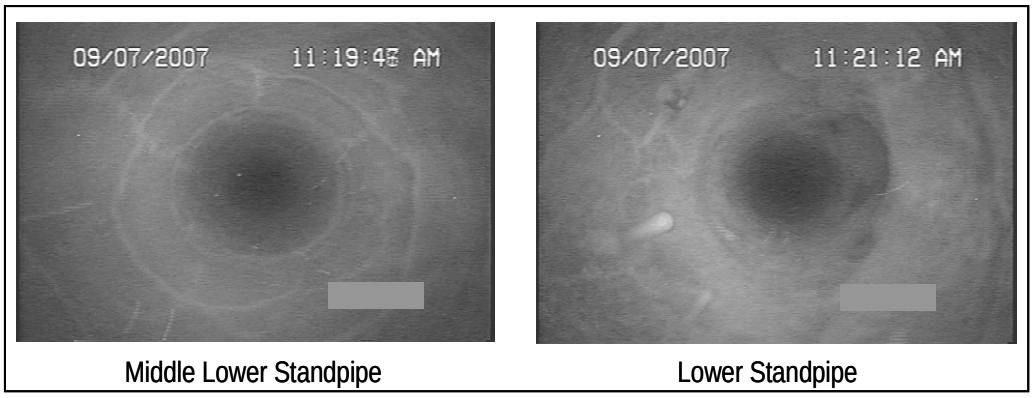


Figure 2. Lower Standpipe Refractory after 70 Thermal Cycles.

First Separation Device Inlet. Following the gasifier modifications, the first separation device contained Actchem 85 refractory. The Actchem 85 properties include a high erosion resistance and high coefficient of thermal expansion, which make it resistant to wear but susceptible to cracking. The Actchem 85 refractory life is heavily dependent on the number of thermal cycles and its rating is about 30 thermal cycles (a ten-year commercial life).

The first solids collection device appeared to be in good condition during visual inspections conducted following the first test run with the new refractory. However, there was some wear present. At the left of Figure 3 is a hairline crack seen from the entrance of the inspection nozzle that was approximately 1.5 inches deep. There was also a small area at the inlet with missing refractory, as shown on the right side of the figure.

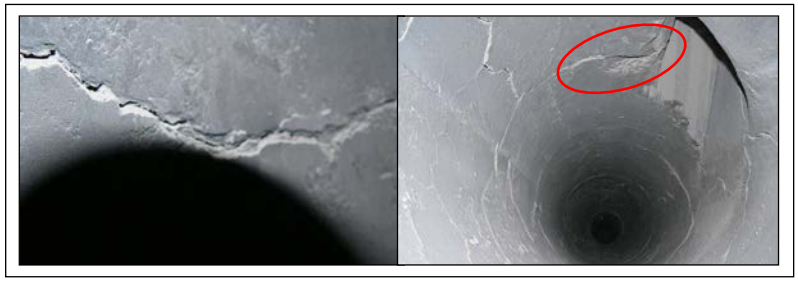


Figure 3. Inspection of Actchem 85VC Refractory following Initial Operation.

Degradation of the Actchem 85 refractory was noted during inspections after 11 thermal cycles, about half the thermal life (post-TC23). The refractory had been exposed to about 900 operating hours of solids circulation. Inspections showed that a portion of refractory was missing in the first stage solids separation inlet. Figure 4 shows examples of the cracking in this refractory.

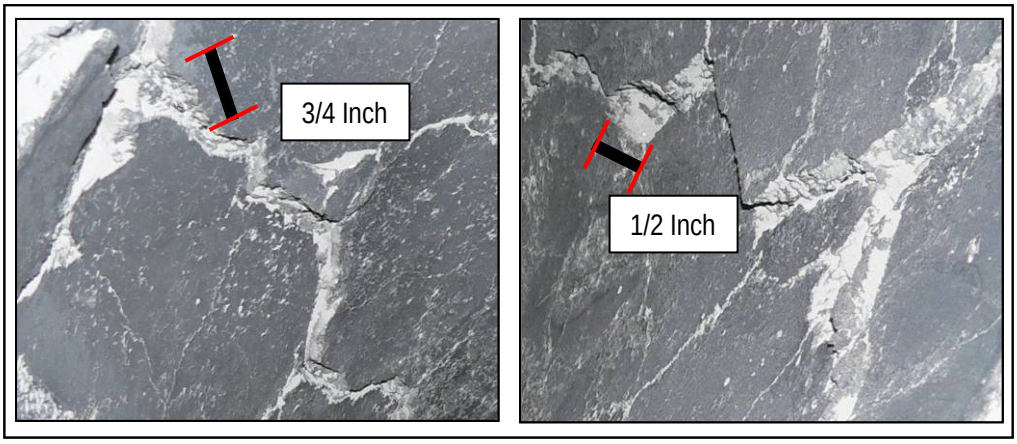


Figure 4. Cracking of Actchem 85VC Refractory after Eleven Thermal Cycles.

During the February 2008 test run, several pieces of separated refractory (the largest being about 12 inches long, 8 inches wide, and 2 inches thick) were found in the solids separation unit. The refractory condition at the inlet of the first solids separation device was of particular concern due to the large refractory pieces recovered and the previous loss of refractory in this area. At the conclusion of the February 2008 test run (TC24), the thermal cycles totaled 15. Inspection of the first stage solids collection revealed that the refractory loss at the inlet had progressed. Figure 5 shows the progression of refractory loss the inlet of the first solids separation device from post-TC23, post-TC24B, and post-TC24C inspections.

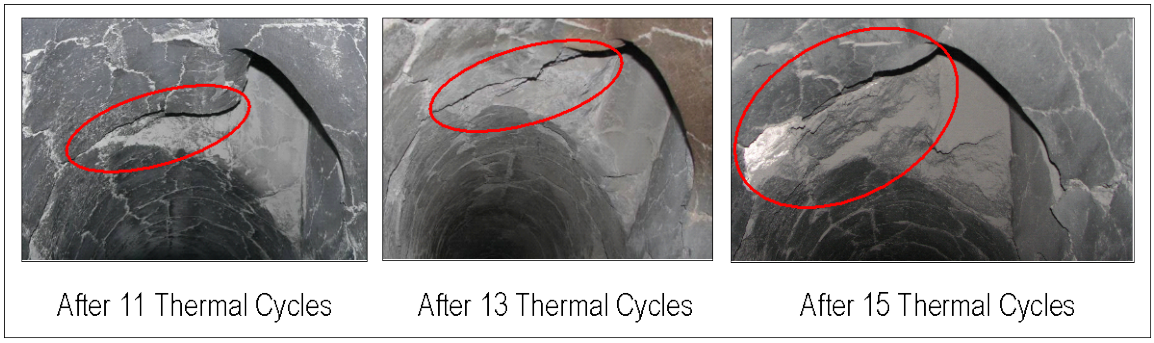


Figure 5. Refractory Loss at the Inlet of the First Solids Separation Device.

The extent of refractory damage made a complete replacement necessary. The Atchem 85VC was replaced with Resocast 88VC. Based on the operating experiencing at PSDF, the Atchem 85VC was not suitable in this application due to the high number of thermal cycles associated with multiple startups and shutdowns.

First Separation Device Inlet. Refractory obstructing the gasifier circulating flow path was found in the slant leg of the seal leg after the July 2008 run (TC25). Figure 6 is a photograph of the refractory and the location from which it was removed. The refractory piece shown in the figure was approximately 18 inches by 12 inches. Chemical analysis of a sample from the piece removed confirmed that it was Sureflow 88 refractory. The restricting refractory likely originated from the upper portion of the slant leg. Repairs were not necessary, and the obstructing refractory was removed.

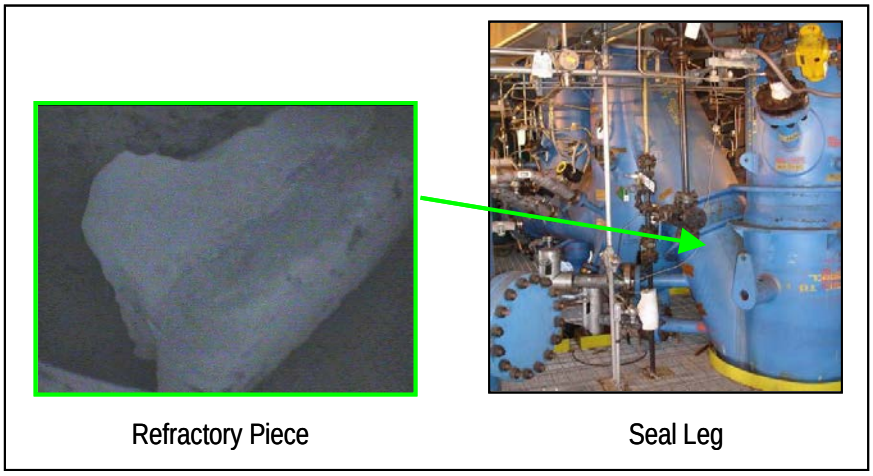


Figure 6. Gasifier Seal Leg Obstruction.

R02 Report

Refractory Evaluation. During the gasifier inspection prior to R02, refractory damage was identified in the standpipe and entailed hot-face refractory loss on both sides of the J-leg / standpipe intersection, as shown in Figure 1. This hot-face refractory is 3 inches thick, and the deepest loss was about 1 ½ to 2 ½ inches. The refractory in the standpipe and J-leg was the refractory originally installed in the gasifier (Resocast 17EC).

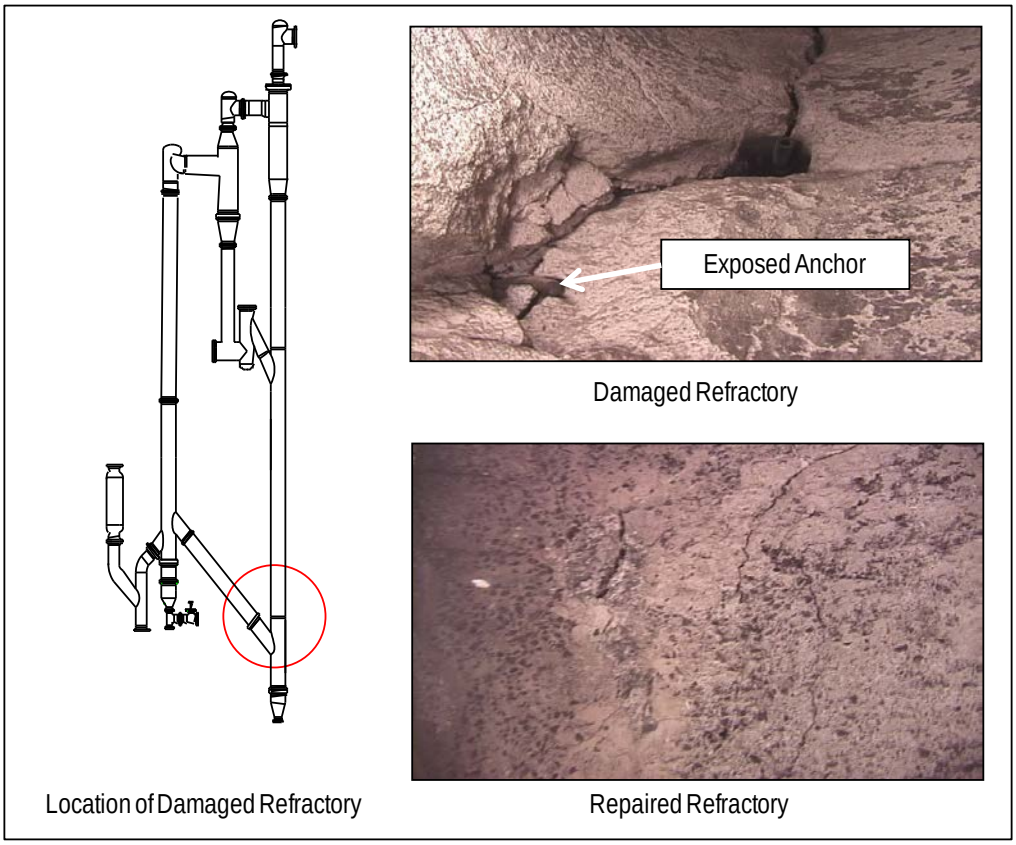


Figure 1. Refractory Damage in Gasifier Standpipe.

Repairs were completed prior to R02 using Resco Quikturn 60 RST refractory. During the run, this area was monitored using a thermal imaging camera and skin-mounted thermocouples. No temperature excursions were detected. Post-run inspections showed that the repaired refractory was in good condition.

R03 Report

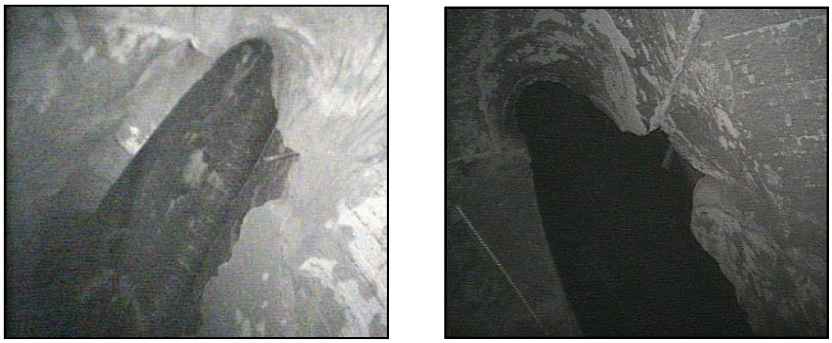
Gasifier Refractory. Inspections of the gasifier refractory showed that the hot-face refractory at the J-leg/standpipe intersection, which had been repaired prior to R02, was still in good condition. A slightly damaged area in the upper standpipe / solids separation unit intersection, which had been discovered prior to R01, continued to show acceptable condition. The damage noted appeared to be related to the extra stress that intersecting areas receive.

R04 Report

Inspections of the gasifier refractory showed that the hot-face refractory at the J-leg / standpipe intersection, which had been repaired prior to R02, was still in good condition, as shown in Figure 1. A slightly damaged area in the upper standpipe / solids separation unit intersection, which had been discovered prior to R01, continued to show acceptable condition, as shown in Figure 2. The damage noted appeared to be related to the extra stress that intersecting areas of refractory receive. The gasifier standpipe, including these two areas of concern, is scheduled to be replaced during the 4th quarter of this year.

Prior to R02 | Post-R04 Inspections

Figure 1. Inspection of Refractory in J-leg / Standpipe Intersection.

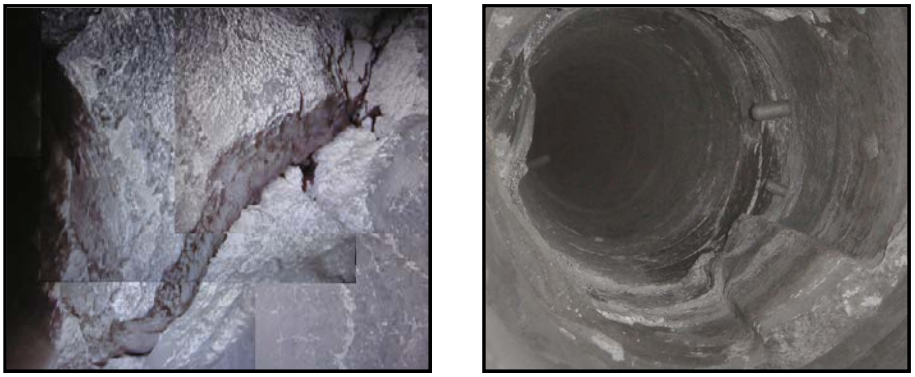


Prior to R01 | Post-R04 Inspections

Figure 2. Inspection of Refractory in Upper Standpipe / Solids Separation Intersection.

R05 Report

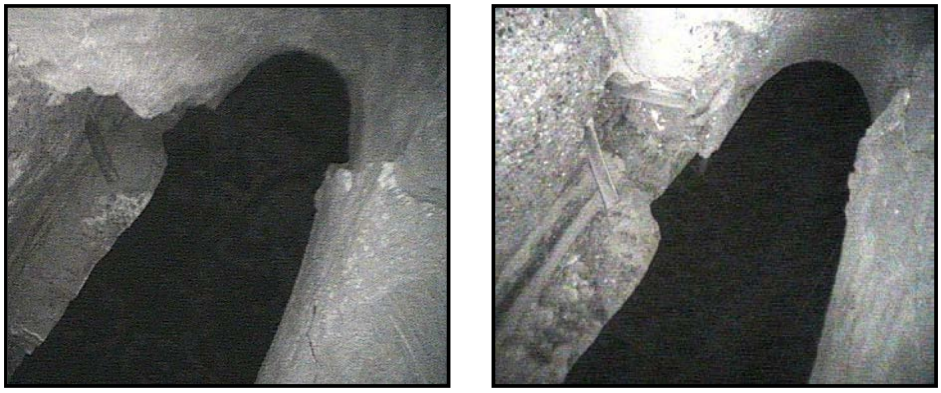
Gasifier Refractory. Inspections of the gasifier refractory indicated that the hot-face refractory at the J-leg / standpipe intersection, which had been repaired prior to R02, was still in good condition, as presented in Figure 1.



Prior to R02 Post-R05 Inspections

Figure 1. Inspection of Refractory in J-leg / Standpipe Intersection.

A slightly damaged area in the upper standpipe / solids separation unit intersection, which had been discovered prior to R01, continued to maintain an acceptable condition, as indicated by Figure 2. The damage noted appeared to be related to the extra stress that intersecting areas of refractory receive. The gasifier standpipe, including these two areas of concern, is scheduled to be replaced during the fourth quarter of 2011.



Prior to R01 Post-R05 Inspections

Figure 2. Inspection of Refractory in Upper Standpipe / Solids Separation Intersection.

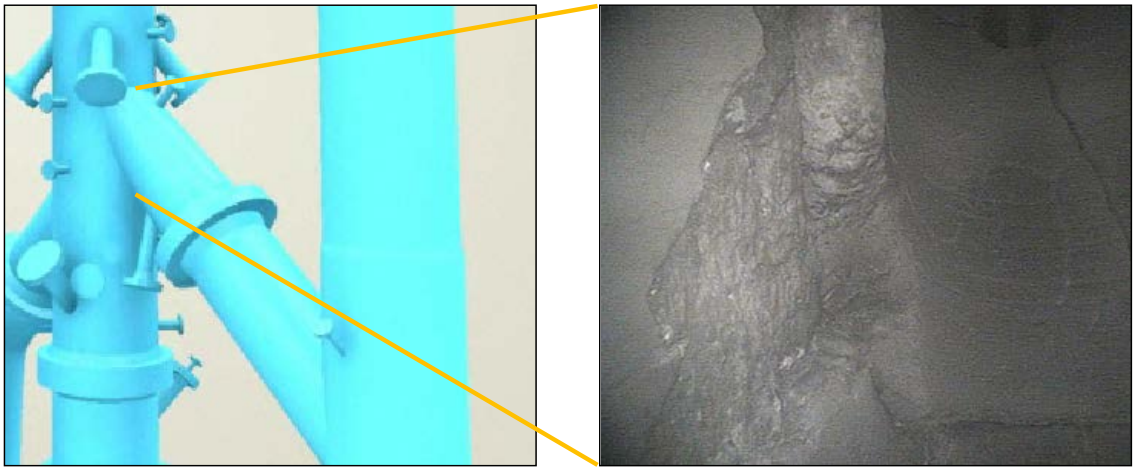
R08 Report

Gasifier system inspections did not reveal any areas of major concern. The new gasifier standpipe installed earlier this year continued to demonstrate excellent refractory performance. Figure 1 shows the condition of the standpipe refractory before and after the final portion of R08 testing during which biomass was used for co-feeding operation.

Inspection prior to Biomass Operation | Inspection after Biomass Operation

Figure 1. Inspections of Standpipe Refractory.

An area that is being closely monitored for refractory loss is the gasifier mixing zone and J-leg intersection (see Figure 2). Refractory wear in this area has been minimal since its initial discovery following R07. A skin temperature monitoring system was installed to allow for real-time monitoring of the area during operations.



Location in Gasifier | Refractory Inspection Photograph

Figure 2. Inspections of Refractory in Mixing Zone and J-Leg Intersection.

2012 Topical Report

A major 2012 project deliverable for DOE was the replacement of the gasifier standpipe. During routine inspections of the gasifier in 2009, refractory damage was identified in the standpipe arising from the loss of hot-face refractory. Two places of concern were the intersection of the solids separation unit and standpipe, and the intersection of the J-leg and standpipe. The refractory in the standpipe and J-leg was the refractory originally installed in the gasifier, and has been in service for 15 years and almost 22,000 hours of operation experiencing more thermal cycles than would a commercial unit. Figure 1 shows boroscope inspection photographs of the standpipe refractory. As seen in the figure, the refractory was in excellent condition following initial operation in runs R08 and R09.

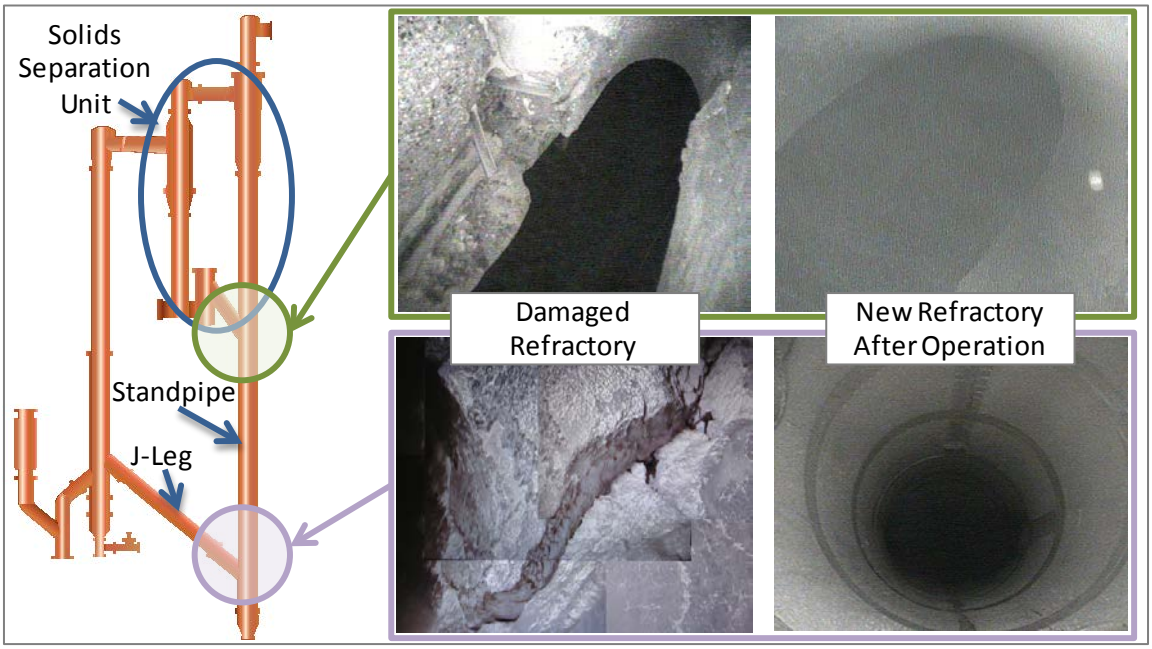


Figure 1. Gasifier Standpipe Refractory before and after Standpipe Replacement.