12. NOVEL GAS CLEANING OPTIONAL PROGRAM TEST CAMPAIGN #3 (NGC-OPT3)

12.1 Objectives

The primary objective of the NGC-OPT3 was to evaluate the performance of the Test Filter-Reactor (TF-R) for mercury removal to very stringent levels (> 90%) from syngas derived from the gasification of a carbonaceous feedstock. The Conditioning Filter-Reactor (CF-R) was to be operated under optimum operating conditions (~ 830ºF, 1-10 pulse cleaning frequency, and trona injected at optimum Na-to-Cl ratio when it is necessary to control HCl levels in the CF-R outlet). During selected test periods, Stage II sulfur and halide sorbents would be injected, simultaneously with the Hg sorbent, into the conditioned syngas upstream of the TF-R to assess their effects on the Hg sorbent performance. This was accomplished through a series of test segments to:

(1) set the Flex-Fuel gasifier operating conditions for producing syngas from the test feedstock (North Dakota Lignite) at 250 psig pressure, preferably with a syngas flow rate at the secondary cyclone exit of at least 3,300 lb/hr.

(2) determine the operating conditions for the entire NGC Process ″Conditioning″ section to consistently result in a syngas with the target characteristics at the TF-R inlet: 1-5 ppmv total sulfur (H_2S + COS), 1-5 ppmv halide (HCl), ~ < 0.1 ppmw particulate content, a temperature of 400 to 572ºF (204 to 300ºC), a pressure of ~ 225 psig, and a flow rate equivalent to a face velocity of at least 3 ft/min. The "Conditioning" section includes the Direct Spray Water Quench (DSQ) system for partial cooling of the raw syngas, the CF-R (including pulsing) vessel for particulate control, the Sorbent (trona) Injection system for bulk HCl removal, a Sulfur Guard Bed (and associated pre-heater and slipstream syngas by-pass) for total sulfur control within the desired range at the TF-R inlet, and a Trim Cooler (indirect heat exchanger) for temperature control.

(3) operate the TF-R to confirm the feasibility of removing > 90% of the total mercury compounds (essentially elemental mercury, Hg^0), via selected dry, fine sorbent injection into the "conditioned" syngas upstream of the TF-R vessel. The key TF-R operating parameters include sorbent-to-mercury mass ratio (i.e., mercury sorbent feed rate), temperature, and pressure (i.e., face velocity).

(4) confirm the effectiveness of ″conventional″ syngas sampling and measurement via gold traps from slipstreams provided by sample extraction & conditioning (SE&C) systems at sampling locations G-8 (CF-R inlet), G-13 (CF-R outlet), G-14 (conditioned syngas), and G-19 (TF-R product syngas) with total mercury concentrations ranging from ~ 0.5 to 2 ppbv (~ 4.1 to 16.4 $\mu g/m^3$) at the TF-R inlet to ~ 0.025 to 0.1 ppbv (0.205 to 0.82 $\mu g/m^3$) at the TF-R outlet.

(5) provide representative slipstream samples from the G-19 sampling location (Test Filter-Reactor outlet) for comprehensive, continuous, sensitive, and accurate measurements using a state-of-the-art on-line mercury measurement instrument (Tekran Mercury Vapour Analyzer 2537A).

12.2 Process Flow Diagram for NGC-OPT3

For this test campaign in the Flex-Fuel Test Facility (FFTF), the syngas flowed through the entire NGC Process pilot-scale test facility (Figure 6), which includes a raw syngas ″Conditioning″ section and a ″Test″ section for deep cleaning of the conditioned syngas stream.

This test involved both Siemens filter-reactors and it was performed similar to the second test campaign (NGC-OPT2A and NGC-OPT2B), except that the Trim Cooler (intermediate indirect heat exchanger) would be operated to further reduce the temperature of the Sulfur Guard Bed outlet syngas to the desired level in the range of ~ 400 to 500ºF.

During the initial part of the test campaign, representative samples of the syngas were extracted, conditioned (de-dusted, cooled, and de-pressured), and analyzed with suitable instruments at two main locations:

G-8: Partially-cooled raw syngas (between DSQ and CF-R)

G-13: Partially-conditioned CF-R product syngas (essentially dust-free, but still containing all the raw syngas sulfur and chlorine).

As indicated in Figure 6, the NGC "Conditioning" section also comprises a Sulfur Guard Bed (SGB) and a Trim Cooler (indirect heat exchanger) for bulk sulfur removal and temperature reduction of the CF-R product gas to meet the requirements of the inlet syngas to the ″Test″ section. Once conditioned, the syngas stream is then introduced into the TF-R vessel for additional deep cleaning via selected dry, fine sorbents that are injected separately into the syngas immediately upstream of the TF-R vessel. Representative samples of the syngas would be extracted, conditioned (de-dusted, cooled, and de-pressured), and analyzed with suitable instruments at two additional locations:

G-14: Conditioned syngas (TF-R inlet)

G-19: Ultra-cleaned syngas (TF-R outlet)

Other analytical work would also be performed on various samples to characterize gasifier performance and efficiency in generating syngas from the test feedstock, to characterize process emissions for permitting activities, and to assess disposal options for the gasification and syngas cleanup byproduct materials. As shown in Figure 17, process samples include fuel feedstock, ash, dust, raw syngas, fresh sorbent materials, spent sorbents, and condensed liquids, in addition to several gas samples throughout the NGC Process section.

12.3 Run Sequence / Chronology

To accomplish test objectives, a sequence was planned similar to the previous test campaigns. This is summarized briefly in Table 27, where the various test segments are defined.

Table 27 - Test Segments Planned in the NGC-OPT3 Test Campaign

NGC-OPT3			
	Lignite		
Overall			
Start	6/7/2005 at ~ 08:00		
End	6/10/2005 at ~ 06:00		
Duration, hr	70		
System heat up with Start-Up Heater & second-stage gasifier heating with met coke (3-TS1)		**TF-R "pre-coating" with Hg Sorbent #2 (3-TS6)**	
Start	6/7/2005 at ~ 08:00	Start	6/9/2005 at ~ 16:00
End	6/8/2005 at ~ 02:00	End	6/9/2005 at ~ 18:00
Duration, hr	18	Duration, hr	2
Establishing Steady State with Lignite coal (3-TS2)		**Hg Sorbent #2 injection (3-TS7)**	
Start	6/8/2005 at ~ 02:00	Start	6/9/2005 at ~ 18:00
End	6/8/2005 at ~ 14:00	End	6/10/2005 at ~ 04:00
Duration, hr	12	Duration, hr	10
Establishing Preferred Conditions in NGC Process Section (3-TS3)		**Pulse TF-R**	6/10/2005 at ~ 05:00
Start	6/8/2005 at ~ 14:00		
End	6/9/2005 at ~ 02:00	**Terminate NGC-OPT3**	6/10/2005 at ~ 06:00
Duration, hr	12		
TF-R "pre-coating" with Hg Sorbent #1 (3-TS4)			
Start	6/9/2005 at ~ 02:00		
End	6/9/2005 at ~ 04:00		
Duration, hr	2		
Hg Sorbent #1 injection (3-TS5)			
Start	6/9/2005 at ~ 04:00		
End	6/9/2005 at ~ 14:00		
Duration, hr	10		
Pulse TF-R	6/9/2005 at ~ 15:00		

The analytical work scope during each test segment planned is highlighted below:

3-TS1

- Calibrate CAT 200 Rosemount analyzer
- Complete revamping of G-8, G-13, G-14, and G-19 sampling lines
- Start setting up Hg gold traps, on-line Hg analyzer, and steam impingers
- Clean Sample Extraction & Conditioning Skid #1 filters A and B
- Assemble G-8 gas sampling cylinders (after cleaning and evacuation by GTI CRS dept.)
- Prepare data sheets, tags, labels, etc.

3-TS2

- Set up impingers for water measurements at G-8 only (these are needed to estimate raw syngas H_2O content).
- Complete setting up gold traps for Hg sampling for subsequent measurement off-line using a Nippon WA-4 Mercury Analyzer.
- Complete setting up Tekran Mercury Vapour Analyzer 2537A instrument for on-line analysis of Hg.
- When gasifier is operating at close to 250 psig:

  - ➢ Make 3 Hg measurements at G-8 (these will provide an indication of the Hg level released in the syngas. Note: char may be affecting these measurements.
  - ➢ How much Hg should we expect to measure?

$$\boxed{[Hg^0]_o \text{ (ppbv)} = 1000 * [MW_{sg} * F * M] / [Qr * MW_{Hg}]}$$

  - $[Hg^0]_o$ = Measured total mercury (Hg^0) concentration in raw (wet) syngas (at G-8), ppbv
  - Q_r = Raw (wet) syngas mass flow rate, lbs/hr
  - MW_{sg} = Molecular weight of raw syngas, lbs/lb-mole
  - F = Coal feed rate to gasifier, lbs/hr
  - M= Coal mercury content, ppmw

<u>Example:</u> A coal containing about 0.06 ppmw Hg (e.g., processed Saskatchewan lignite) fed to the Flex-Fuel gasifier at a rate of 650 lbs/hr to generate a raw, wet syngas stream of 3,000 lbs/hr with an average MW of 25, the estimated syngas mercury content is ~ 1.62 ppbv, ~ 13.29 $\mu g/m^3$ (1 ppbv = 8.2041 $\mu g/m^3$). This is well above the detection limit of the Nippon WA-4 Mercury Analyzer (0.01 $\mu g/m^3$).

  - ➢ Make 3 Hg measurements at G-13. At this sampling location syngas is essentially dust-free and we should expect that these will be the highest levels we'll measure beyond the CF-R.

- Solids analysis: to estimate carbon conversion and Hg balance (lignite feed, gasifier ash, secondary cyclone fines, SE&C Skid #1 char).
- Gas sampling at SE&C Skid #1: take 3 samples towards the end of 3-TS2 for mass balance considerations. Note: no gas sampling is required at the other skids (beyond G-8).

3-TS3

- Test Filter-Reactor (TF-R) at $T_1 \approx 350$ºF (above steam condensation point? Verify)

- Send entire syngas stream through Sulfur Guard Bed (SGB) (Sorbent 1 does not require a particular sulfur level in the syngas to work effectively since it had already been "especially sulfided" by supplier (Synetix/Johnson Matthey). Note: we will not have the HP 5890 GC set up at G-14 to measure H_2S (and COS) level in the conditioned syngas. SGB breakthrough an issue?

- Hg sampling: up to 8 samples at G-13; up to 6 samples at G-14; and up to 3 samples at G-19. G-14 Hg samples are needed to assess effect of SGB on Hg concentration in the syngas. G-19 samples will determine effect of "empty" TF-R on Hg in the syngas (ideally, G-14 and G-19 samples should be the same)

- G-8: up to 6 (one every 2 hours) gas samples at G-8 (select which to submit for analysis in consultation with FFTF operating crew).

- Water impingers at G-8: up to 6

- Solids analysis: T-502 (gasifier ash), T-402 (secondary cyclone fines): 2 samples every hour. Determine which samples should be analyzed (this work can be done post-test depending on budget and need)

3-TS4 and 3-TS5

$$\boxed{\text{Hg Sorbent Injection Rate (grams/min)} = [453.6/(60 * 10^6)] * F * M * MR}$$

- F = Coal feed rate to gasifier, lbs/hr
- M= Coal mercury content, ppmw
- MR= Sorbent-to-mercury mass ratio

<u>Example:</u> A coal containing about 0.06 ppmw Hg (e.g., processed Saskatchewan lignite) fed to the Flex-Fuel gasifier at a rate of 650 lbs/hr to generate a raw, wet syngas stream of 3,000 lbs/hr with an average MW of 25, the estimated syngas mercury content is ~ 1.62 ppb**v**, ~ 13.29 $\mu g/m^3$ (1 ppbv = 8.2041 $\mu g/m^3$). This is equivalent to ~ 13 ppb**w** Hg. For a Hg sorbent-to-mercury mass ratio (MR) of 2000, the Hg sorbent feed rate into the conditioned syngas upstream of the TF-R is ~ 0.59 gram/min.

- Hg sampling: up to 8 samples at G-14; up to 6 samples at G-19; and up to 3 samples at G-13 (if possible). G-14 Hg samples are needed to monitor variations in syngas Hg content, inlet to the TF-R. G-19 samples will determine extent of Hg removal via dry sorbent injection in the TF-R. G-13 samples may be a good idea to see effect of SGB as more sulfur is loaded onto the Süd-Chemie SGB material.

- G-8: up to 6 (one sample every 2 hours) gas samples at G-8 (select which to submit for analysis in consultation with FFTF operating crew).

- Water impingers at G-8: up to 6

- Solids analysis: T-502 (gasifier ash), T-402 (secondary cyclone fines): 2 samples every hour. Determine which samples should be analyzed (this work can be done post-test depending on budget and need)

3-TS6 and 3-TS7

- Hg sampling: up to 8 samples at G-14; up to 6 samples at G-19; and up to 3 samples at G-13 (if possible). G-14 Hg samples are needed to monitor variations in syngas Hg content, inlet to the TF-R. G-19 samples will determine extent of Hg removal via dry sorbent injection in the TF-R. G-13 samples may provide insight into the effect of SGB as more S is loaded onto the Süd-Chemie SGB material.

- G-8: up to 6 (one every 2 hours) gas samples at G-8 (select which to submit for analysis in consultation with FFTF operating crew).

- Water impingers at G-8: up to 6

- Solids analysis: T-502 (gasifier ash), T-402 (secondary cyclone fines): 2 samples every hour. Select samples for analysis).

Post-test analytical work

- Char from SE&C Skid #1
- CF-R char
- TF-R spent sorbent/char mix
- Etc.

12.4 Results and Discussion - NGC-OPT3

The NGC-OPT3 test campaign was initiated on Wednesday June 8, 2005 with lignite (Fort Union, ND). Unfortunately, several feed interruptions were experienced, which were caused by plugging of the gasifier fluid-bed discharge. This part of the test, designated as NGC-OPT3A, had to be aborted the following day, on Thursday June 9, 2005. A plugged feed screw equalization line was suspected, confirmed, and cleared. The piping was modified to eliminate this problem in the future. The NGC Process section was inspected and the Conditioning Filter-Reactor (CF-R) hopper drained for a clean start. The Sulfur Guard Bed (SGB) and Test Filter-Reactor (TF-R) were maintained under a hot nitrogen purge to keep them hot and dry.

Testing was resumed on Sunday June 12 (i.e., NGC-OPT3B) also with lignite. The Flex-Fuel Test Facility (including the NGC Process section) was operated continuously for 51 hours, accomplishing a significant portion of the third test campaign objectives. The major accomplishments and findings from this work included:

- GTI demonstrated the capability to measure mercury at parts-per-billion levels in coal-derived syngas and obtain reasonable material balance.

- There was evidence of a significant level of mercury capture (50-75%) with the higher-temperature Hg removal sorbent (TDA sorbent) at the relatively high temperature of 572ºF (300ºC, optimum NGC Process Stage II operating temperature).

- Approximately 200 gas, solid, and liquid samples were taken and analyzed, and additional post-test analyses were performed.

12.4.1 Gasifier and Filter-Reactor Operations

The Flex-Fuel Test Facility (gasification and Novel Gas Cleaning Process sections) was successfully operated throughout most of the NGC-OPT3B test campaign, including two Siemens' barrier filters (Conditioning Filter-Reactor, CF-R, and Test Filter-Reactor, TF-R), Sulfur Guard Bed, SGB (and associated low-pressure nitrogen pre-heater and slipstream by-pass system), and Stage II sulfur (G-72E) and halide (G-92C) sorbent feeders. The T-2107 Stage II Sulfur Sorbent Feeder was dedicated to feeding the finely-ground mercury sorbents. The T-2108 Stage II Halide Sorbent Feeder was used to feed a mixture of finely-ground G-72E sulfur sorbent and finely-ground G-92C halide sorbent (in combination with nahcolite to improve its feeding) during the 3B-TS7 test segment when the effect of the Stage II sulfur and halide sorbents on the Hg sorbent mercury removal performance was evaluated. In addition, because only the higher-temperature Hg removal sorbent was evaluated during this campaign, there was no need to engage the Trim Cooler (located between the SGB and TF-R) to reduce the conditioned syngas temperature at the TF-R inlet to ~ 400ºF, as had been planned.

Because the raw syngas stream contained steam, it was necessary to heat up the SGB catalyst bed (Süd-Chemie's G-72E catalyst) in the NGC Process "Conditioning" section above the syngas dew point to avoid water condensation, which otherwise would severely damage the catalyst's desulfurization performance. Accordingly, during the NGC-OPT3B campaign the raw syngas was initially routed from the DSQ system (HE-2001-A) through the CF-R vessel (T-2153), and then bypassed directly to the PCV-602 pressure let-down system. Simultaneously, low-pressure nitrogen was fed through the Nitrogen Pre-Heater (SH-2002) into the SGB vessel (R-2002), which had been isolated from the front-end of the NGC Process section (Figure 2 and Figure 31). The hot nitrogen exiting the SGB vessel was then routed around the Trim Cooler (HE-2071) through the Test Filter-Reactor (T-2147), and then through the PCV-2181 pressure let-down system. This made it possible to also pre-heat the TF-R vessel before directing the conditioned syngas stream into it.

Once the "Conditioning" section reached steady state and the TF-R brought to a sufficiently high temperature, the partially-cooled and essentially particulate-free syngas stream exiting the CF-R was sent through the SGB vessel, then bypassed through the PCV-2006, around the Trim Cooler, to the Condensate Knock-Out Tank (T-2072), and then to the TF-R. Pressure in the "Conditioning" section was controlled by the PCV-2003 pressure let-down system, and pressure in the "Test" section was controlled by the PCV-2181 pressure let-down system. In order to evaluate the performance of the higher-temperature Hg removal sorbent under optimum Stage II operating conditions for desulfurization and dechlorination sorbents in the "Test" section of the NGC Process, the temperature in the TF-R should be in the 550°F to 575°F range. Since no trona injection was necessary in the "Conditioning" section (lignite contained even less chlorine than the washed Indian coal), the operating temperature for the CF-R vessel was determined primarily by the requirements of the SGB vessel. Therefore, the temperature strategy adopted involved setting the inlet temperature to the CF-R vessel so that, with ambient heat losses from the intervening vessels and piping, the operating temperature of the TF-R vessel would be in the optimal range. Moreover, to minimize mercury/char interactions in the CF-R vessel, the inlet temperature was maintained slightly higher than in previous tests by slightly modifying the operating conditions of the DSQ system. This also helped ensure the inlet temperature to the SGB was sufficiently high to prevent early breakthrough of the SGB (the same, partially utilized catalyst load from previous tests was used).

During the third test campaign, raw syngas, derived from the gasification of North Dakota lignite (0.89% S, ~ 122 µg/g Cl, 0.06 µg/g Hg), was successfully conditioned to the temperatures and contaminant levels required at the inlet to the TF-R. Throughout testing, temperatures across the NGC Process section were maintained at ~ 1450ºF at the secondary cyclone, ~ 1400ºF at the inlet to the Direct Spray Water Quench, ~ 700ºF at the inlet to the CF-R, ~ 650ºF at the outlet of the CF-R, ~ 650ºF at the SGB inlet, ~ 600ºF at the SGB outlet, ~ 600ºF at the TF-R inlet, and ~ 550ºF at the TF-R outlet. These conditions ensured that the SGB was operated at optimal conditions for maximized utilization of the SGB catalyst and efficient sulfur removal. These conditions also ensured that contaminant removal reactions across the TF-R vessel were kept within the optimum temperature range (550°F to 575°F). The total sulfur concentration (H_2S and COS) at the inlet was estimated to be within the 1-5 ppmv range throughout testing, although the entire syngas stream was passed through the SGB vessel (the on-line GC/FPD that provided near-continuous H_2S and COS measurements during the first and second test campaigns was not available for this third test campaign). As indicated above, there was no need to engage the Trim Cooler for this test campaign. In addition, because of low levels of HCl in the raw syngas (~ < 20 ppmv) and some measured HCl removal in the CF-R vessel (through interaction with char) and in the SGB vessel (a small amount of CaO in the SGB catalyst), it was not necessary to engage the trona sorbent feeder upstream of the CF-R for bulk HCl removal. No impinger sampling was performed for HCl measurement via ion chromatography in this campaign and the on-line FT-IR instrument was not available for HCl analysis. However, based on the NGC-OPT2A and NGC-OPT2B test campaign results, the conditioned syngas HCl content was probably ~ 1 ppmv or lower. Results from this test campaign are discussed in more detail below.

Conditioning the raw syngas (at G-14, TF-R inlet), performing Hg measurements in the syngas throughout the NGC Process section, and evaluating the mercury removal performance of the higher-temperature Hg sorbent ("activated" and finely-ground TDA sorbent) were the focus of this third test campaign (NGC-OPT3B). This campaign comprised the test segments shown in Table 28. As indicated, gasification of metallurgical coke (Bethlehem Coke Breeze, for second-stage heating up of the gasifier) and then North Dakota lignite occurred over ~ 51 hours, from ~ 01:00 on 6/13/2005 through 04:00 on 6/15/2005. The period on lignite coal, during which mercury measurements and removal testing were performed, began at ~ 21:00 on 6/13/2005 and continued for 36 hours, until the test was terminated. The gasification section was operated under steady state conditions throughout most of these test segments as demonstrated by the stable gasifier output shown in Figure 68. In this figure the hydrogen (H_2), carbon monoxide (CO), and methane (CH_4) concentrations in the raw, dry product syngas are given, as measured by the Rosemount CAT 200 online analyzer at the G-8 sampling location (CF-R inlet). The noticeable changes in the CO concentration during the 3B-TS6 test segment, from ~ 21:45 on 6/14/05 to ~ 02:00 on 6/15/05 are related to changes in the gasifier operating conditions that were implemented to circumvent some difficulties experienced with the DSQ system.

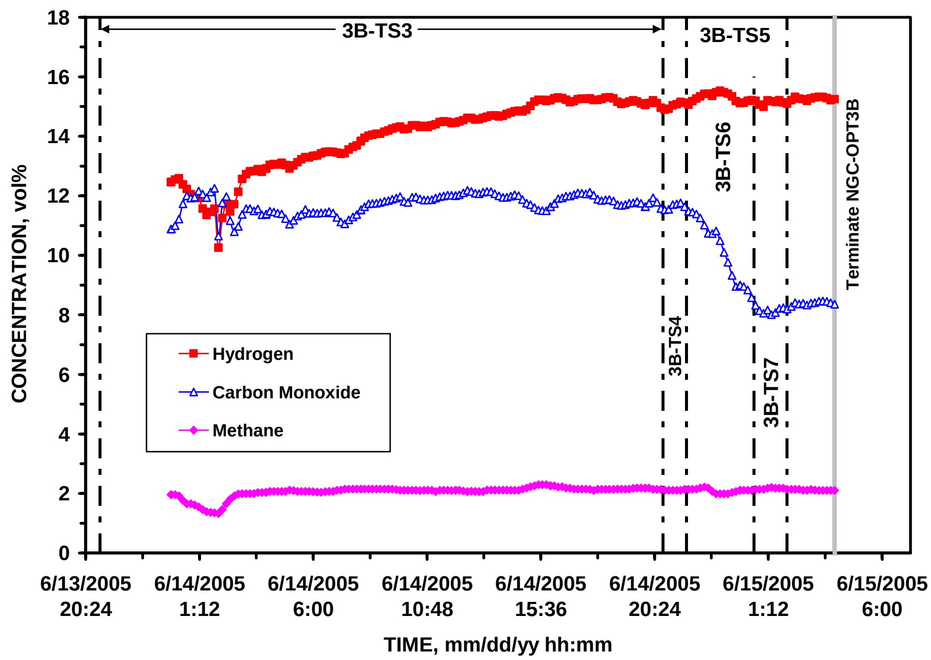


Figure 68 - H_2, CO, and CH_4 in the Raw Gasifier Product Syngas at G-8 (CF-R Inlet) during the NGC-OPT3B Test Campaign

Table 28 - Test Segments in the NGC-OPT3B Test Campaign (June 13-15, 2005)

NGC-OPT3B

Overall	
Start	6/13/2005 at ~ 01:00
End	6/15/2005 at ~ 04:00
Duration, hr	51
System heat up with Start-Up Heater & second-stage gasifier heating with met coke (3B-TS1)	
Start	6/13/2005 at ~ 01:00
End	6/13/2005 at ~ 16:00
Duration, hr	15
Establishing Steady State with Lignite coal (3B-TS2)	
Start	6/13/2005 at ~ 16:00
End	6/13/2005 at ~ 21:00
Duration, hr	5
Establishing Preferred Conditions in NGC Process Section (3B-TS3)	
Start	6/13/2005 at ~ 21:00
End	6/14/2005 at ~ 20:45
Duration, hr	~ 24
TF-R "pre-coating" with Hg "higher-temperature" sorbent (3B-TS4)	
Start	6/14/2005 at ~ 20:45
End	6/14/2005 at ~ 21:45
Duration, hr	1
Hg "higher-temperature" sorbent injection (3B-TS5)	
Start	6/14/2005 at ~ 21:45
End	6/15/2005 at ~ 02:00
Duration, hr	~ 4
Hg "higher-temperature" sorbent injection (3B-TS7) simultaneously with S & halide Stage II sorbent mix	
Start	6/15/2005 at ~ 00:35
End	6/15/2005 at ~ 02:00
Duration, hr	1.5
Terminate NGC-OPT3	6/15/2005 at ~ 04:00
Pulse TF-R	Post-test

12.4.1.1 Gasifier Performance

Summary

Throughout this report, gasification of the PDU test program carbonaceous feedstocks (Bethlehem Coke Breeze, washed Indian coal, and North Dakota lignite) is reported only in the context of the Novel Gas Cleaning Program testing. Given that the lignite used is a domestic fuel, its gasification is discussed in more detail in the section below (similar data are provided in Appendix B for operation with washed Indian coal during the second test campaign).

As mentioned earlier, GTI arranged with the Green River Energy Coal Creek Station (GRE/CCS) to have about 100 tons of Fort Union lignite processed (crushed, screened, and dried) to meet the Flex-Fuel gasifier specifications. GRE's fluidized-bed drying process produced three streams: product, elutriates, and undercuts, with a surface moisture of ~ 0% and inherent moisture of ~ 20%. To preserve the quality of the lignite and more importantly the contaminant levels for the PDU test program (especially mercury content), the product and elutriates fractions were blended and the undercuts re-crushed, screened, and stored in proper containers for additional blending as necessary. Samples from the lignite fed throughout the third test campaign indicated the lignite feed contained an average of ~ 0.084 ppmw of mercury, compared to the 0.093 ppmw estimate provided by GRE (Table 15). It should also be noted that the lignite used contained ~ 5.4% Na_2O.

Lignite was first gasified during the latter stages of the second test campaign (NGC-OPT2B), where its suitability was confirmed as the feedstock of choice for the third test campaign. The results obtained in this testing demonstrated the technical feasibility of the filter-reactor concept and the ability of the NGC Process to deep clean the gasifier product gas to very stringent levels (10-50 ppbv for H_2S, COS, and HCl). The same cleaning efficiencies were measured with lignite as were achieved with the washed Indian coal, showing that the NGC Process functioned very well with two diverse fuels.

This third test campaign, which focused on the evaluation of mercury capture with sorbents at relatively high temperatures, used lignite exclusively as the source of syngas and provided another opportunity to demonstrate efficient gasification of lignite in the fluidized bed gasifier. Hot operation extended for a total of 48 hours, gasifying approximately 36,000 lbs (18 tons) of lignite. The Conditioning Filter-Reactor (CF-R) was online through all startup, steady-state, and shutdown operations (100% availability). The maximum lignite coal feed rate was ~ 750 lbs/h and the longest continuous operating period was 36 hours, yielding balances at 250 psig operation.

Steady-state air-blown operation at true ash-balanced conditions was achieved at 250 psig during this third test campaign, with excellent material and energy balances (Table 29). MAF (moisture- and ash-free) coal and carbon conversions have been estimated at 94% and 91%, respectively (Table 30). Table 31 provides particle size distributions for samples from the lignite gasifier feed, classifier discharge, secondary cyclone fines, and Conditioning Filter-Reactor fines. The dry product gas consisted of approximately 14% H_2, 14% CO_2, 13% CO, 2% CH_4, 57% N_2, and a total sulfur (H_2S + COS) concentration of ~ 1,150 ppmv (Table 35). The corresponding nitrogen purge free heating value of the dry syngas was 123 Btu/scf (Table 30).

Based on the above performance a syngas heating value of over 150 Btu/scf can be expected in a commercial-scale gasifier with its lower heat losses and more efficiently integrated plant design. Carbon conversion in the 95-98% range should also be achievable. The GTI U-GAS® gasification process is therefore quite suitable for scale-up to commercial power generation applications. Indeed, this was the subject of a recent study by GTI and Nexant on lignite-based IGCC using the GTI U-GAS® gasification technology together with currently available technologies for coal crushing and drying, coal feeding, and gas cleaning. Sensitivity of the economics to various technical and economic factors was also explored in this study. In addition to the feasibility of scaling up GTI's gasification technology for power generation with lignite, this study showed that incremental improvement in coal and gas handling systems and overall plant integration could further improve the economics of this approach.[14]

Gasifier Performance Determination Procedures

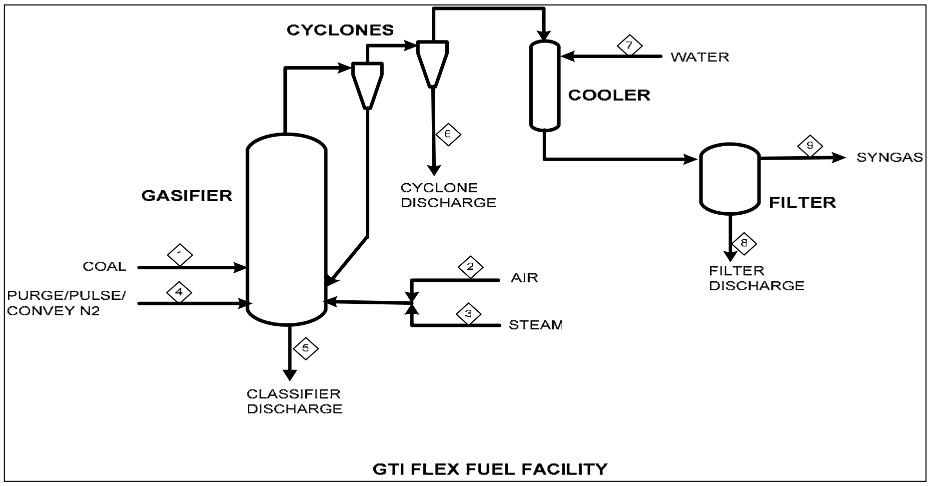
Several assumptions/adjustments/simplifications are typically made in the assessment of gasifier performance. The assumptions made in the lignite gasification case are listed below:

1. The ultimate analysis of lignite coal feed (Table 14) was adjusted to make the ash content consistent with the proximate analysis.
2. The syngas analyses (Table 35) were adjusted to an oxygen free basis. The moisture content was assumed to be ~ 25 vol% based on impinger sampling data.
3. The Conditioning Filter-Reactor solids discharge rate was determined based on the actual fines collected from the filter vessel divided by the test duration (780.4 lbs during 36 hours, or about 21.7 lb/hr). This is very close to 3% of the coal feed rate that is typically assumed in this type of estimations.
4. The heat loss was calculated based on an estimated total surface area for the system (gasifier, cyclones and diplegs, cooler, filter, and connecting piping), 200ºF shell temperature, 60ºF ambient temperature, 2.42 Btu/ft^2-h combined radiation and convection heat transfer coefficient, zero wind speed, and 0.96 surface emissivity.
5. The measured heating values of the classifier, cyclone, and filter solids were used for the heat balance.

Steady state was selected to correspond to the ash-balanced operating period from 09:00 to 19:00 on 6/14/05, by examining the quick ash data (Table 36 and Table 34). During this steady-state period, coal conversion was estimated at 94% and the gas heating value at 123 Btu/scf.

Table 29 – Material and Energy Balance During Steady State Operation with Lignite

Flex Fuel
Test: Lignite Coal
Period:
From: 6-14-05 09:00
To: 6-14-05 19:00



Stream No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Stream Discription	**Coal Feed**	**Air Feed**	**Steam Feed**	**Nitrogen Feed**	**Classifier Discharge**	**Cyclone Discharge**	**Water Feed**	**Filter Discharge**	**Product Syngas**
Temperature, °F	60	112	439	90	952	1318	60	706	706
Solids Flow, lb/h	**709**				**68**	**20**		**22**	
Dry Solids Composition, wt%									
Ash	14.18				70.93	69.67		58.62	
Carbon	59.30				27.07	27.40		35.50	
Hydrogen	3.86				0.33	0.32		0.42	
Nitrogen	0.90				0.33	0.26		0.34	
Sulfur	0.87				0.80	2.35		1.50	
Oxygen	20.89				0.54	0.00		3.62	
Total	100.00				100.00	100.00		100.00	
Liquid Flow, lb/h							**285**		
Gas Flow, lb/h		**1527**	**195**	**209**					**2936**
Gas Composition, mol%									
H2									10.57
CO2									10.30
O2		21.00							0.00
N2		79.00		100.00					42.53
CO									9.67
CH4									1.82
C2H6									0.01
C2H4									0.00
C6+									0.01
H2S									0.08
COS									0.01
H2O		0.00	100.00	0.00					25.00
Total		100.00	100.00	100.00					100.00

INPUT STREAMS	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulfur**	**Ash**	**Total**	**Btu/h**
Coal Feed	342.3	37.1	237.9	5.2	5.0	81.9	709.3	5.89E+06
Air Feed			355.6	1171.3			1526.9	1.80E+04
Steam Feed		21.8	173.0				194.8	2.40E+05
N2 Feed				208.9			208.9	1.50E+03
Water Feed		31.9	253.4				285.3	0.00E+00
Total Input	342.3	90.8	1019.9	1385.4	5.0	81.9	2925.3	6.15E+06
OUTPUT STREAMS								
Product Syngas	319.0	96.3	1072.5	1445.2	3.3		2936.2	5.06E+06
Classifier Discharge	18.4	0.2	0.4	0.2	0.5	49.4	69.1	2.87E+05
2nd Cyclone Discharge	5.5	0.1	0.0	0.1	0.5	14.0	20.1	8.99E+04
Filter Discharge	7.7	0.1	0.0	0.1	0.3	13.5	21.7	1.14E+05
Heat Loss								5.45E+05
Total Output	350.5	96.7	1072.8	1445.5	4.6	76.9	3047.1	6.10E+06
Out - In	8.2	5.9	52.9	60.1	-0.4	-5.0	121.8	-4.71E+04
% Balance (Out/In)	102.4	106.5	105.2	104.3	92.6	93.9	104.2	99.2

(All units in lb/h unless otherwise noted)

Table 30 – Gasifier Operating and Performance Parameters with Washed Indian Coal

GASIFIER OPERATING & PERFORMANCE DATA	
Gasifier Pressure, psig	261
Gasifier Bed Temperature, °F	1539
Coal Feed Rate, lb/h	709
Air Feed Rate, lb/h	1527
Steam Feed Rate, lb/h	195
Steam/Carbon Ratio, lb/lb	0.57
Oxygen/Carbon Ratio, lb/lb	1.04
Gasifier Bed Density, lb/cu ft	29.6
Gasifier Bed Height, ft	8.7
Gasifier Superficial Velocity, ft/s	2.1
MAF Coal Gasification Intensity, lb/cu ft -hr	57
Dry & Purge N2 Free Syngas HHV, Btu/SCF	123
MAF Coal Conversion, %	94

Table 31 – Feed and Discharge Solids Particle Size Distributions

Retained on US Sieve, wt %	Coal Feed	Classifier Disch	Cyclone Disch	Filter Disch
6	9	6.0	0.0	0.6
12	23.8	21.8	0.0	0.4
20	26.3	16.8	0.0	0.4
40	21.5	11.8	0.0	1.0
60	11.6	10.3	0.2	1.0
80	4.5	12.0	0.2	1.0
100	1.3	8.1	0.4	0.6
140	1.0	8.1	1.9	2.3
200	0.4	2.4	5.1	2.7
230	0.1	0.6	3.4	1.7
270	0.1	0.3	6.3	2.3
325	0.1	0.2	5.5	2.9
Pan	0.3	1.6	77.0	83.1
Total	100.0	100.0	100.0	100.0

12.4.1.2 Filter-Reactor Operations

Temperature drop and pressure drop behaviors, and key process parameters (inlet syngas temperature, syngas mass flowrate, and operating face velocity) for the CF-R and TF-R vessels are reported in Figure 69 through Figure 72 for the NGC-OPT3B campaign. The figures shown cover the entire test duration, and on each figure the various test segments are delineated consistent with the information provided in Table 28. The Flex-Fuel gasifier pressure was brought up to ~ 250 psig after initiating the gasification of lignite coal (during test segment 3B-TS2). The inlet temperature for the syngas to the CF-R was also reduced from ~ 790ºF to ~ 690ºF and then raised back to ~ 800-825ºF during the latter stages of the 3B-TS3 test segment. It steadily decreased and then stabilized at ~ 660ºF during the sorbent injection test segments 3B-TS4 and 3B-TS5. Figure 69 shows there were two distinct periods during which process conditions were relatively constant for the CF-R vessel: from ~ 02:30 to 20:45 on 6/14/05 and from 20:45 on 6/14/05 to 04:00 on 6/15/05, when the NGC-OPT3B campaign was terminated. Although in both periods lignite was being gasified, these differences in the CF-R pulsing cycles were caused by changes in the gasifier operating conditions.

The syngas mass flowrate at the CF-R inlet was initially at ~ 2,600 lbs/hr, which corresponds to approximately 2.5 ft/min operating face velocity. Both the syngas flowrate and the face velocity for the CF-R vessel increased during the 3B-TS3 test segment, as shown in Figure 69, as gasifier performance improved. During the steady-state operating period from ~ 09:00 to ~ 19:00 on 6/14/05, the syngas mass flowrate and the CF-R face velocity averaged about 2,850 lbs/hr and 2.77 ft/min, respectively. The solids loading in the syngas was moderate, and the time between pulses varied from ~ 9 to 11 minutes during the first period and 20 to 22 minutes during the second period. As shown in Figure 69, the differential pressure (PDI-2153) was allowed to increase to about 72 in wg before pulsing was initiated. After pulsing the differential pressure was about 38 in wg during the first stable operating period for the CF-R, and about 22 in wg during the second period. Pulsing was performed successfully with the fast-acting valves. The syngas temperature drop across the CF-R vessel appears to be in the range of 40 to 50ºF, especially during steady state operating periods.

At ~ 19:15 on 6/14/05, it became necessary for the operating crew to start reducing gasifier pressure to circumvent a rising pressure drop across the DSQ system and continue the test campaign. As the gasifier pressure was reduced, the syngas mass flowrate started to decline, as shown in Figure 71, reaching ~ 2,670 lbs/hr at 20:45 when the 3B-TS4 test segment was initiated. [Note: it was decided to proceed with sorbent injection in the 3B-TS4 test segment despite the occurring changes]. The syngas mass flowrate continued to drop, reaching ~ 2,645 lbs/hr at the end of the 3B-TS4 test segment and ~ 1,885 lbs/hr by ~ 00:35 on 6/15/05 when the 3B-TS7 test segment was started (i.e., "higher-temperature" Hg sorbent injection simultaneously with sulfur and halide Stage II sorbent mix**)**. As shown in Figure 71, throughout the 3B-TS7 test segment and until the campaign was terminated, operating conditions were stable. The syngas mass flowrate averaged about 1,940 lbs/hr during the 3B-TS7 test segment and the face velocity about 2.19 ft/min.

Figure 70 shows the measured temperature and pressure drop behavior for the TF-R vessel. Figure 72 shows the measured inlet syngas temperature and mass flowrate, and the calculated operating face velocity for the TF-R vessel. The syngas temperature at the TF-R inlet was about 650ºF at 20:45 on 6/14/05 when the 3B-TS4 test segment was initiated. It showed a decreasing trend and reached about 516ºF at the beginning of test segment 3B-TS7. It remained constant at about this level throughout the 3B-TS7 test segment. Similarly, the TF-R outlet temperature decreased from ~ 601ºF at 20:45 on 6/14/05 (i.e., start of 3B-TS4) to ~ 478ºF at 00:35 on 6/15/05 (start of 3B-TS7). During this latter test segment, the syngas temperature at the TF-R outlet averaged about 455ºF. Therefore, it appears that during the 3B-TS7 test segment, the TF-R was operated at a temperature of about 486ºF, i.e., ~ 65ºF lower than in the second test campaign (NGC-OPT2A and 2B). The syngas mass flowrate at the TF-R inlet and the face velocity profiles showed similar trends to their CF-R counterparts, although increases in the TF-R face velocity towards the latter stages of the 3B-TS3 test segment were more noticeable (Figure 72).

The pressure drop behavior depicted in Figure 70 for the TF-R vessel is distinctly different from the pressure drop behavior for the CF-R vessel (Figure 69). In addition, because of the changes in operating conditions that were implemented to contain the difficulties experienced with the DSQ system, the TF-R pressure drop profile requires close examination. Figure 70 shows that the TF-R ΔP ranged between 17 and 20 in wg during most of the 3B-TS3 test segment, and increased to about 22 in wg during the latter stages of this test segment as syngas mass flowrate increased. Because the syngas mass flowrate continued to drop during the 3B-TS4 and the 3B-TS6 test segments, no increases in the TF-R ΔP were measured despite the fact that sorbent injection was performed during these test periods. As shown in

Figure 70, ΔP across the TF-R continued to drop and reached about 12 in wg. However, during sorbent injection in the 3B-TS7 test segment, which, as pointed out above, was performed under stable operating conditions, the TF-R ΔP is seen to increase, evidence that at least portions of the sorbents being injected were reaching the filter elements (candles).

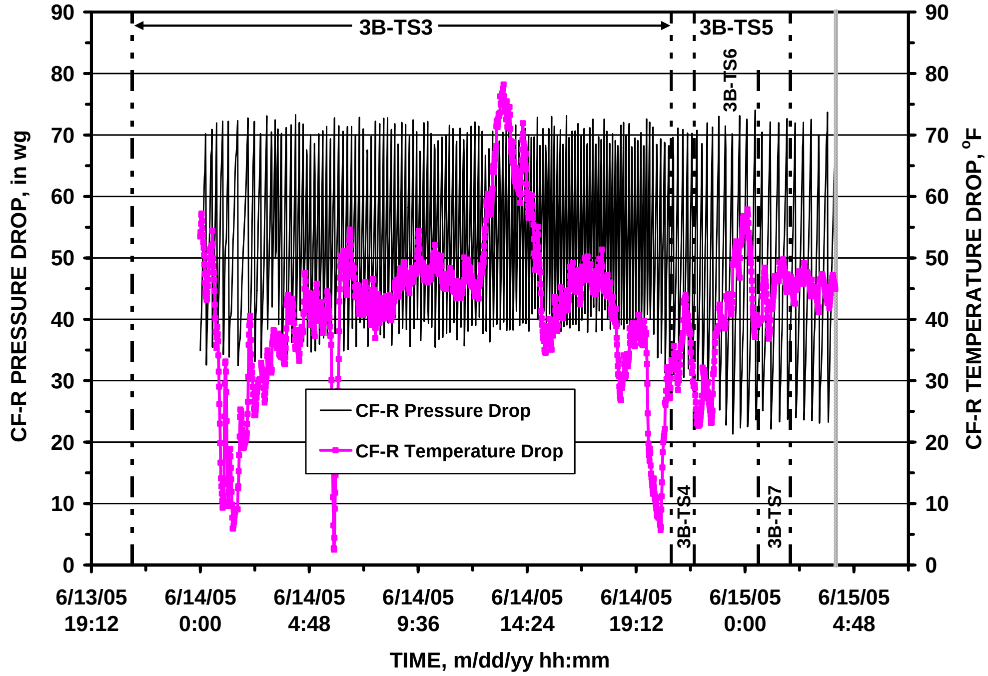


Figure 69 - Temperature and Pressure Drop Behavior of the Conditioning Filter-Reactor during the NGC-OPT3B Campaign

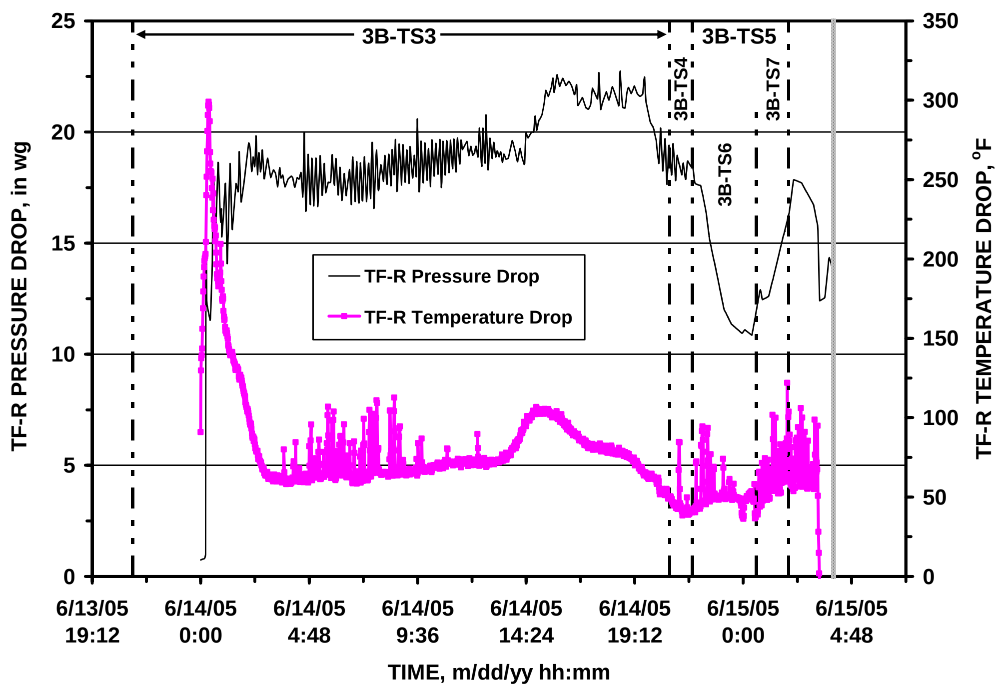


Figure 70 - Temperature and Pressure Drop Behavior of the Test Filter-Reactor during the NGC-OPT3B Campaign

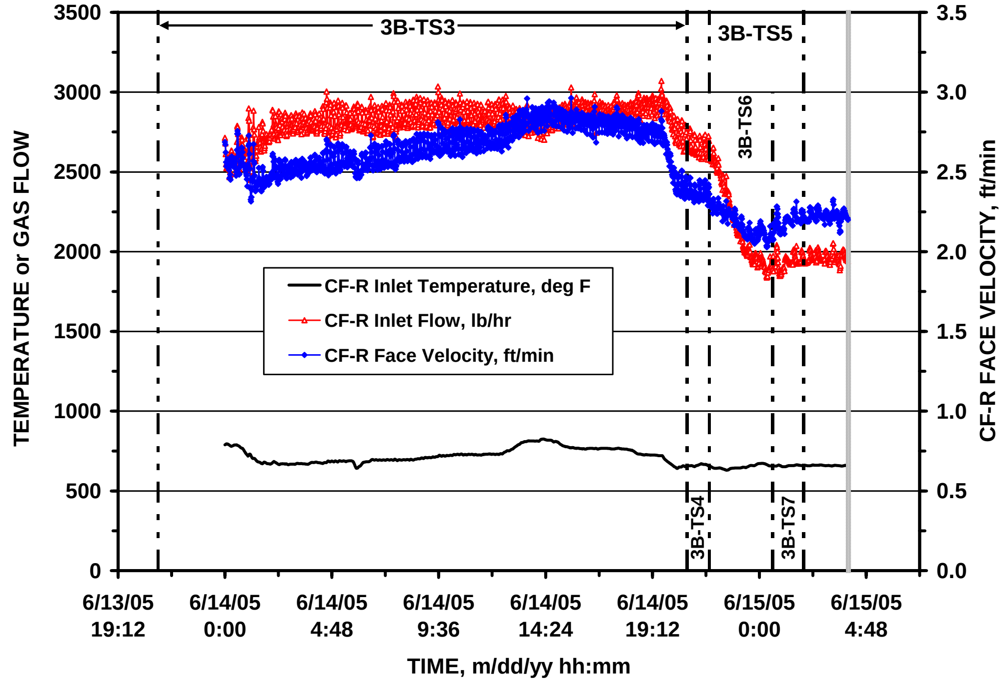


Figure 71 - Temperature, Syngas Flowrate, and Face Velocity at the Conditioning Filter-Reactor Inlet during the NGC-OPT3B Campaign

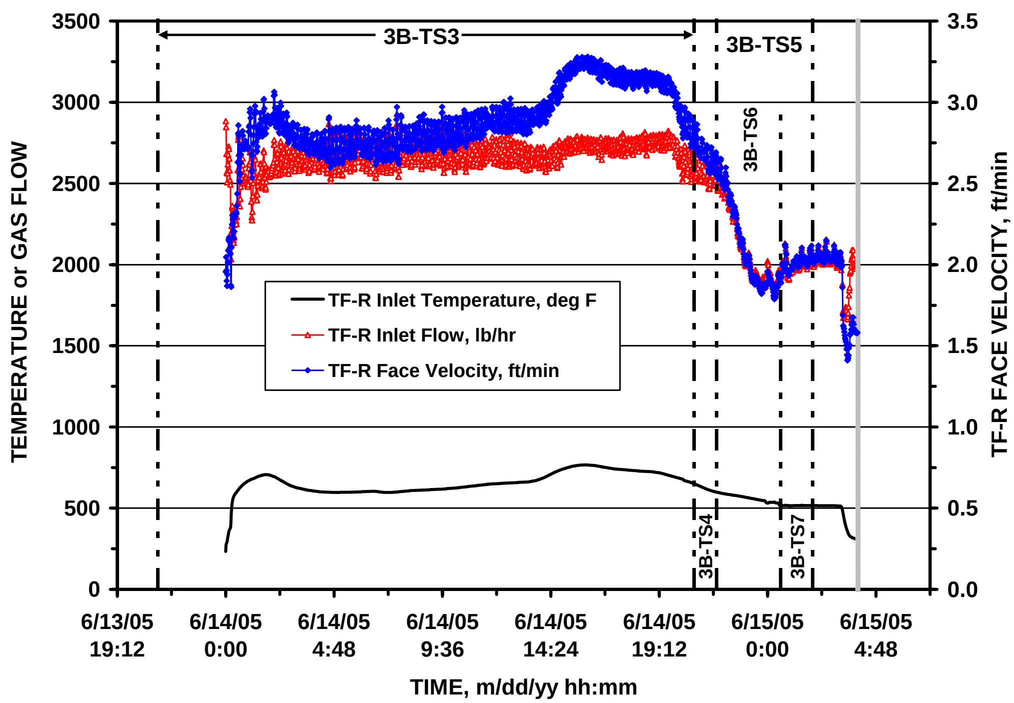


Figure 72 - Temperature, Syngas Flowrate, and Face Velocity at the Test Filter-Reactor Inlet during the NGC-OPT3B Campaign

12.4.1.3 Syngas Mercury Measurements

The lignite-derived raw syngas was estimated to contain ~ 1.8 ppbv of elemental mercury (Hg0) or ~ 14.8 µg/m3, if all the mercury in processed lignite (~ 0.06 ppmw) were released in the product syngas. Close to 200 gas, solid, and liquid samples were taken throughout the duration of the NGC-OPT3B campaign, as shown in Table 36 through Table 38. Solids included lignite feed (S-1), gasifier ash (S-5), secondary cyclone fines (S-6), and char samples from the first Sample Extraction and Conditioning (SE&C) Skid at the G-8 sampling location. Solid samples (Table 36 and Table 34) were analyzed mostly for ash to monitor gasifier performance, but some selected samples were also analyzed for mercury. Liquid (water) samples from the SE&C Skids at the G-8, G-13/G-14, and G-19 sampling locations were also analyzed for mercury to confirm viability of the sampling technique used (Table 38). Gas samples (Table 38) consisted mostly of dry samples (water removed by gas cooling to 40-50ºF) taken at the various sampling points using gold traps. These traps were then analyzed for mercury off-line using a Nippon WA-4 Mercury Analyzer (~ 0.01 µg/m3 detection limit). Other gas samples were taken via sampling cylinders at G-8 (to determine the overall composition and sulfur content of the raw syngas stream) and at G-14 (to confirm low-S content of the conditioned syngas and ensure that the SGB continued to perform well, Table 35).

Numerous Hg samples were taken during the third test segment (3B-TS3) when the gasifier was operating under steady state conditions and preferred operating conditions were being (or had been) established in the NGC Process section. As can be seen in Table 38, initial Hg analyses were very low, much lower than expected. At the G-8 location, it was suspected char on the Mott filter (maintained at 400ºF) on the SE&C Skid #1 was interfering with the sampling. Water samples at G-8 contained very little Hg (about 1 ppb), ruling out the possibility that mercury was being lost to the water during gas cooling. At the G-13 location (CF-R outlet) where char is minimal or non-existent, it was suspected Hg could be removed by char within the CF-R vessel. Although the inlet and outlet CF-R temperatures were about 700ºF, there were other locations within the vessel at much lower temperatures. Hg removal within the CF-R vessel would also explain the very low Hg analyses obtained at the G-14 location, where the conditioned syngas was essentially dust-free and desulfurized to very low levels.

Based on the results obtained a few options were determined to proceed. First, samples from the lignite feed were submitted for Hg analysis. The assays obtained, 0.061 and 0.090 ppmw (see 051263-070 and -089 in Table 38), confirmed the previous analysis that was performed in February 2005 on a composite sample. As discussed above, this Hg content in the feedstock could generate syngas mercury contents that would be at least 3 orders of magnitude higher than the detection limit of the Hg analysis method employed (~ 15 to 22 µg/m^3). [Note: additional post-test analyses on selected lignite feed samples indicated an average Hg content of ~ 0.084 µg/g, as shown in Figure 73.] Therefore, it would not be helpful to switch to a different coal (such as washed Indian coal, which had a higher Hg content, about 0.14 ppmw). Second, an online analyzer (Tekran Mercury Vapour Analyzer 2537A) was quickly set up at the G-19 location that was much more sensitive than the off-line instrument. Simultaneously, we started sampling with gold traps at G-19, the TF-R outlet. Expecting to obtain a very low Hg content, we sampled for 90 minutes (see 051263-121 in Table 38). Immediately, the on-line analyzer indicated "high" Hg levels in the TF-R outlet syngas. Our Analytical Lab also informed us that the 90-min sample out-ranged their instrument, indicating Hg levels > 146 (Table 38). We were advised to reduce the sampling duration to 15 minutes or lower, and to discontinue using the on-line instrument for fear it would be "overwhelmed" and contaminated with mercury. Its use should be dedicated to sorbent injection periods, where the Hg level in the TF-R product syngas could be expected to be much lower.

It is possible that the gold traps at the G-8 and G-13 sampling locations were poisoned by sulfur in the syngas, preventing them from picking up any mercury. At these sampling locations, H_2S concentration was in the 1,000 to 1,200 ppmv range (Table 35). At G-14, where the syngas was desulfurized to a very high extent using the SGB, the gold traps could not have been poisoned. The fact that no mercury could be measured at G-14 was probably caused by a malfunctioning temperature controller on the SE&C Skid #2. The Mott filter on this skid could not be maintained at the desired temperature of 400ºF, and it was observed that this filter did not get heated beyond 277ºF. Unfortunately, no residues could be collected from this sample train for Hg analysis to verify if any mercury removal took place at this location.

Five (5) gold trap samples were taken at the G-19 location prior to initiating sorbent injection. Two samples (#128 and #129 in Table 38) indicated 17.0 and 15.9 $\mu g/m^3$, which was well within the expected concentration range. One sample was not analyzed for fear its Hg content was too high because of much larger volume of gas. Unfortunately, the 2 samples that were taken immediately before sorbent injection measured lower Hg contents (5.9 and 4.9 $\mu g/m^3$). This discrepancy cannot be explained at this time.

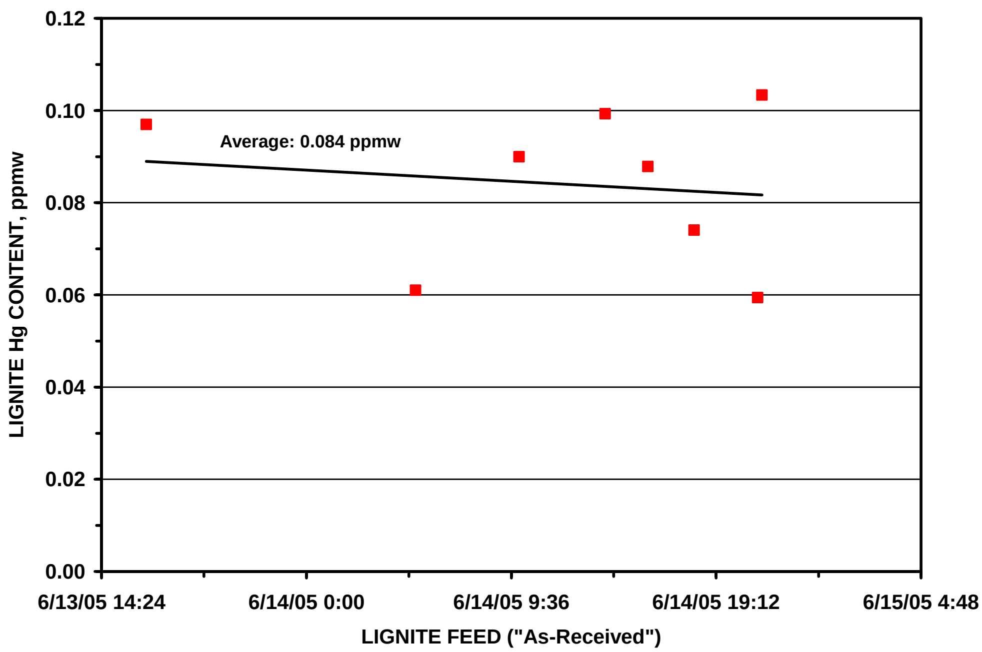


Figure 73 - Hg Content of Selected Samples from the Lignite Feed during the NGC-OPT3B Test Campaign

12.4.1.4 Mercury Sorbent Performance Evaluation

As done in previous test campaigns, sorbent injection was performed in two phases, first at a higher sorbent injection rate to "pre-coat" the TF-R candles with sorbent before reducing the injection rate to the desired level and maintaining it for a given period of time. To evaluate mercury removal under TF-R optimum temperature for combined sulfur (H_2S and COS) and halide (HCl) removal (i.e., 300ºC or 572ºF), the TF-R was operated under conditions that were nearly identical to the second test campaign. The TDA mercury sorbent, following activation and grinding at GTI as instructed by TDA, was selected as the "higher-temperature" sorbent. TDA sorbent was fed using the T-2107 Stage II Sulfur Sorbent Feeder. TDA sorbent injection was performed from ~ 21:45 on 06/14/05 to 02:00 on 06/15/05. To make a preliminary evaluation of the effect of the Stage II sulfur and halide sorbents on the performance of the Hg sorbent, an equal-weight mixture of the G-72E, G-92C, and nahcolite sorbents was fed (using the T-2108 Stage II Halide Sorbent Feeder) from ~ 00:35 to 02:00, concurrently with the TDA sorbent.

The Hg analyses at G-19 (TF-R outlet) during sorbent injection indicate some positive mercury removal results, particularly at such relatively high temperatures. During mercury sorbent injection, the Hg concentration in the TF-R product gas was measured at ~ 3.5 to 4 µg/m^3. Assuming a 16 µg/m^3 mercury concentration in the TF-R inlet, then approximately 75% removal was achieved during injection of the mercury sorbent alone. When the sulfur and halide sorbents were injected concurrently with the mercury sorbent, mercury concentration in the TF-R outlet syngas slowly increased to ~ 8 µg/m^3, corresponding to about 50% removal. This was probably due to the fact that much less sulfur was available to interact with Hg. These data, summarized in Figure 74, can be used to develop appropriate projections of TDA's mercury removal sorbent performance at lower temperatures.

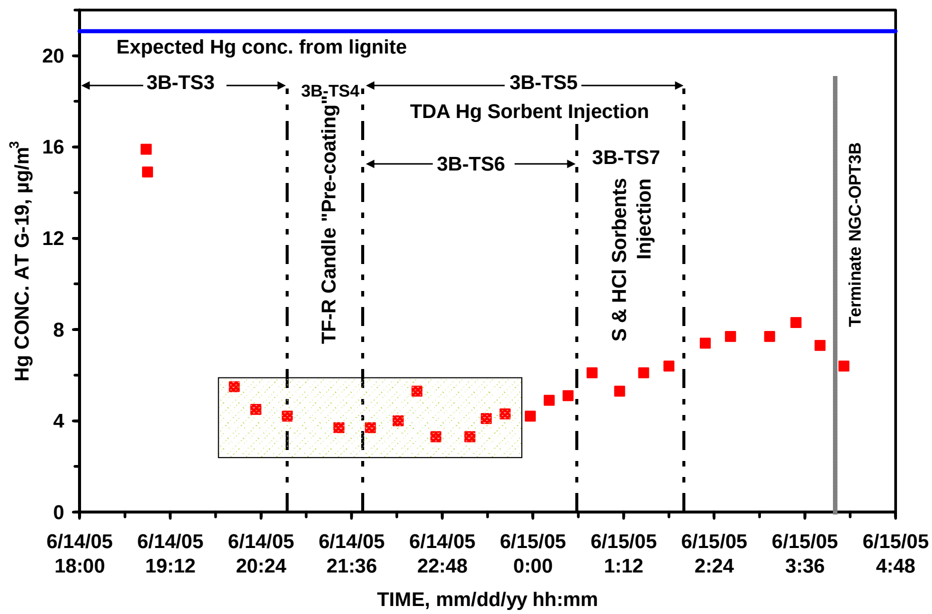


Figure 74 - Measured Hg Concentration at the TF-R Outlet during the Test Campaign #3 (NGC-OPT3)

As mentioned earlier, a plug developed in the spray quench tower, with the ΔP gradually increasing to 10 psi or so through the course of the 6/14/05 evening and night. We started turning down the gasifier in the evening to reduce syngas flow and pressure drop across the plug, and that allowed enough time to proceed with the testing (determining the mercury level in the syngas and performing the "higher-temperature" sorbent injection tests). The NGC-OPT3B had to be terminated at ~ 04:00 on 6/15/05. The operating team brought the system down without any damage to the filter candles, and with a clean gasifier. Samples have been taken for post-test analyses to determine the nature of the plug so that it can be prevented in the future.

12.4.1.5 Post-Test Analyses

In this test campaign we developed a clear approach to operating the facility and performing Hg sampling and analyses. However, additional testing should be performed to evaluate Hg removal at lower temperatures (350 to 450ºF) using both the TDA and JM sorbents. Table 32 through Table 34 below provide additional analyses that were performed on solid samples collected post-tests. The Hg analyses for the coal feed, gasifier bottom ash, secondary cyclone fines, and CF-R fines confirm that ~ 98.4% of the Hg in the feed reported to the gas phase.

Table 32 – NGC-OPT3 Equal Weight Composite Sample of Ten Secondary Cyclone Fines (Lab #'s 051263-085, -094, -098, -099, -105, -116, -119, -123, -126, & -130)

Proximate Analysis	(As received)	(As received) w/SO_3 correction	(Dry basis) w/SO_3 correction
Moisture, %	1.05	1.05	---
Volatile Matter, %	6.20	6.20	6.27
Ash (750ºC), %	74.57	69.05	69.78
Fixed Carbon, % (by difference)	18.18	23.70	23.95
Ultimate Analysis	(Dry basis)		
Ash (750ºC), %	69.78	Mercury, µg/g 0.016	
Carbon, %	27.44		
Hydrogen, %	0.32		
Nitrogen, %	0.26		
Sulfur, %	2.35		
Oxygen, % (by difference)	B.D.L.		
Heating Value	(Dry basis)		
BTU/lb	4,040		
Screen Analysis			
	Retained on	Wt. %	
	6	0.0	
	12	0.0	
	20	0.0	
	40	0.0	
	60	0.2	
	80	0.2	
	100	0.4	
	140	1.9	
	200	5.1	
	230	3.4	
	270	6.3	
	325	5.5	
	PAN	77.0	
	Total	100.0	

Table 33 - NGC-OPT3 Equal-Weight Composite Sample of Ten Gasifier Bottom Ash Fines (Lab #'s 051263-095, -100, -101, -106, -107, -117, -120, -124, -127, & -131)

Proximate Analysis	(As received)	(As received) w/SO_3 correction	(Dry basis) w/SO_3 correction
Moisture, %	0.51	0.51	---
Volatile Matter, %	5.03	5.03	5.06
Ash (750ºC), %	72.49	70.56	70.93
Fixed Carbon, % (by difference)	21.97	23.90	24.01
Ultimate Analysis	(Dry basis)		
Ash (750ºC), %	70.93	Mercury, µg/g < 0.010	
Carbon, %	27.07		
Hydrogen, %	0.33		
Nitrogen, %	0.33		
Sulfur, %	0.80		
Oxygen, % (by difference)	0.54		
Heating Value	(Dry basis)		
BTU/lb	3,920		
Screen Analysis	Retained on	Wt. %	
	6	6.0	
	12	21.8	
	20	16.8	
	40	11.8	
	60	10.3	
	80	12.0	
	100	8.1	
	140	8.1	
	200	2.4	
	230	0.6	
	270	0.3	
	325	0.2	
	PAN	1.6	
	Total	100.0	

Table 34 - NGC-OPT3 Equal-Weight Composite Sample of Four Conditioning Filter-Reactor Fines (T-2050 Drum 1 13:55 6/16/05, T-2050 Drum 3 6/16/05, T-2050 Drum 7 6/16/05, T-2153 Bottom 6/24/05)

Proximate Analysis	(As received)	(As received) w/SO_3 correction	(Dry basis) w/SO_3 correction
Moisture, %	3.09	3.09	---
Volatile Matter, %	11.10	11.10	11.45
Ash (750ºC), %	60.20	56.81	58.62
Fixed Carbon, % (by difference)	25.61	29.00	29.93
Ultimate Analysis	(Dry basis)		
Ash (750ºC), %	58.62	Mercury, µg/g 0.028	
Carbon, %	35.50		
Hydrogen, %	0.42		
Nitrogen, %	0.34		
Sulfur, %	1.50		
Oxygen, % (by difference)	3.62		
Heating Value	(Dry basis)		
BTU/lb	5,050		
Screen Analysis			
	Retained on	Wt. %	
	6	0.6	
	12	0.4	
	20	0.4	
	40	1.0	
	60	1.0	
	80	1.0	
	100	0.6	
	140	2.3	
	200	2.7	
	230	1.7	
	270	2.3	
	325	2.9	
	PAN	83.1	
	Total	100.0	

Table 35 - Summary of Batch Sample Gas Analyses during the NGC-OPT3B Test Campaign

Ref	Lab Sample ID	Sample Point	Date	Time	Test Segment	H2	CO2	O2/Ar	N2	CO	CH4	Hexane Plus	H2S (ppmv)	COS (ppmv)
1	051263-073	G-8	6/14/2005	5:39	3B-TS3	13.2%	13.6%	0.70%	57.8%	12.29%	2.307%	0.017%	1040	83.6
2	051263-090	G-8	6/14/2005	9:30	3B-TS3	13.8%	13.6%	0.70%	56.6%	12.78%	2.385%	0.017%	1050	70.2
3	051263-091	G-8	6/14/2005	10:31	3B-TS3	13.8%	13.6%	0.69%	56.6%	12.75%	2.355%	0.017%	1090	73.5
4	051263-109	G-8	6/14/2005	11:30	3B-TS3	13.9%	13.5%	0.69%	56.4%	12.89%	2.377%	0.015%	1040	72.5
5	051263-110	G-8	6/14/2005	14:17	3B-TS3	14.1%	13.6%	0.69%	56.3%	12.79%	2.364%	0.016%	1080	74.6
6	051263-111	G-14	6/14/2005	14:20	3B-TS3	19.5%	19.4%	0.64%	52.9%	5.32%	2.204%	0.016%		0.11
7	051263-114	G-14	6/14/2005	16:30	3B-TS3	19.3%	19.1%	0.64%	52.9%	5.68%	2.298%	0.015%		0.47
8	051263-115	G-8	6/14/2005	16:35	3B-TS3	14.3%	13.7%	0.68%	55.9%	12.76%	2.441%	0.016%	1140	73.8
9	051263-180	G-8	6/14/2005	19:20	3B-TS3	14.1%	13.8%	0.69%	56.1%	12.70%	2.517%	0.016%	922	74.6
10	051263-149	G-14	6/14/2005	22:25	3B-TS5	14.4%	14.4%	0.66%	57.3%	10.73%	2.419%	0.014%		0.24
11	051263-152	G-8	6/14/2005	23:40	3B-TS5	13.9%	14.7%	0.66%	58.8%	9.52%	2.298%	0.014%	1200	65.4
12	051263-171	G-14	6/15/2005	2:35	3B-TS7	13.9%	15.2%	0.66%	59.1%	8.75%	2.353%	0.017%		0.14

Table 36 - Samples of Secondary Cyclone Fines during the NGC-OPT3 Test Campaign

Ref	Lab Sample ID	Sample Point	Date	Time	Test Segment	As-received Ash, wt%	Microwave Ash, wt%	Mercury micro-g/g	Comments
1	051263-004	S-6 (T-402)	6/9/2005	12:48		18.68	18.33	-	
2	051263-005	S-6 (T-402)	6/9/2005	13:45		42.51	40.87	-	
3	051263-007	S-6 (T-402)	6/9/2005	14:44		45.81	45.34	-	
4	051263-009	S-6 (T-402)	6/9/2005	15:41		50.02	49.82	-	
1	051263-014	S-6 (T-402)	6/13/2005	15:19	3B-TS1	31.48	31.19	-	
2	051263-016	S-6 (T-402)	6/13/2005	16:28	3B-TS2	34.62	34.24	-	
3	051263-017	S-6 (T-402)	6/13/2005	17:09	3B-TS2	34.95	34.66	-	
4	051263-020	S-6 (T-402)	6/13/2005	18:09	3B-TS2	36.54	36.87	-	
5	051263-022	S-4 (T-402)	6/13/2005	19:18	3B-TS2	43.24	42.29	-	
6	051263-024	S-4 (T-402)	6/13/2005	20:22	3B-TS2	51.70	51.50	-	
7	051263-028	S-4 (T-402)	6/13/2005	21:17	3B-TS2	53.82	52.82	-	
8	051263-031	S-4 (T-402)	6/13/2005	22:12	3B-TS3	56.24	55.46	-	
9	051263-035	S-4 (T-402)	6/13/2005	23:14	3B-TS3	60.44	59.02	-	
10	051263-040	S-4 (T-402)	6/14/2005	0:19	3B-TS3	61.52	61.71	-	
11	051263-044	S-4 (T-402)	6/14/2005	1:11	3B-TS3	62.22	60.31	-	
12	051263-048	S-4 (T-402)	6/14/2005	2:17	3B-TS3	55.74	55.77	-	
13	051263-052	S-4 (T-402)	6/14/2005	3:12	3B-TS3	63.71	63.05	-	
14	051263-056	S-4 (T-402)	6/14/2005	4:11	3B-TS3	65.84	65.19	-	
15	051263-066	S-4 (T-402)	6/14/2005	5:10	3B-TS3	66.48	66.02	-	
16	051263-074	S-4 (T-402)	6/14/2005	6:12	3B-TS3	66.66	65.70	-	
17	051263-078	S-6 (T-402)	6/14/2005	7:15	3B-TS3	-	67.22	-	
18	051263-079	S-6 (T-402)	6/14/2005	8:12	3B-TS3	-	68.79	-	
19	051263-084	S-6 (T-402)	6/14/2005	9:12	3B-TS3	-	70.50	-	
20	051263-085	S-6 (T-402)	6/14/2005	10:18	3B-TS3	-	71.50	-	
21	051263-094	S-6 (T-402)	6/14/2005	11:19	3B-TS3	-	71.94	0.015	
22	051263-098	S-6 (T-402)	6/14/2005	12:22	3B-TS3	-	73.40	-	
23	051263-099	S-6 (T-402)	6/14/2005	13:13	3B-TS3	-	75.16	-	
24	051263-105	S-6 (T-402)	6/14/2005	14:15	3B-TS3	-	74.67	-	
25	051263-116	S-6 (T-402)	6/14/2005	15:16	3B-TS3	-	74.63	-	
26	051263-119	S-6 (T-402)	6/14/2005	16:20	3B-TS3	-	73.77	-	
27	051263-123	S-6 (T-402)	6/14/2005	17:10	3B-TS3	-	73.92	-	
28	051263-126	S-6 (T-402)	6/14/2005	18:11	3B-TS3	-	73.48	-	
29	051263-130	S-6 (T-402)	6/14/2005	19:15	3B-TS3	-	73.34	-	
30	051263-136	S-6 (T-402)	6/14/2005	20:07	3B-TS3	-	71.57	-	
31	051263-141	S-6 (T-402)	6/14/2005	21:13	3B-TS4	-	69.44	-	
32	051263-144	S-6 (T-402)	6/14/2005	22:11	3B-TS5	-	69.90	-	
33	051263-150	S-4 (T-402)	6/14/2005	23:20	3B-TS5	-	68.33	-	
34	051263-160	S-4 (T-402)	6/15/2005	0:19	3B-TS5	-	67.56	-	
35	051263-162	S-4 (T-402)	6/15/2005	1:12	3B-TS5/3B-TS6	-	67.63	-	
36	051263-168	S-4 (T-402)	6/15/2005	2:16	3B-TS5/3B-TS6	-	65.83	-	
37	051263-174	S-4 (T-402)	6/15/2005	3:15	3B-TS7	-	64.92	-	

Table 37 - Samples of Gasifier Ash during the NGC-OPT3 Test Campaign

Ref	Lab Sample ID	Sample Point	Date	Time	Test Segment	As-received Ash, wt%	Microwave Ash, wt%	Mercury micro-g/g	Comments
1	051263-001	S-5 (T-502)	6/9/2005	11:49		19.62	18.21	-	
2	051263-002	S-5 (T-502)	6/9/2005	12:32		15.62	15.03	-	
3	051263-003	S-5 (T-502)	6/9/2005	13:12		18.88	18.76	-	
4	051263-006	S-5 (T-502)	6/9/2005	14:20		30.57	30.09	-	
5	051263-008	S-5 (T-502)	6/9/2005	15:12		38.23	38.03	-	
1	051263-013	S-5 (T-502)	6/13/2005	14:40	3B-TS1	20.12	19.58	-	
2	051263-015	S-5 (T-502)	6/13/2005	15:39	3B-TS1	22.41	22.46	-	
3	051263-018	S-5 (T-502)	6/13/2005	16:44	3B-TS2	17.20	16.86	-	
4	051263-019	S-5 (T-502)	6/13/2005	17:38	3B-TS2	18.06	18.00	-	
5	051263-023	S-5 (T-502)	6/13/2005	19:40	3B-TS2	22.22	22.05	-	
6	051263-025	S-5 (T-502)	6/13/2005	20:38	3B-TS2	23.15	23.19	-	
7	051263-029	S-5 (T-502)	6/13/2005	21:44	3B-TS3	29.23	29.18	-	
8	051263-032	S-5 (T-502)	6/13/2005	22:48	3B-TS3	30.50	30.51	-	
9	051263-036	S-5 (T-502)	6/13/2005	23:39	3B-TS3	37.09	37.05	-	
10	051263-041	S-5 (T-502)	6/14/2005	0:50	3B-TS3	38.51	38.47	-	
11	051263-045	S-5 (T-502)	6/14/2005	1:40	3B-TS3	34.64	34.29	-	
12	051263-049	S-5 (T-502)	6/14/2005	2:41	3B-TS3	37.56	37.50	-	
13	051263-053	S-5 (T-502)	6/14/2005	3:46	3B-TS3	43.24	41.35	-	
14	051263-057	S-5 (T-502)	6/14/2005	4:44	3B-TS3	51.08	50.88	-	
15	051263-067	S-5 (T-502)	6/14/2005	5:39	3B-TS3	51.38	50.98	-	
16	051263-075	S-5 (T-502)	6/14/2005	6:42	3B-TS3	54.10	53.31	-	
17	051263-086	S-5 (T-502)	6/14/2005	7:43	3B-TS3	-	44.66	-	
18	051263-087	S-5 (T-502)	6/14/2005	8:42	3B-TS3	-	50.84	-	
19	051263-088	S-5 (T-502)	6/14/2005	9:43	3B-TS3	-	60.20	-	
20	051263-095	S-5 (T-502)	6/14/2005	10:40	3B-TS3	-	65.32	0.005	
21	051263-100	S-5 (T-502)	6/14/2005	11:52	3B-TS3	-	69.64	-	
22	051263-101	S-5 (T-502)	6/14/2005	12:44	3B-TS3	-	71.21	-	
23	051263-106	S-5 (T-502)	6/14/2005	13:00	3B-TS3	-	76.75	-	
24	051263-107	S-5 (T-502)	6/14/2005	14:47	3B-TS3	-	74.93	-	
25	051263-117	S-5 (T-502)	6/14/2005	15:35	3B-TS3	-	80.43	-	
26	051263-120	S-5 (T-502)	6/14/2005	16:45	3B-TS3	-	75.73	-	
27	051263-124	S-5 (T-502)	6/14/2005	17:42	3B-TS3	-	73.90	-	
28	051263-127	S-5 (T-502)	6/14/2005	18:42	3B-TS3	-	73.27	-	
29	051263-131	S-5 (T-502)	6/14/2005	19:44	3B-TS3	-	61.20	-	
30	051263-137	S-5 (T-502)	6/14/2005	20:41	3B-TS3	-	71.31	-	
31	051263-142	S-5 (T-502)	6/14/2005	21:40	3B-TS4	-	76.18	-	
32	051263-145	S-5 (T-502)	6/14/2005	22:38	3B-TS5	-	69.24	-	
33	051263-151	S-5 (T-502)	6/14/2005	23:46	3B-TS5	-	69.81	-	
34	051263-161	S-5 (T-502)	6/15/2005	0:47	3B-TS5/3B-TS6	-	73.30	-	
35	051263-163	S-5 (T-502)	6/15/2005	1:54	3B-TS5/3B-TS6	-	76.99	-	
36	051263-169	S-5 (T-502)	6/15/2005	2:39	3B-TS7	-	79.51	-	
37	051263-175	S-5 (T-502)	6/15/2005	3:45	3B-TS7	-	73.48	-	

Table 38 - Summary of Mercury Analyses during the NGC-OPT3 Test Campaign

Ref	Lab Sample ID	Sample Point	Date	Time Period	Average Time (min)	Test Segment	Gas Hg Content (micro-grams/cu m)	Solid/Liquid Hg Content (micro-grams/g)
1	051263-010	G-8 (gas)	6/9/2005	16:37-16:57	20		<0.05	
2	051263-011	G-13 (gas)	6/9/2005	17:08-17:28	20		<0.05	
3	051263-012	G-8 (gas)	6/9/2005	17:18-17:38	20		<0.05	
1	051263-021	G-8 (gas)	6/13/2005	19:55-20:36	41	3B-TS2	0.07	
2	051263-026	G-8 (gas)	6/13/2005	20:55-21:37	42	3B-TS2	<0.02	
3	051263-027	G-8 (water)	6/13/2005	20:55-21:37	42	3B-TS2		<0.001
4	051263-030	LC (bag #1)	6/13/2005	16:30		3B-TS3		0.097
5	051263-033	G-8 (gas)	6/13/2005	22:44-23:22	38	3B-TS3	<0.02	
6	051263-034	G-8 (water)	6/13/2005	22:44-23:22	38	3B-TS3		0.004
7	051263-037	Lignite Feed	6/13/2005	23:30		3B-TS3		
8	051263-038	G-8 (gas)	6/13/2005	23:37-00:07	30	3B-TS3	<0.02	
9	051263-039	G-8 (water)	6/13/2005	23:37-00:07	30	3B-TS3		
10	051263-042	G-8 (gas)	6/14/2005	00:22-01:12	50	3B-TS3	<0.02	
11	051263-043	G-8 (water)	6/14/2005	00:22-01:12	50	3B-TS3		
12	051263-046	G-8 (gas)	6/14/2005	01:45-02:24	39	3B-TS3	<0.02	
13	051263-047	G-8 (water)	6/14/2005	01:45-02:24	39	3B-TS3		
14	051263-050	G-8 (gas)	6/14/2005	02:28-03:04	36	3B-TS3	<0.02	
15	051263-051	G-8 (water)	6/14/2005	02:28-03:04	36	3B-TS3		
16	051263-054	G-8 (gas)	6/14/2005	03:08-03:46	38	3B-TS3	<0.02	
17	051263-055	G-8 (water)	6/14/2005	03:08-03:46	38	3B-TS3		0.002
18	051263-058	G-8 (gas)	6/14/2005	03:50-04:35	45	3B-TS3	<0.02	
19	051263-059	G-8 (water)	6/14/2005	03:50-04:35	45	3B-TS3		0.001
20	051263-060	G-13 (gas)	6/14/2005	03:54-04:41	47	3B-TS3	0.02	
21	051263-061	G-13 (water)	6/14/2005	03:54-04:41	47	3B-TS3		
22	051263-062	G-8 (gas)	6/14/2005	04:38-05:26	48	3B-TS3	<0.02	
23	051263-063	G-8 (water)	6/14/2005	04:38-05:26	48	3B-TS3		0.001
24	051263-064	G-13 (gas)	6/14/2005	04:44-05:31	47	3B-TS3	0.008	
25	051263-065	G-13 (water)	6/14/2005	04:44-05:31	47	3B-TS3		
26	051263-068	Lignite Feed #3	6/14/2005			3B-TS3		
27	051263-069	Lignite Feed #4	6/14/2005			3B-TS3		
28	051263-070	Lignite Feed #6	6/14/2005	5:07		3B-TS3		0.061
29	051263-071	G-13 (gas)	6/14/2005	05:34-06:13	39	3B-TS3	0.01	
30	051263-072	G-13 (water)	6/14/2005	05:34-06:13	39	3B-TS3		
31	051263-076	G-13 (gas)	6/14/2005	06:15-07:00	45	3B-TS3	0.01	
32	051263-077	G-13 (water)	6/14/2005	06:15-07:42	87	3B-TS3		
33	051263-080	G-13 (gas)	6/14/2005	07:45-08:28	43	3B-TS3	0.01	
34	051263-081	G-13 (water)	6/14/2005	07:45-08:28	43	3B-TS3		
35	051263-082	G-13 (gas)	6/14/2005	08:40-09:33	53	3B-TS3	0.01	
36	051263-083	G-13 (water)		08:40-09:33	53	3B-TS3		
37	051263-089	Lignite Feed #7	6/14/2005	9:58		3B-TS3		0.090
38	051263-092	G-13 (gas)	6/14/2005	09:40-10:35	55	3B-TS3	0.01	
39	051263-093	G-13 (water)	6/14/2005	09:40-10:35	55	3B-TS3		0.036
40	051263-096	G-13 (gas)	6/14/2005	10:40-11:25	45	3B-TS3	0.01	
41	051263-097	G-13 (water)	6/14/2005	10:40-11:25	45	3B-TS3		0.018
42	051263-102	Lignite Feed #8	6/14/2005	11:39		3B-TS3		
43	051263-103	G-14 (gas)	6/14/2005	13:45-14:05	20	3B-TS3	0.01	
44	051263-104	G-14 (water)	6/14/2005	13:45-14:05	20	3B-TS3		0.002
45	051263-108	Lignite Feed #9	6/14/2005	14:00		3B-TS3		0.122 (dry basis) / 0.099
46	051263-112	G-14 (gas)	6/14/2005	14:35-15:37	62	3B-TS3	<0.01	
47	051263-113	G-14 (water)	6/14/2005	14:35-15:37	62	3B-TS3		0.009
48	051263-118	Lignite Feed #10	6/14/2005	16:00		3B-TS3		0.108 (dry basis) / 0.088
49	051263-121	G-19 (gas)	6/14/2005	16:28-18:00	92	3B-TS3	> 146	
50	051263-122	G-19 (water)	6/14/2005	16:28-18:00	92	3B-TS3		<0.001
51	051263-125	Lignite Feed #11	6/14/2005	18:10		3B-TS3		0.091 (dry basis) / 0.074
52	051263-128	G-19 (gas)	6/14/2005	18:30-18:45	45	3B-TS3	15.9	
53	051263-129	G-19 (gas)	6/14/2005	18:46-19:02	16	3B-TS3	14.9	
54	051263-132	G-19 (gas)	6/14/2005	19:40-19:50	10	3B-TS3	not analyzed	
55	051263-133	G-19 (gas)	6/14/2005	19:55-20:10	15	3B-TS3	5.5	
56	051263-134	G-19 (gas)	6/14/2005	20:12-20:27	15	3B-TS3	4.5	
57	051263-135	Lignite Feed #12	6/14/2005	21:09		3B-TS3		0.073 (dry basis) / 0.059
58	051263-138	G-19 (gas)	6/14/2005	20:42-20:47	5	3B-TS4	4.2	
59	051263-139	G-19 (gas)	6/14/2005	21:26	?	3B-TS4	3.7	
60	051263-140	G-19 (gas)	6/14/2005	21:51	?	3B-TS4	3.7	
61	051263-143	Lignite Feed #13	6/14/2005	21:21		3B-TS4		0.127 (dry basis) / 0.103
62	051263-146	G-19 (gas)	6/14/2005	22:10-22:16	6	3B-TS5	4.0	
63	051263-147	G-19 (gas)	6/14/2005	22:25-22:31	6	3B-TS5	5.3	
64	051263-148	G-19 (gas)	6/14/2005	22:40-22:46	6	3B-TS5	3.3	
65	051263-153	G-19 (gas)	6/14/2005	23:06-23:14	8	3B-TS5	3.3	
66	051263-154	G-19 (gas)	6/14/2005	23:20-23:26	6	3B-TS5	4.1	
67	051263-155	G-19 (gas)	6/14/2005	23:35-23:41	6	3B-TS5	4.3	
68	051263-156	G-19 (gas)	6/14/2005	23:54-00:01	7	3B-TS5	4.2	
69	051263-157	G-19 (gas)	6/15/2005	00:10-00:15	5	3B-TS5	4.9	
70	051263-158	G-19 (gas)	6/15/2005	00:25-00:31	6	3B-TS5	5.1	
71	051263-159	G-19 (gas)	6/15/2005	00:44-00:50	6	3B-TS5/3B-TS6	6.1	
72	051263-164	Lignite Feed #14	6/15/2005			3B-TS5/3B-TS6		
73	051263-165	G-19 (gas)	6/15/2005	01:05-01:12	7	3B-TS5/3B-TS6	5.3	
74	051263-166	G-19 (gas)	6/15/2005	01:25-01:31	6	3B-TS5/3B-TS6	6.1	
75	051263-167	G-19 (gas)	6/15/2005	01:45-01:51	6	3B-TS5/3B-TS6	6.4	
76	051263-170	Lignite Feed #15	6/15/2005			3B-TS5/3B-TS6		
77	051263-172	G-19 (gas)	6/15/2005	02:14-02:20	6	3B-TS7	7.4	
78	051263-173	G-19 (gas)	6/15/2005	02:34-02:40	6	3B-TS7	7.7	
79	051263-176	G-19 (gas)	6/15/2005	03:05-03:11	6	3B-TS7	7.7	
80	051263-177	G-19 (gas)	6/15/2005	03:26-03:32	6	3B-TS7	8.3	
81	051263-178	G-19 (gas)	6/15/2005	03:45-03:51	6	3B-TS7	7.3	
82	051263-179	G-19 (gas)	6/15/2005	04:04-04:10	6	Terminate Test	6.4	
83	051263-184	Filter A (SE&C Skid #1)	Post-test					0.027
84	051263-185	Filter B (SE&C Skid #1)	Post-test					0.005

13. CONCLUSIONS AND RECOMMENDATIONS

Three test campaigns were successfully completed as proof-of-principle demonstration of the NGC Process "filter-reactor" concept configuration in full integration with GTI's Flex-Fuel Test Facility. Extensive efforts in these tests were devoted to designing, installing, and validating state-of-the-art gas sampling equipment and instruments to meet the very stringent analytical needs of the program, involving measurements of concentrations of various compounds ranging from hundreds of parts-per-million (ppmv) to very low concentrations at the parts-per-billion (ppbv) level. The test program clearly demonstrated the flexibility of the Flex-Fuel Test Facility (gasifier/NGC Process section) to efficiently produce syngas from three different feedstocks, to condition the resulting raw syngas to meet the requirements of the NGC Process Test section, and to ultra-clean the conditioned syngas to meet the very stringent cleaning requirements of chemical synthesis applications (i.e., total S < 50 ppbv, total halides < 10 ppbv, particulate < 0.1 ppmw).

Consistent with the significance of the data developed in the PDU test program and the recommendations of conceptual process evaluations, GTI highly recommends the NGC Process development work enter into a process optimization phase. Specifically, four additional test campaigns are proposed prior to undertaking further scale-up work and ultimately commercial-scale demonstration. The objectives of these tests are to:

- Optimize key process parameters:
    - sorbent feed rates
    - Sorbent sizes and size distributions
    - process operating temperatures
    - inlet contaminant levels
- Explore the envelope of these parameters both separately and in an integrated configuration
    - Develop the necessary data to extract quantitative design parameters for scaling up the bulk HCl removal performance (in the Stage I barrier filter-reactor simultaneously with ash), and the combined removal of sulfur and halide species to ppbv levels in the Stage II barrier filter-reactor.
    - Extract quantitative information (filter cake permeability, cake thickness, portion of ash reaching the filter elements, etc) from the pressure drop data (based on ash flow rate and size distribution to the CF-R and filter cake properties, such as density, re-entrainment rate, etc.)
- Conduct integrated testing to demonstrate NGC Process suitability for meeting "futuristic" IGCC fuel gas cleaning targets (sulfur, halides, mercury, and particulate). Futuristic is used to mean emissions from advanced natural gas-fired combined cycle systems. Ammonia will be monitored, but not controlled, in these test campaigns, which can be carried out in the existing NGC Process section in the Flex-Fuel Test Facility.
- Conduct integrated testing to demonstrate NGC Process suitability for meeting methanol synthesis cleaning targets (sulfur, halides, mercury, ammonia, and particulate). For these tests, a warm water scrubber column may be incorporated into the NGC Process to remove ammonia and control halides to less than 10 ppbv, eliminating the need for a Stage II halide sorbent. Commercial evaluations have shown this to be the best method for cleaning the methanol syngas stream in the co-production plant.

In addition to process optimization, the proposed campaigns will provide another opportunity to perform additional mercury removal testing (using both the lower temperature and higher temperature sorbents and potentially other promising Hg sorbents), further advancing the syngas mercury capture technology base. Other facets of the process will also be explored including bulk HCl removal at higher temperature, continuous removal of ash/spent halide sorbent fines from the CF-R, etc.

14. REFERENCES

1. Newby, R.A. and Slimane, R.B., “Novel Gas Cleaning/Conditioning for Integrated Gasification Combined Cycle,” Base Program Final Report, DOE Award No. DE-AC26-99FT40674, Oct. 1, 1999 – Aug. 31, 2001.

2. Program Research and Development Announcement (PRDA) No. DE-RA26-99FT40346 for “Novel Gas Cleaning/Conditioning for Integrated Gasification Combined Cycle (IGCC),” U.S. Department of Energy, April 1, 1999.

3. Newby, R. A., M. A. Alvin, D. M. Bachovchin, E. E. Smeltzer, T. E. Lippert, "Integrated Low Emissions Cleanup System for Coal-Fuels Turbines, Phase III Topical Report -- Bench-Scale Testing and Evaluation," Final Report to DOE/ METC under Contract No. DE-AC21-87MC24257, Aug. 1995 (DOE/MC/24257—5059).

4. Abbasian, J., Slimane, R.B., Williams, B., Akpolat, O., Lau, F., Newby, R.A., and Jain, S., “Novel Gas Cleaning/Conditioning for Integrated Gasification Combined Cycle,” Proceedings of the 17th Annual International Pittsburgh Coal Conference, Sept. 11-15, 2000, Pittsburgh, PA.

5. Slimane, R.B., Akpolat, O.M., Lau, F.S., Newby, R.A., Jain, S.C., "Experimental Studies In Support of the Ultra-Clean Gas Cleanup Process Development," 18th Annual International Pittsburgh Coal Conference, Dec. 4-7, 2001, Newcastle, New South Wales, Australia.

6. Slimane, R.B., Jadhav, R., Pandya, K., Lau, F., Pratapas, J., Newby, R.A., and Jain, S.C., “Sorbent-based Syngas Mercury Removal in the Ultra-Clean Process,” Paper presented and published in the Natural Gas Technologies II Conference & Exhibition, Feb. 8-11, 2004, Phoenix, Arizona.

7. Denton, D.L., “Update on Eastman’s Coal Gasification Operating Performance and Gasification Services Business,” Paper presented at the Pittsburgh Coal Conference, Sept. 23, 2003.

8. Rutkowski, M.D., et al., “The Cost of Mercury Removal from Coal-Based IGCC Relative to a PC Plant,” Gasification Technologies 2002, San Francisco, CA, Oct. 27-30, 2002.

9. Peltier, R., “Mercury Removal Standards are Coming. Where's the Technology?,” Power (05/03) Vol. 147, No. 4, p. 40.

10. Shain, S.J., et al., “Direct Extraction of Hydrogen from Coal Using a Membrane Reactor Integrated with a Gasifier,” Proceedings of the 22nd Annual International Pittsburgh Coal Conference, Pittsburgh, PA, Sept. 12-15, 2005.

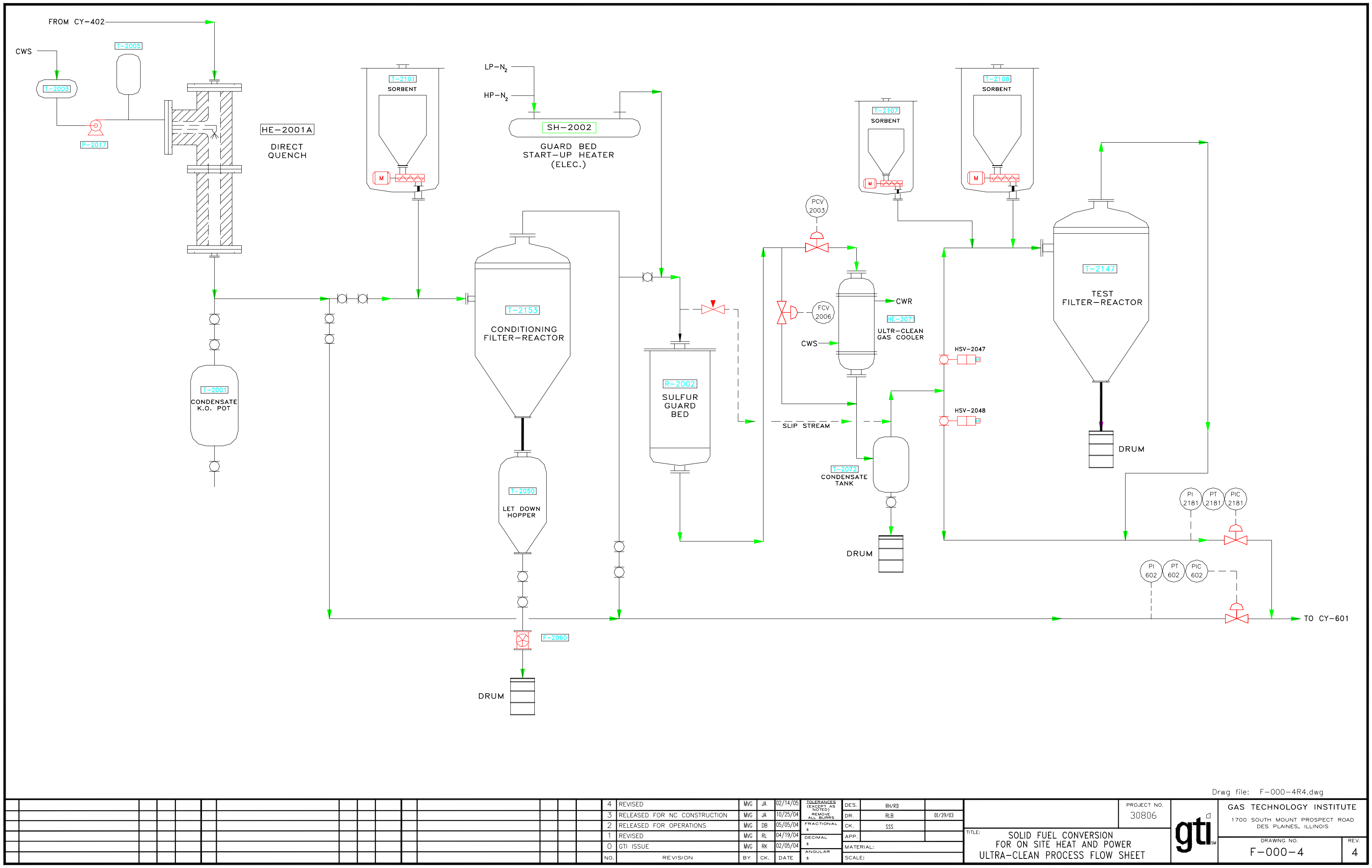
11. Bush, P.V., “Platform for Cost-Effective Evaluation of Gas Conditioning Technologies with Real Syngas,” DOE Program DE-FC36-03GO13175.

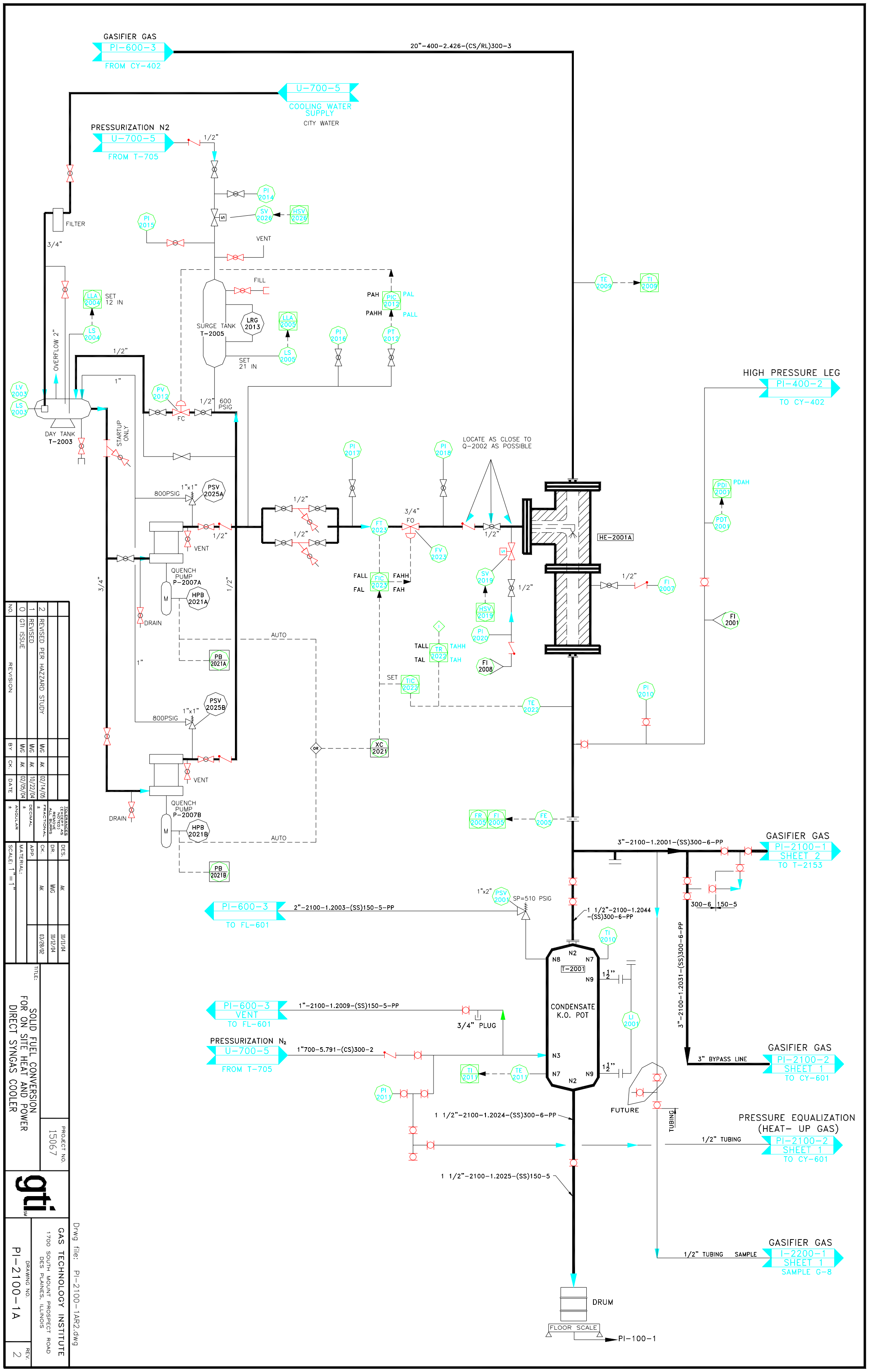
12. Bush, P.V., “State-of-the-Art Analytical Suite to Monitor Syngas Composition,” DOE Program DE-FC36-02GO12024.

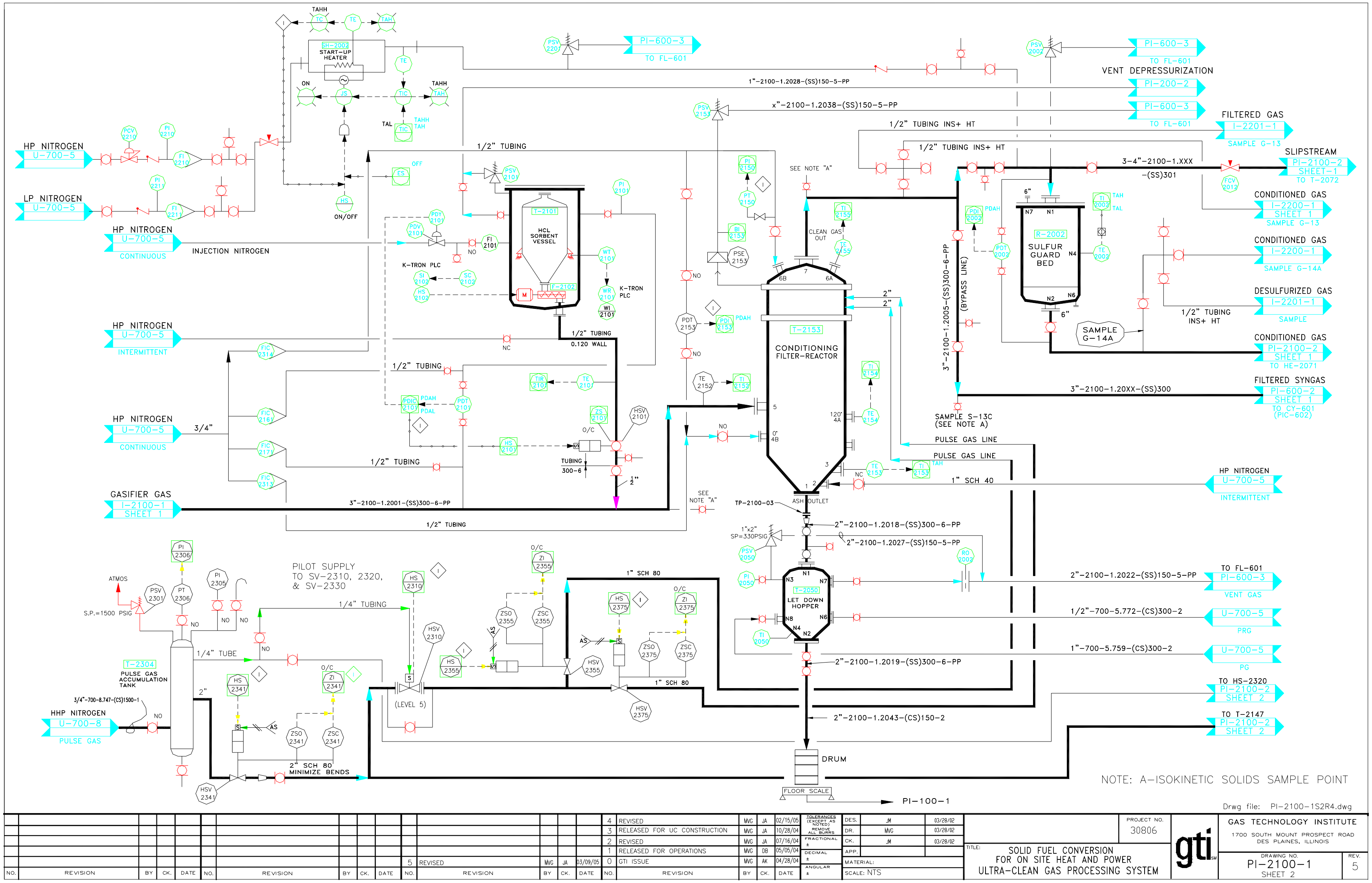
13. Bryan, B.G., et al. “Flex-Fuel Test Facility: Evaluation of Fluidized-Bed Gasification for IGCC Power Production with High-Ash Indian Coal,” Proceedings of the 22nd Annual International Pittsburgh Coal Conference, Pittsburgh, PA, Sept. 12-15, 2005.

14. Nizamoff, A.J., et al., “Lignite-Fueled IGCC Power Plant,” Proceedings of the 22nd Annual International Pittsburgh Coal Conference, Pittsburgh, PA, Sept. 12-15, 2005.

15. APPENDIX A: NGC PROCESS SECTION PIPING AND INSTRUMENTATION DIAGRAMS


FROM CY-402
CWS
HE-2001A
DIRECT QUENCH
CONDENSATE K.O. POT
SORBENT
LP-N2
HP-N2
SH-2002
GUARD BED START-UP HEATER (ELEC.)
CONDITIONING FILTER-REACTOR
LET DOWN HOPPER
DRUM
SULFUR GUARD BED
PCV 2003
FCV 2006
CWR
ULTR-CLEAN GAS COOLER
SLIP STREAM
CONDENSATE TANK
HSV-2047
HSV-2048
TEST FILTER-REACTOR
PI 2181
PT 2181
PIC 2181
PI 602
PT 602
PIC 602
TO CY-601
Drwg file: F-000-4R4.dwg
4 REVISED MWG JA 02/14/05
3 RELEASED FOR NC CONSTRUCTION MWG JA 10/25/04
2 RELEASED FOR OPERATIONS MWG DB 05/05/04
1 REVISED MWG RL 04/19/04
0 GTI ISSUE MWG RK 02/05/04
NO. REVISION BY CK. DATE
PROJECT NO. 30806
TITLE: SOLID FUEL CONVERSION FOR ON SITE HEAT AND POWER ULTRA-CLEAN PROCESS FLOW SHEET
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD DES PLAINES, ILLINOIS
DRAWING NO. F-000-4
REV. 4


GASIFIER GAS
PI-600-3
FROM CY-402
20"-400-2.426-(CS/RL)300-3
U-700-5
COOLING WATER SUPPLY
CITY WATER
PRESSURIZATION N2
U-700-5
FROM T-705
FILTER
SURGE TANK
T-2005
DAY TANK
T-2003
QUENCH PUMP
P-2007A
QUENCH PUMP
P-2007B
HE-2001A
LOCATE AS CLOSE TO Q-2002 AS POSSIBLE
HIGH PRESSURE LEG
PI-400-2
TO CY-402
3"-2100-1.2001-(SS)300-6-PP
GASIFIER GAS
PI-2100-1
SHEET 2
TO T-2153
PI-600-3
TO FL-601
2"-2100-1.2003-(SS)150-5-PP
SP=510 PSIG
CONDENSATE K.O. POT
T-2001
PI-600-3
VENT
TO FL-601
1"-2100-1.2009-(SS)150-5-PP
PRESSURIZATION N2
U-700-5
FROM T-705
1"700-5.791-(CS)300-2
3" BYPASS LINE
GASIFIER GAS
PI-2100-2
SHEET 1
TO CY-601
PRESSURE EQUALIZATION (HEAT- UP GAS)
1/2" TUBING
PI-2100-2
SHEET 1
TO CY-601
FUTURE
1 1/2"-2100-1.2024-(SS)300-6-PP
1 1/2"-2100-1.2025-(SS)150-5
GASIFIER GAS
I-2200-1
SHEET 1
SAMPLE G-8
1/2" TUBING SAMPLE
DRUM
FLOOR SCALE
PI-100-1
2 REVISED PER HAZZARD STUDY
1 REVISED
0 GTI ISSUE
NO. REVISION BY CK. DATE
SOLID FUEL CONVERSION FOR ON SITE HEAT AND POWER DIRECT SYNGAS COOLER
PROJECT NO. 15067
gti
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD
DES PLAINES, ILLINOIS
DRAWING NO.
PI-2100-1A
REV. 2
Drwg file: PI-2100-1AR2.dwg


HP NITROGEN
U-700-5
LP NITROGEN
U-700-5
HP NITROGEN
U-700-5
CONTINUOUS
INJECTION NITROGEN
HP NITROGEN
U-700-5
INTERMITTENT
HP NITROGEN
U-700-5
CONTINUOUS
3/4"
GASIFIER GAS
I-2100-1
SHEET 1
3"-2100-1.2001-(SS)300-6-PP
1/2" TUBING
START-UP HEATER
ON
ON/OFF
TAHH
TAL
1/2" TUBING
K-TRON PLC
HCL SORBENT VESSEL
T-2101
1/2" TUBING
0.120 WALL
1/2" TUBING
1/2" TUBING
TUBING 300-6
1"-2100-1.2028-(SS)150-5-PP
x"-2100-1.2038-(SS)150-5-PP
PI-600-3
TO FL-601
PI-200-2
PI-600-3
TO FL-601
VENT DEPRESSURIZATION
1/2" TUBING INS+ HT
1/2" TUBING INS+ HT
FILTERED GAS
I-2201-1
SAMPLE G-13
SLIPSTREAM
PI-2100-2
SHEET-1
TO T-2072
3-4"-2100-1.XXX
-(SS)301
SEE NOTE "A"
CLEAN GAS OUT
T-2153
CONDITIONING FILTER-REACTOR
ASH OUTLET
R-2002
SULFUR GUARD BED
CONDITIONED GAS
I-2200-1
SHEET 1
SAMPLE G-13
CONDITIONED GAS
I-2200-1
SAMPLE G-14A
DESULFURIZED GAS
I-2201-1
SAMPLE
SAMPLE G-14A
1/2" TUBING INS+ HT
CONDITIONED GAS
PI-2100-2
SHEET 1
TO HE-2071
3"-2100-1.2005-(SS)300-6-PP
(BYPASS LINE)
3"-2100-1.20XX-(SS)300
FILTERED SYNGAS
PI-600-2
SHEET 1
TO CY-601
(PIC-602)
SAMPLE S-13C
(SEE NOTE A)
PULSE GAS LINE
PULSE GAS LINE
1" SCH 40
HP NITROGEN
U-700-5
INTERMITTENT
TP-2100-03
2"-2100-1.2018-(SS)300-6-PP
1"x2"
SP=330PSIG
2"-2100-1.2027-(SS)150-5-PP
LET DOWN HOPPER
2"-2100-1.2022-(SS)150-5-PP
TO FL-601
PI-600-3
VENT GAS
1/2"-700-5.772-(CS)300-2
U-700-5
PRG
1"-700-5.759-(CS)300-2
U-700-5
PG
2"-2100-1.2019-(SS)300-6-PP
TO HS-2320
PI-2100-2
SHEET 2
2"-2100-1.2043-(CS)150-2
TO T-2147
PI-2100-2
SHEET 2
DRUM
FLOOR SCALE
PI-100-1
PILOT SUPPLY
TO SV-2310, 2320, & SV-2330
1/4" TUBING
1" SCH 80
1" SCH 80
(LEVEL 5)
ATMOS
S.P.=1500 PSIG
1/4" TUBE
T-2304
PULSE GAS ACCUMULATION TANK
3/4"-700-8.747-(CS)1500-1
HHP NITROGEN
U-700-8
PULSE GAS
2" SCH 80
MINIMIZE BENDS
NOTE: A-ISOKINETIC SOLIDS SAMPLE POINT
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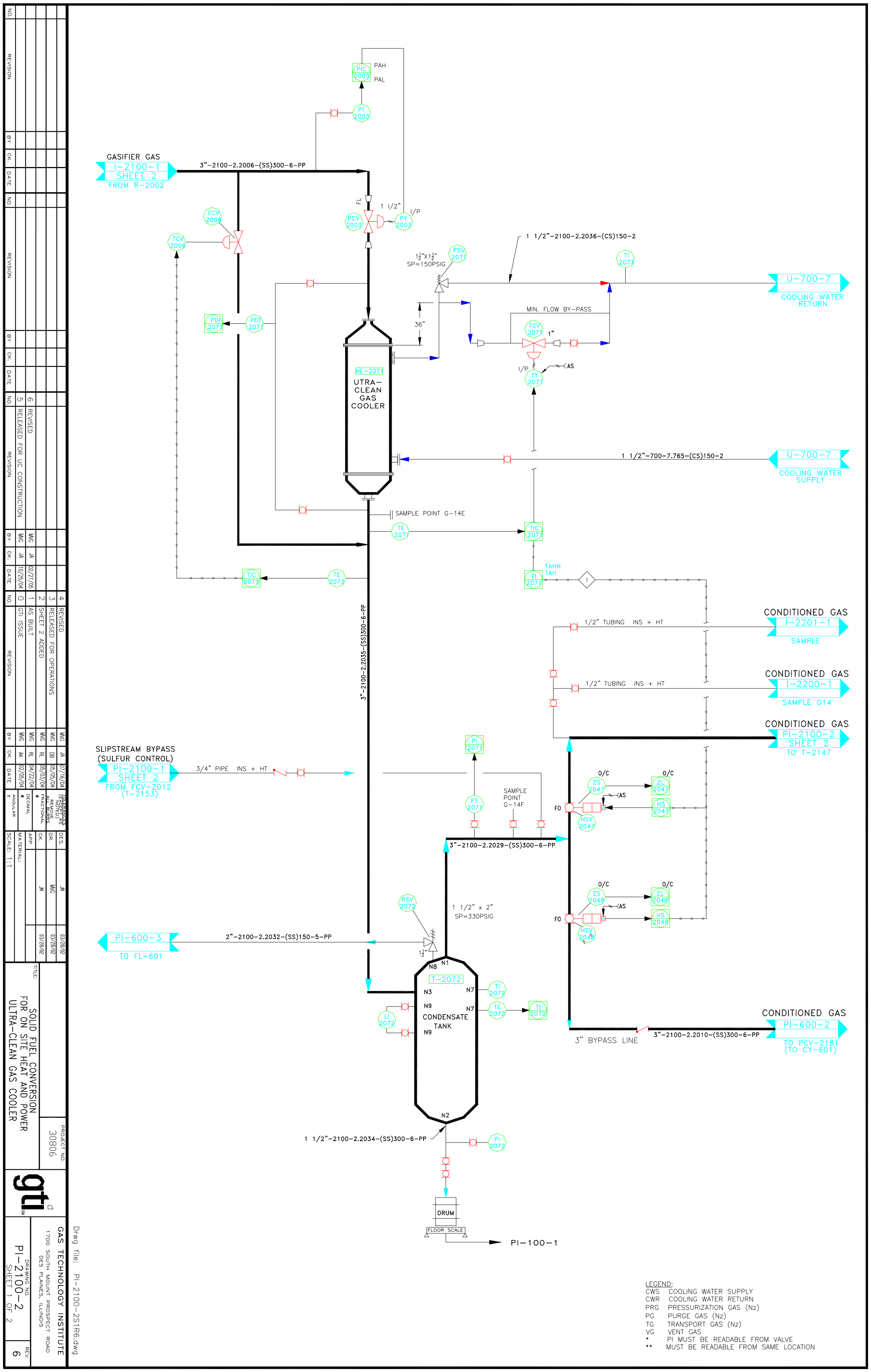
5 REVISED MVG JA 03/09/05
4 REVISED MVG JA 02/15/05
3 RELEASED FOR UC CONSTRUCTION MVG JA 10/28/04
2 REVISED MVG JA 07/16/04
1 RELEASED FOR OPERATIONS MVG DB 05/05/04
0 GTI ISSUE MVG AK 04/28/04
NO. REVISION BY CK. DATE
DES. JM 03/28/02
DR. MVG 03/28/02
CK. JM 03/28/02
APP.
MATERIAL:
SCALE: NTS
PROJECT NO.
30806
TITLE:
SOLID FUEL CONVERSION
FOR ON SITE HEAT AND POWER
ULTRA-CLEAN GAS PROCESSING SYSTEM
gti
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD
DES PLAINES, ILLINOIS
DRAWING NO.
PI-2100-1
SHEET 2
REV.
5



GASIFIER GAS
I-2100-1
SHEET 2
FROM R-2002
3"-2100-2.2006-(SS)300-6-PP
PIC 2003
PAH
PAL
PT 2003
FCV 2006
TCV 2006
PCV 2003
PY 2003
I/P
1 1/2"
FL
1 1/2"-2100-2.2036-(CS)150-2
PSV 2071
1½"X1½"
SP=150PSIG
TI 2071
U-700-7
COOLING WATER RETURN
MIN. FLOW BY-PASS
36"
PDI 2071
PDT 2071
TCV 2071
TY 2071
AS
HE-2071
UTRA-CLEAN GAS COOLER
1 1/2"-700-7.765-(CS)150-2
U-700-7
COOLING WATER SUPPLY
SAMPLE POINT G-14E
TE 2071
TIC 2071
TAHH
TAH
TI 2071
TIC 2073
TE 2073
3"-2100-2.2035-(SS)300-6-PP
1/2" TUBING INS + HT
CONDITIONED GAS
I-2201-1
SAMPLE
CONDITIONED GAS
I-2200-1
SAMPLE G14
CONDITIONED GAS
PI-2100-2
SHEET 2
TO T-2147
SLIPSTREAM BYPASS
(SULFUR CONTROL)
PI-2100-1
SHEET 2
FROM FCV-2012
(T-2153)
3/4" PIPE INS + HT
PI 2071
PT 2071
SAMPLE POINT G-14F
3"-2100-2.2029-(SS)300-6-PP
O/C
ZS 2047
ZL 2047
HS 2047
HSV 2047
FO
ZS 2048
ZL 2048
HS 2048
HSV 2048
PSV 2072
1 1/2" x 2"
SP=330PSIG
PI-600-3
TO FL-601
2"-2100-2.2032-(SS)150-5-PP
N8
N1
T-2072
N3
N7
N9
CONDENSATE TANK
N2
TI 2072
TE 2072
LI 2072
CONDITIONED GAS
PI-600-2
TO PCV-2181
(TO CY-601)
3" BYPASS LINE
3"-2100-2.2010-(SS)300-6-PP
1 1/2"-2100-2.2034-(SS)300-6-PP
PI 2072
DRUM
FLOOR SCALE
PI-100-1
LEGEND:
CWS COOLING WATER SUPPLY
CWR COOLING WATER RETURN
PRG PRESSURIZATION GAS (N2)
PG PURGE GAS (N2)
TG TRANSPORT GAS (N2)
VG VENT GAS
* PI MUST BE READABLE FROM VALVE
** MUST BE READABLE FROM SAME LOCATION
6 REVISED
5 RELEASED FOR UC CONSTRUCTION
4 REVISED
3 RELEASED FOR OPERATIONS
2 SHEET 2 ADDED
1 AS BUILT
0 GTI ISSUE
SCALE: 1:1
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SOLID FUEL CONVERSION FOR ON SITE HEAT AND POWER
ULTRA-CLEAN GAS COOLER
PROJECT NO. 30806
gti
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD
DES PLAINES, ILLINOIS
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SHEET 1 OF 2
REV 6
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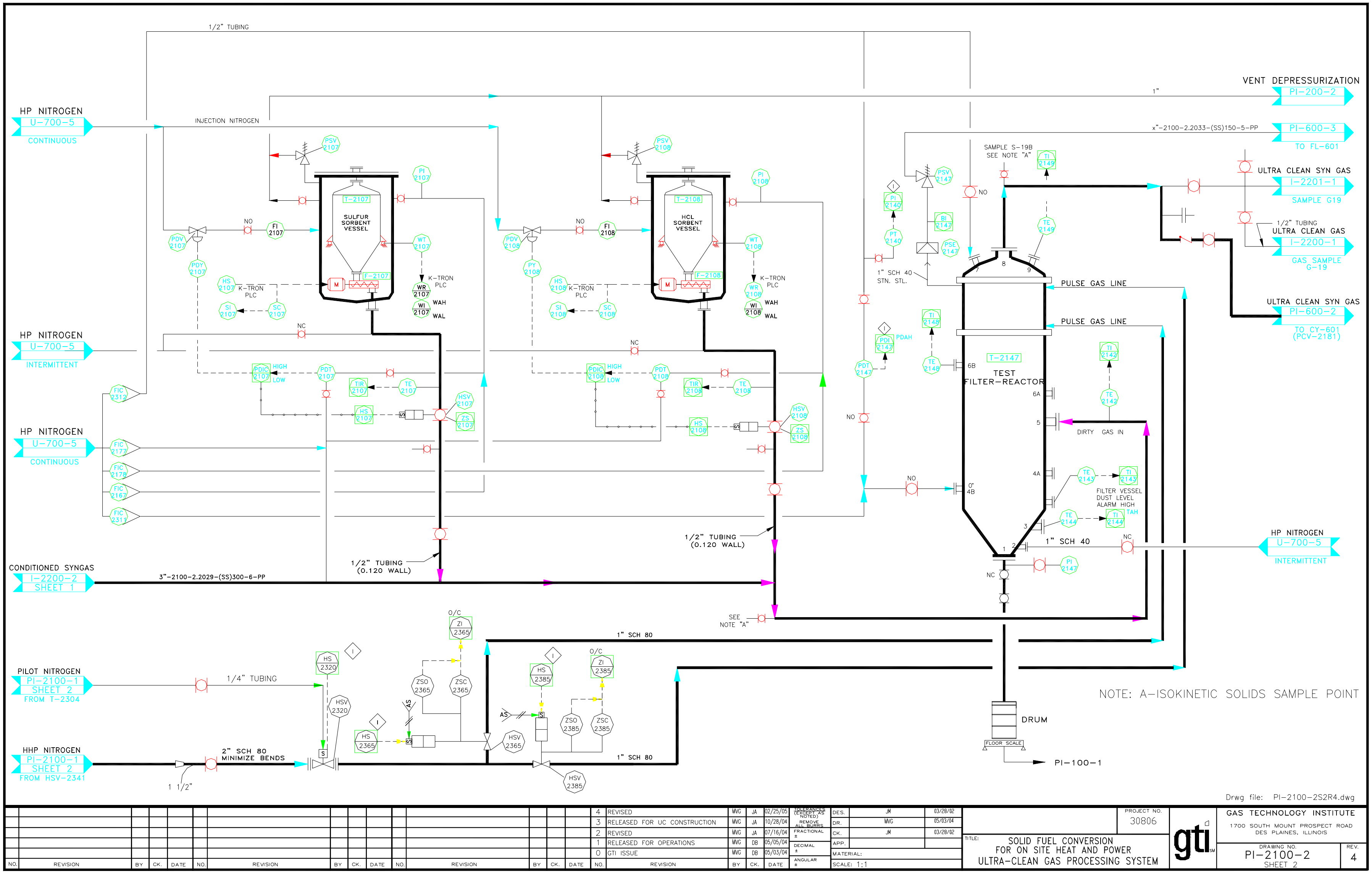

1/2" TUBING
VENT DEPRESSURIZATION
PI-200-2
HP NITROGEN
U-700-5
CONTINUOUS
INJECTION NITROGEN
SULFUR SORBENT VESSEL
HCL SORBENT VESSEL
K-TRON PLC
x"-2100-2.2033-(SS)150-5-PP
PI-600-3
TO FL-601
SAMPLE S-19B
SEE NOTE "A"
ULTRA CLEAN SYN GAS
I-2201-1
SAMPLE G19
1/2" TUBING
ULTRA CLEAN GAS
I-2200-1
GAS SAMPLE G-19
ULTRA CLEAN SYN GAS
PI-600-2
TO CY-601
(PCV-2181)
1" SCH 40 STN. STL.
PULSE GAS LINE
TEST FILTER-REACTOR
DIRTY GAS IN
FILTER VESSEL DUST LEVEL ALARM HIGH
HP NITROGEN
U-700-5
INTERMITTENT
1/2" TUBING (0.120 WALL)
CONDITIONED SYNGAS
I-2200-2
SHEET 1
3"-2100-2.2029-(SS)300-6-PP
1" SCH 80
PILOT NITROGEN
PI-2100-1
SHEET 2
FROM T-2304
1/4" TUBING
HHP NITROGEN
PI-2100-1
SHEET 2
FROM HSV-2341
2" SCH 80
MINIMIZE BENDS
1 1/2"
DRUM
FLOOR SCALE
PI-100-1
NOTE: A-ISOKINETIC SOLIDS SAMPLE POINT
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3 RELEASED FOR UC CONSTRUCTION MWG JA 10/28/04
2 REVISED MWG JA 07/16/04
1 RELEASED FOR OPERATIONS MWG DB 05/05/04
0 GTI ISSUE MWG DB 05/03/04
PROJECT NO. 30806
TITLE: SOLID FUEL CONVERSION FOR ON SITE HEAT AND POWER ULTRA-CLEAN GAS PROCESSING SYSTEM
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD DES PLAINES, ILLINOIS
DRAWING NO. PI-2100-2 SHEET 2
REV. 4
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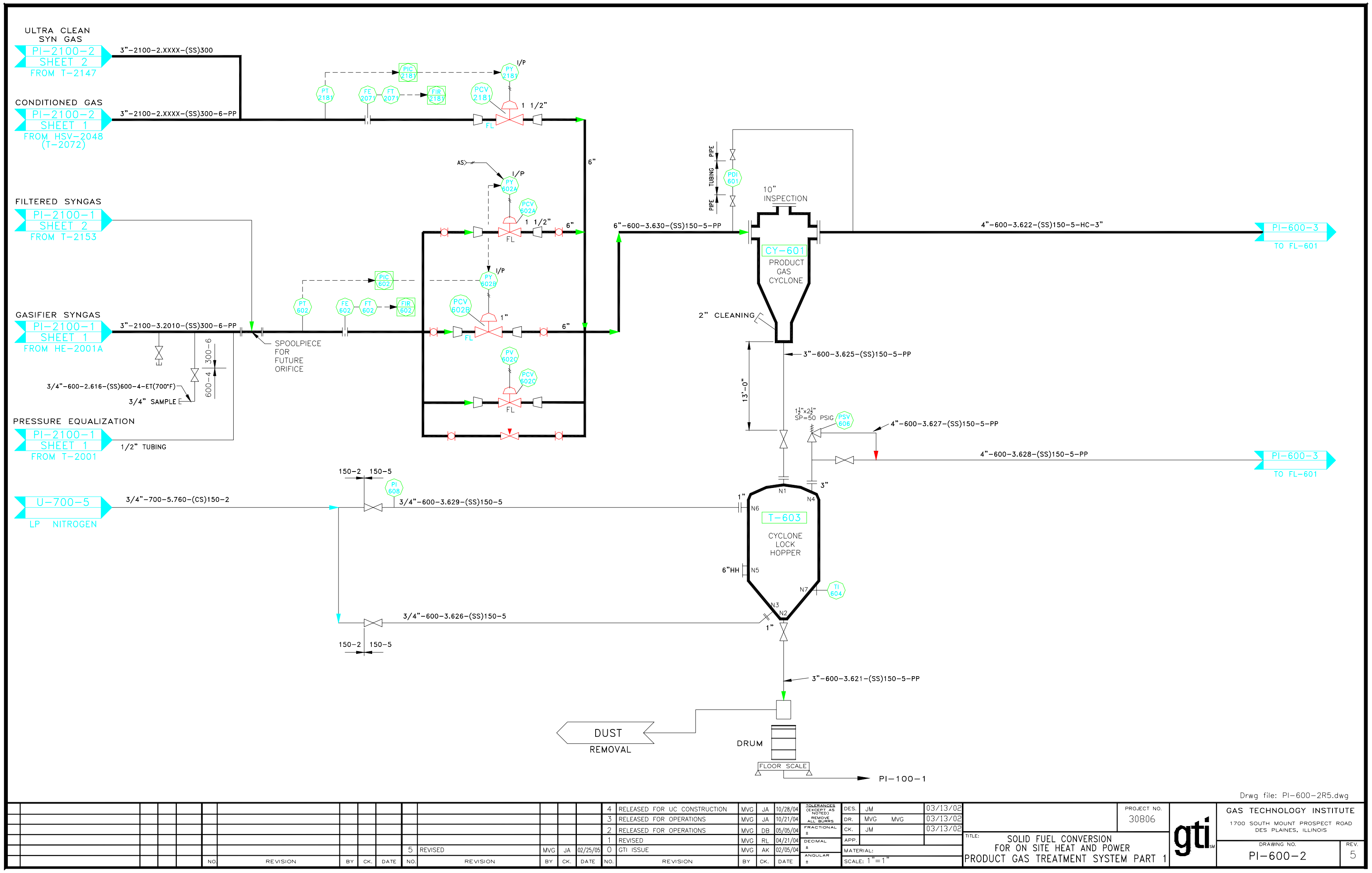
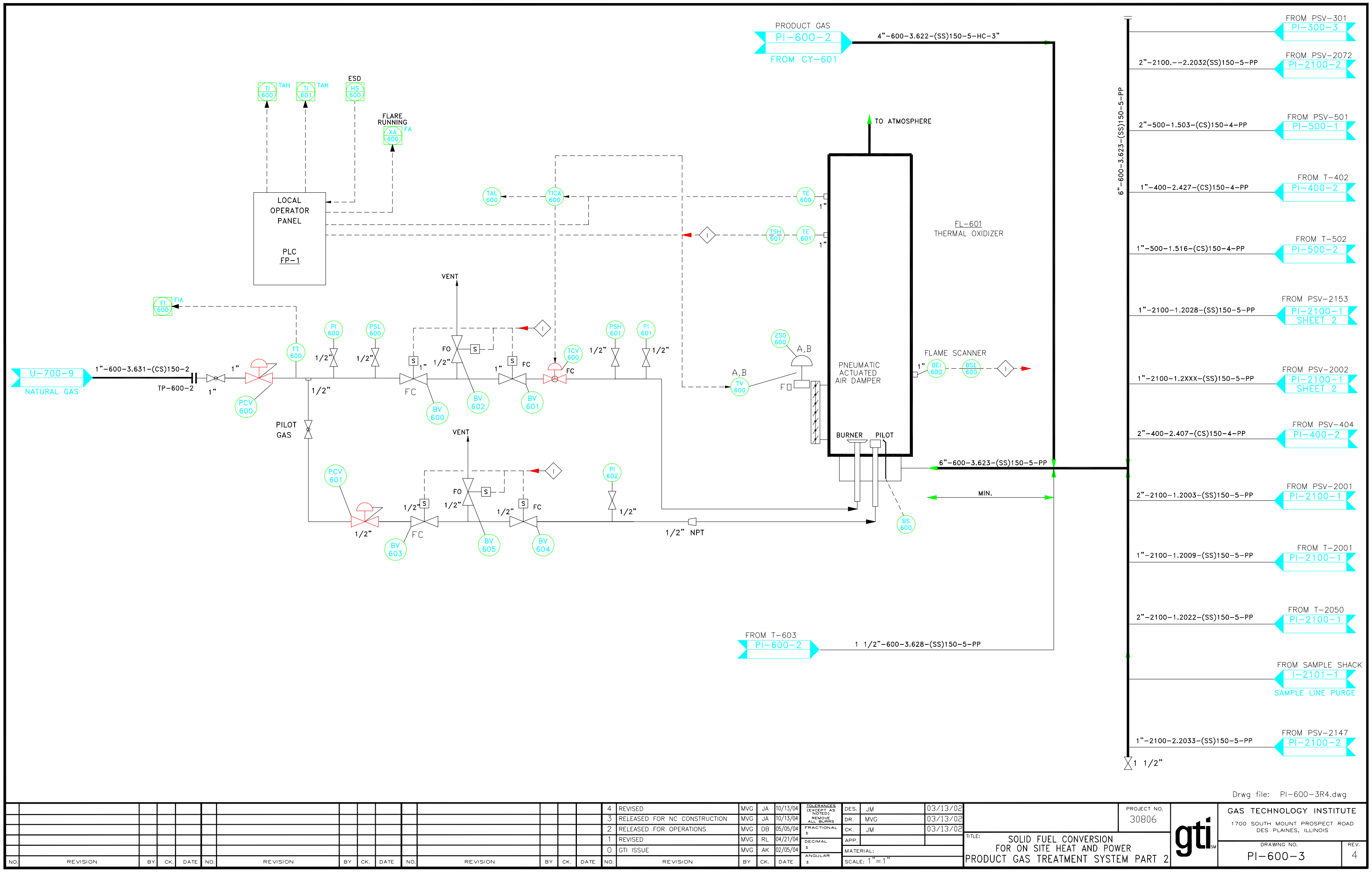


ULTRA CLEAN SYN GAS
PI-2100-2 SHEET 2
FROM T-2147
3"-2100-2.XXXX-(SS)300
CONDITIONED GAS
PI-2100-2 SHEET 1
FROM HSV-2048 (T-2072)
3"-2100-2.XXXX-(SS)300-6-PP
FILTERED SYNGAS
PI-2100-1 SHEET 2
FROM T-2153
GASIFIER SYNGAS
PI-2100-1 SHEET 1
FROM HE-2001A
3"-2100-3.2010-(SS)300-6-PP
SPOOLPIECE FOR FUTURE ORIFICE
3/4"-600-2.616-(SS)600-4-ET(700°F)
3/4" SAMPLE
PRESSURE EQUALIZATION
PI-2100-1 SHEET 1
FROM T-2001
1/2" TUBING
U-700-5
LP NITROGEN
3/4"-700-5.760-(CS)150-2
3/4"-600-3.629-(SS)150-5
3/4"-600-3.626-(SS)150-5
6"-600-3.630-(SS)150-5-PP
10" INSPECTION
CY-601
PRODUCT GAS CYCLONE
2" CLEANING
4"-600-3.622-(SS)150-5-HC-3"
PI-600-3
TO FL-601
3"-600-3.625-(SS)150-5-PP
13'-0"
SP=50 PSIG
4"-600-3.627-(SS)150-5-PP
4"-600-3.628-(SS)150-5-PP
T-603
CYCLONE LOCK HOPPER
3"-600-3.621-(SS)150-5-PP
DUST REMOVAL
DRUM
FLOOR SCALE
PI-100-1
Drwg file: PI-600-2R5.dwg
RELEASED FOR UC CONSTRUCTION
RELEASED FOR OPERATIONS
REVISED
GTI ISSUE
PROJECT NO. 30806
SOLID FUEL CONVERSION FOR ON SITE HEAT AND POWER
PRODUCT GAS TREATMENT SYSTEM PART 1
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD DES PLAINES, ILLINOIS
DRAWING NO. PI-600-2
REV. 5


PRODUCT GAS
PI-600-2
FROM CY-601
4"-600-3.622-(SS)150-5-HC-3"
FROM PSV-301
PI-300-3
FROM PSV-2072
PI-2100-2
2"-2100.--2.2032(SS)150-5-PP
FROM PSV-501
PI-500-1
2"-500-1.503-(CS)150-4-PP
FROM T-402
PI-400-2
1"-400-2.427-(CS)150-4-PP
FROM T-502
PI-500-2
1"-500-1.516-(CS)150-4-PP
FROM PSV-2153
PI-2100-1
SHEET 2
1"-2100-1.2028-(SS)150-5-PP
FROM PSV-2002
PI-2100-1
SHEET 2
1"-2100-1.2XXX-(SS)150-5-PP
FROM PSV-404
PI-400-2
2"-400-2.407-(CS)150-4-PP
FROM PSV-2001
PI-2100-1
2"-2100-1.2003-(SS)150-5-PP
FROM T-2001
PI-2100-1
1"-2100-1.2009-(SS)150-5-PP
FROM T-2050
PI-2100-1
2"-2100-1.2022-(SS)150-5-PP
FROM SAMPLE SHACK
I-2101-1
SAMPLE LINE PURGE
FROM PSV-2147
PI-2100-2
1"-2100-2.2033-(SS)150-5-PP
1 1/2"
6"-600-3.623-(SS)150-5-PP
TO ATMOSPHERE
FL-601
THERMAL OXIDIZER
PNEUMATIC
ACTUATED
AIR DAMPER
FLAME SCANNER
BURNER
PILOT
MIN.
LOCAL
OPERATOR
PANEL
PLC
FP-1
ESD
FLARE
RUNNING
VENT
U-700-9
NATURAL GAS
1"-600-3.631-(CS)150-2
TP-600-2
PILOT
GAS
1/2" NPT
FROM T-603
PI-600-2
1 1/2"-600-3.628-(SS)150-5-PP
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3 RELEASED FOR NC CONSTRUCTION MVG JA 10/13/04
2 RELEASED FOR OPERATIONS MVG DB 05/05/04
1 REVISED MVG RL 04/21/04
0 GTI ISSUE MVG AK 02/05/04
DES. JM 03/13/02
DR. MVG 03/13/02
CK. JM 03/13/02
APP.
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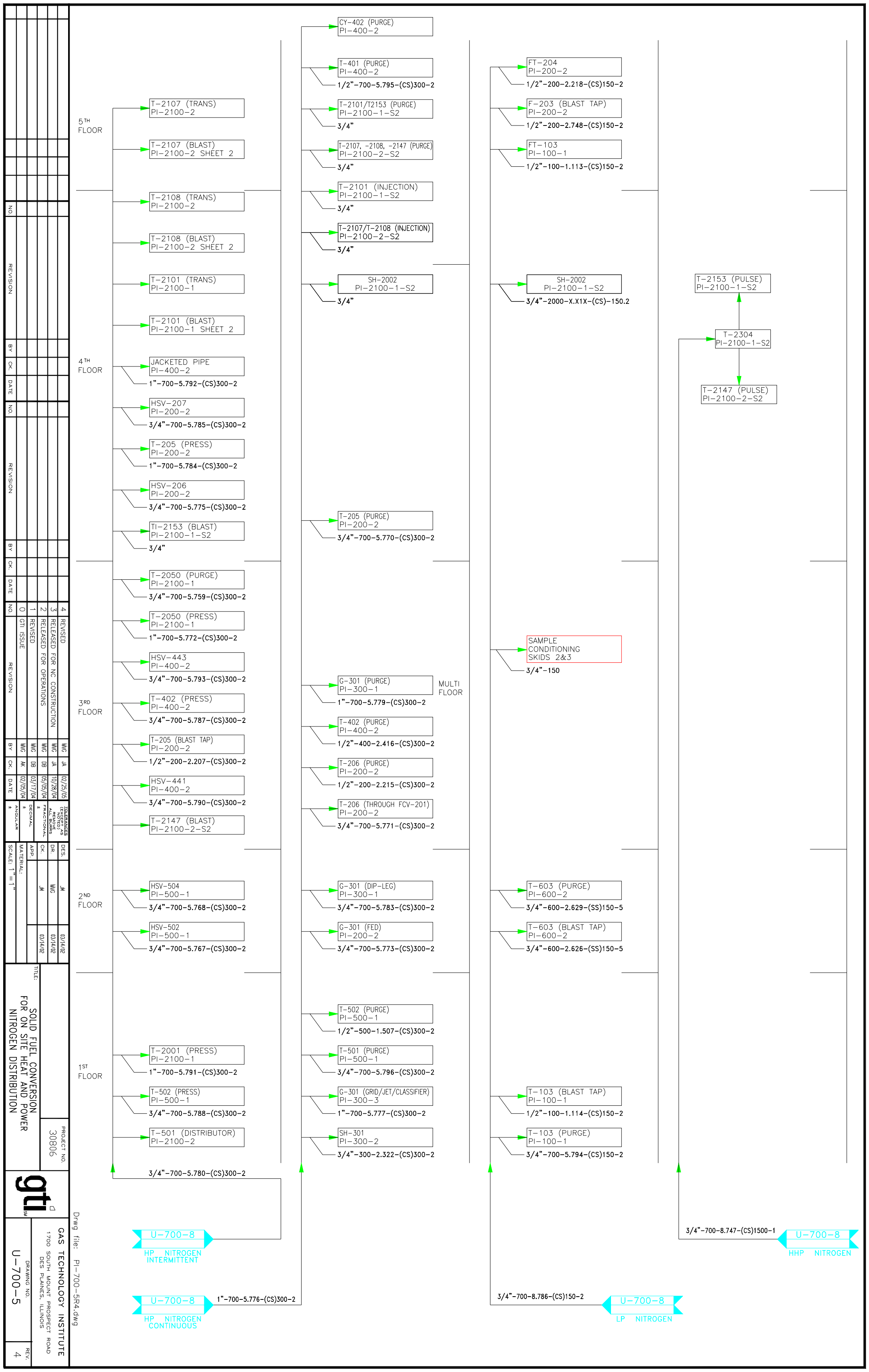
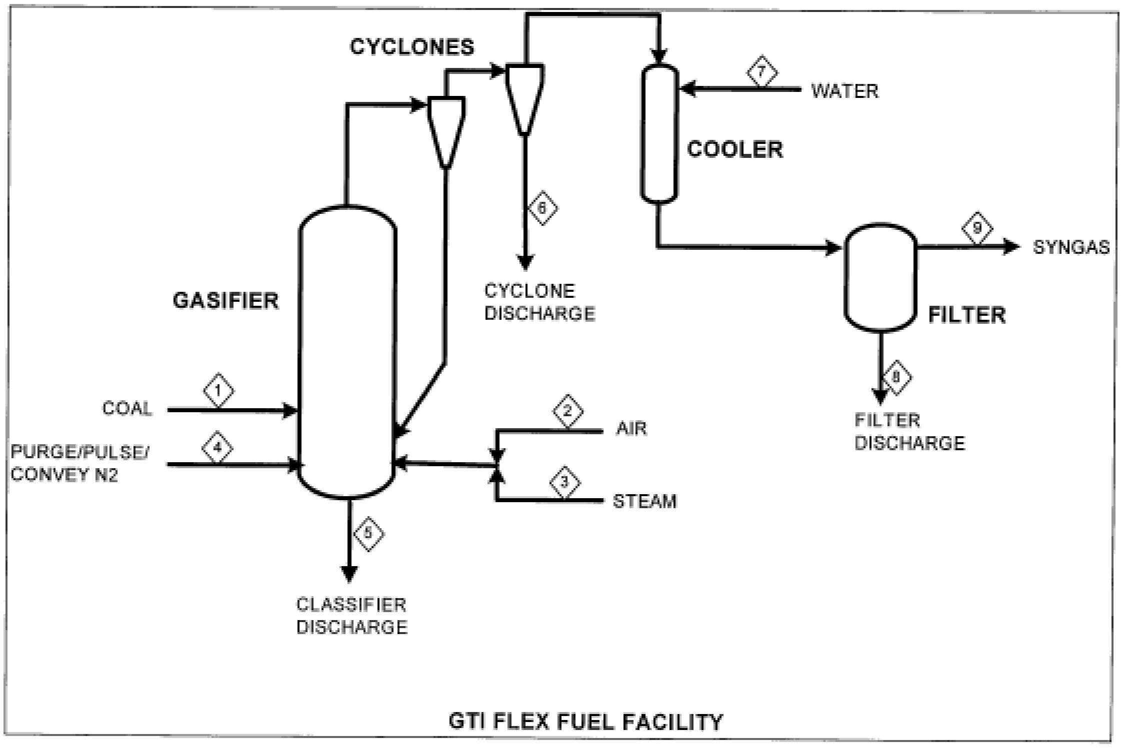
SCALE: 1"=1"
PROJECT NO.
30806
TITLE:
SOLID FUEL CONVERSION
FOR ON SITE HEAT AND POWER
PRODUCT GAS TREATMENT SYSTEM PART 2
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD
DES PLAINES, ILLINOIS
DRAWING NO.
PI-600-3
REV.
4



CY-402 (PURGE) PI-400-2
T-401 (PURGE) PI-400-2
1/2"-700-5.795-(CS)300-2
T-2101/T2153 (PURGE) PI-2100-1-S2
3/4"
T-2107, -2108, -2147 (PURGE) PI-2100-2-S2
3/4"
T-2101 (INJECTION) PI-2100-1-S2
3/4"
T-2107/T-2108 (INJECTION) PI-2100-2-S2
3/4"
SH-2002 PI-2100-1-S2
3/4"
FT-204 PI-200-2
1/2"-200-2.218-(CS)150-2
F-203 (BLAST TAP) PI-200-2
1/2"-200-2.748-(CS)150-2
FT-103 PI-100-1
1/2"-100-1.113-(CS)150-2
SH-2002 PI-2100-1-S2
3/4"-2000-X.X1X-(CS)-150.2
T-2153 (PULSE) PI-2100-1-S2
T-2304 PI-2100-1-S2
T-2147 (PULSE) PI-2100-2-S2
5TH FLOOR
T-2107 (TRANS) PI-2100-2
T-2107 (BLAST) PI-2100-2 SHEET 2
T-2108 (TRANS) PI-2100-2
T-2108 (BLAST) PI-2100-2 SHEET 2
T-2101 (TRANS) PI-2100-1
T-2101 (BLAST) PI-2100-1 SHEET 2
4TH FLOOR
JACKETED PIPE PI-400-2
1"-700-5.792-(CS)300-2
HSV-207 PI-200-2
3/4"-700-5.785-(CS)300-2
T-205 (PRESS) PI-200-2
1"-700-5.784-(CS)300-2
HSV-206 PI-200-2
3/4"-700-5.775-(CS)300-2
TI-2153 (BLAST) PI-2100-1-S2
3/4"
T-205 (PURGE) PI-200-2
3/4"-700-5.770-(CS)300-2
T-2050 (PURGE) PI-2100-1
3/4"-700-5.759-(CS)300-2
T-2050 (PRESS) PI-2100-1
1"-700-5.772-(CS)300-2
SAMPLE CONDITIONING SKIDS 2&3
3/4"-150
3RD FLOOR
HSV-443 PI-400-2
3/4"-700-5.793-(CS)300-2
T-402 (PRESS) PI-400-2
3/4"-700-5.787-(CS)300-2
T-205 (BLAST TAP) PI-200-2
1/2"-200-2.207-(CS)300-2
HSV-441 PI-400-2
3/4"-700-5.790-(CS)300-2
T-2147 (BLAST) PI-2100-2-S2
G-301 (PURGE) PI-300-1
1"-700-5.779-(CS)300-2
MULTI FLOOR
T-402 (PURGE) PI-400-2
1/2"-400-2.416-(CS)300-2
T-206 (PURGE) PI-200-2
1/2"-200-2.215-(CS)300-2
T-206 (THROUGH FCV-201) PI-200-2
3/4"-700-5.771-(CS)300-2
2ND FLOOR
HSV-504 PI-500-1
3/4"-700-5.768-(CS)300-2
HSV-502 PI-500-1
3/4"-700-5.767-(CS)300-2
G-301 (DIP-LEG) PI-300-1
3/4"-700-5.783-(CS)300-2
G-301 (FED) PI-200-2
3/4"-700-5.773-(CS)300-2
T-603 (PURGE) PI-600-2
3/4"-600-2.629-(SS)150-5
T-603 (BLAST TAP) PI-600-2
3/4"-600-2.626-(SS)150-5
1ST FLOOR
T-502 (PURGE) PI-500-1
1/2"-500-1.507-(CS)300-2
T-2001 (PRESS) PI-2100-1
1"-700-5.791-(CS)300-2
T-501 (PURGE) PI-500-1
3/4"-700-5.796-(CS)300-2
T-502 (PRESS) PI-500-1
3/4"-700-5.788-(CS)300-2
G-301 (GRID/JET/CLASSIFIER) PI-300-3
1"-700-5.777-(CS)300-2
T-501 (DISTRIBUTOR) PI-2100-2
3/4"-700-5.780-(CS)300-2
SH-301 PI-300-2
3/4"-300-2.322-(CS)300-2
T-103 (BLAST TAP) PI-100-1
1/2"-100-1.114-(CS)150-2
T-103 (PURGE) PI-100-1
3/4"-700-5.794-(CS)150-2
U-700-8 HP NITROGEN INTERMITTENT
U-700-8 HP NITROGEN CONTINUOUS
1"-700-5.776-(CS)300-2
3/4"-700-8.786-(CS)150-2
U-700-8 LP NITROGEN
3/4"-700-8.747-(CS)1500-1
U-700-8 HHP NITROGEN
Drwg file: PI-700-5R4.dwg
TITLE: SOLID FUEL CONVERSION FOR ON SITE HEAT AND POWER NITROGEN DISTRIBUTION
PROJECT NO. 30806
gti
GAS TECHNOLOGY INSTITUTE
1700 SOUTH MOUNT PROSPECT ROAD DES PLAINES, ILLINOIS
DRAWING NO. U-700-5
REV. 4
4 REVISED
3 RELEASED FOR NC CONSTRUCTION
2 RELEASED FOR OPERATIONS
1 REVISED
0 GTI ISSUE

16. APPENDIX B: GASIFIER PERFORMANCE WITH WASHED INDIAN COAL



Flex Fuel
Test: Washed Indian Coal
Period:
From: 3-31-05 0:00
To: 3-31-05 6:00

MAJOR PROCESS STREAM CONDITIONS

Stream No	1	2	3	4	5	6	7	8	9
Stream Discription	Coal	Air	Steam	Nitrogen	Classifier Solids	Cyclone Solids	Quench Water	Filter Solids	Product Syngas
Temperature, °F	60	101	438	81	990	1501	60	685	685
Solids Flow Rate, lb/h	671				134	71		34	
Dry Solids Composition, wt%									
Ash	34.89				81.25	84.60		70.76	
Carbon	48.65				18.42	15.16		27.58	
Hydrogen	2.93				0.00	0.00		0.00	
Nitrogen	1.07				0.18	0.16		0.25	
Sulfur	0.57				0.15	0.08		0.48	
Oxygen	11.89				0.00	0.00		0.93	
Total	100.00				100.00	100.00		100.00	
Liquid Flow Rate, lb/h							444		
Gas Flow Rate, lb/h		1555	192	247					2979
Gas Composition, mol%									
H2									7.05
CO2									8.30
O2		21.00							0.00
N2		79.00		100.00					42.94
CO									7.69
CH4									0.94
C2H6									0.00
C2H4									0.00
C6+									0.00
H2S									0.07
COS									0.01
H2O		0.00	100.00	0.00					33.00
Total		100.00	100.00	100.00					100.00

			OVERALL PLANT MASS & HEAT BALANCE
Flex Fuel			
Test	Washed Indian Coal		
Period			
From	3/31/05	0:00	
To	3/31/05	6:00	

INPUT STREAMS	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulfur**	**Ash**	**Total**	**Btu/h**
Coal Feed	286.6	26.4	142.7	6.3	3.4	206.2	671.6	4.89E+06
Air Feed			362.1	1192.7			1554.9	1.47E+04
Steam Feed		21.5	170.5				192.0	2.37E+05
N2 Feed				247.1			247.1	1.19E+03
Water Feed		49.6	393.9				443.5	0.00E+00
Total Input	286.6	97.5	1069.2	1446.1	3.4	206.2	3109.1	5.15E+06
OUTPUT STREAMS								
Product Syngas	251.7	104.7	1132.8	1486.7	2.9		2978.8	4.09E+06
Classifier Discharge	24.7	0.0	0.0	0.2	0.2	109.3	134.5	4.04E+05
2nd Cyclone Discharge	10.8	0.0	0.0	0.1	0.1	60.6	71.6	1.94E+05
Filter Discharge	9.3	0.0	0.0	0.1	0.2	24.3	33.9	1.41E+05
Heat Loss								3.70E+05
Total Output	296.6	104.7	1132.8	1487.1	3.3	194.2	3218.8	5.20E+06
Out - In	10.0	7.1	63.6	41.0	-0.1	-12.0	109.7	4.96E+04
% Balance (Out/In)	103.5	107.3	105.9	102.8	98.9	94.2	103.5	101.0

(All units in lb/h unless otherwise noted)

GASIFIER OPERATING & PERFORMANCE PARAMETERS

Gasifier Pressure, psig	256
Gasifier Bed Temperature, °F	1741
Coal Feed Rate, lb/h	671
Air Feed Rate, lb/h	1555
Steam Feed Rate, lb/h	192
Steam/Carbon Ratio, lb/lb	0.67
Oxygen/Carbon Ratio, lb/lb	1.26
Gasifier Bed Density, lb/cu ft	32.1
Gasifier Bed Height, ft	9.5
Gasifier Superficial Velocity, ft/s	2.4
MAF Coal Gasification Intensity, lb/cu ft -hr	37.5
Dry & Purge N2 Free Syngas HHV, Btu/SCF	92.8
MAF Coal Conversion, %	88.2
Carbon Conversion, %	84.4

Washed Indian Coal - Particle Size Distributions
Test Period From 3/31/05 0:00 to 3/31/05 6:00

US Sieve No	Averaged Sieve Opening, microns	COAL FEED		CLASSIFIER SOLIDS		2° CYCLONE SOLIDS		FILTER SOLIDS	
		Differential wt%, Retained	Cumulative wt%, Retained	Differential wt%, Retained	Cumulative wt%, Retained	Differential wt%, Retained	Cumulative wt%, Retained	Differential wt%, Retained	Cumulative wt%, Retained
6	4851	3.8	3.8	12.3	12.3	0.0	0.0	0.0	0.0
12	2516	10.6	14.4	27.3	39.6	0.0	0.0	0.0	0.0
20	1260	16.2	30.6	19.4	59.0	0.0	0.0	0.3	0.3
40	630	20.5	51.1	11.4	70.4	0.0	0.0	0.3	0.6
60	334	16.8	67.9	6.0	76.4	0.4	0.4	0.3	0.9
80	213	10.7	78.6	3.7	80.1	0.8	1.2	0.3	1.2
100	164	5.6	84.2	2.3	82.4	0.6	1.8	0.3	1.5
140	127	7.7	91.9	4.6	87.0	1.5	3.3	0.5	2.0
200	89	4.5	96.4	4.0	91.0	3.2	6.5	1.3	3.3
230	69	1.1	97.5	1.0	92.0	2.2	8.7	0.8	4.1
270	58	0.9	98.4	0.9	92.9	4.3	13.0	1.0	5.1
325	48	0.5	98.9	0.7	93.6	4.6	17.6	1.3	6.4
Pan	25	1.1	100	6.4	100.0	82.4	100.0	93.6	100.0
Total		100.0		100.0		100.0		100.0	
Avg Diameter*, microns		266		227		32		30	

Note : Averaged particle diameter = Sauter mean Diameter =1/[summation (Wi/dpi)]

17. APPENDIX C: ANALYTICAL REPORT SAMPLES

1. Gasifier Coal Feed

Sample Login No: 051143-242 Date: April 13, 2005

Sample Description: NGC-OPT2B composite of four "S1" feed coal bags #38, #39, #40, & #41

(Note: samples from bags 38 & 39 had visible condensation in the containers, samples from bags 40 & 41 did not. This is the analysis of the entire composite.)

Air-Dry Moisture, % 10.56

Proximate Analysis	(As received)	(As received) w/SO3 correction	(Dry basis) w/SO3 correction
Moisture, %	12.19	12.19	- - -
Volatile Matter, %	25.34	25.34	28.86
Ash (750°C), %	30.73	30.63	34.89
Fixed Carbon, % (by difference)	31.74	31.84	36.25

Ultimate Analysis	(Dry basis)
Ash (750°C), %	34.89
Carbon, %	48.65
Hydrogen, %	2.93
Nitrogen, %	1.07
Sulfur, %	0.57
Oxygen, % (by difference)	11.89

Heating Value	(Dry basis)
BTU/lb.	8,300

Analyst: NJP

2. Gasifier Bottom Ash

Sample Login No: 051143-243 Date: April 13, 2005

Sample Description: NGC-OPT2B composite of seven T-502's from 3/31/05

(Lab #'s 051143-205, 051143-207, 051143-210, 051143-212, 051143-216, 051143-218, & 051143-220)

Proximate Analysis	(As received)	(As received) w/SO3 correction	(Dry basis) w/SO3 correction
Moisture, %	0.27	0.27	- - -
Volatile Matter, %	2.08	2.08	2.09
Ash (750°C), %	81.20	81.07	81.29
Fixed Carbon, % (by difference)	16.45	16.58	16.62

Ultimate Analysis	(Dry basis)
Ash (750°C), %	81.29
Carbon, %	18.43
Hydrogen, %	< 0.01
Nitrogen, %	0.18
Sulfur, %	0.15
Oxygen, % (by difference)	B.D.L.

Heating Value	(Dry basis)
BTU/lb.	2,570

Analyst: NJP

3. Gasifier Secondary Cyclone Fines

Sample Login No: 051143-244 Date: April 13, 2005

Sample Description: NGC-OPT2B composite of seven T-402's from 3/31/05

(Lab #'s 051143-206, 051143-208, 051143-211, 051143-213, 051143-217, 051143-219, & 051143-221)

Proximate Analysis	(As received)	(As received) w/SO3 correction	(Dry basis) w/SO3 correction
Moisture, %	0.39	0.39	- - -
Volatile Matter, %	1.72	1.72	1.73
Ash (750°C), %	84.59	84.47	84.79
Fixed Carbon, % (by difference)	13.30	13.42	13.48

Ultimate Analysis	(Dry basis)
Ash (750°C), %	84.79
Carbon, %	15.19
Hydrogen, %	< 0.01
Nitrogen, %	0.16
Sulfur, %	0.08
Oxygen, % (by difference)	B.D.L.

Heating Value	(Dry basis)
BTU/lb.	2,130

Analyst: NJP

4. Conditioning Filter-Reactor Fines

Sample Login No: 051143-241 Date: April 13, 2005
Sample Description: NGC-OPT2B T-2050 Dump # 14 11:33 4/01/05

Proximate Analysis	(As received)	(As received) w/SO3 correction	(Dry basis) w/SO3 correction
Moisture, %	0.66	0.66	- - -
Volatile Matter, %	4.22	4.22	4.25
Ash (750°C), %	71.64	70.30	70.76
Fixed Carbon, % (by difference)	23.48	24.82	24.99

Ultimate Analysis	(Dry basis)
Ash (750°C), %	70.76
Carbon, %	27.58
Hydrogen, %	< 0.01
Nitrogen, %	0.25
Sulfur, %	0.48
Oxygen, % (by difference)	0.93

Heating Value	(Dry basis)
BTU/lb.	4,030

Analyst: NJP

5. Raw Syngas Bulk Composition and Sulfur Analyses (CF-R Inlet at G-8)

Major Component Gas Analysis By Gas Chromatography

Report Date: 8-Apr-05
Client Name: 15352.1.05
GTI Sample Number: 051143-204
Sample Description: NGC-OPT2 G8 Gas 3/31/2005 00:20
Date Analyzed: 7-Apr-05 **Analyst:** MAD

Component	Mol %	Det. Limit	Weight %
Helium		0.1%	
Hydrogen	10.5%	0.1%	0.78%
Carbon Dioxide	12.1%	0.03%	19.7%
Oxygen/Argon	0.73%	0.03%	0.88%
Nitrogen	63.9%	0.03%	66.0%
Carbon Monoxide	11.3%	0.03%	11.7%
Methane	1.41%	0.002%	0.836%
Ethane		0.002%	
Ethene		0.002%	
Ethyne		0.002%	
Propane		0.002%	
Propene		0.002%	
Propadiene		0.002%	
Propyne		0.002%	
i-Butane		0.002%	
n-Butane		0.002%	
1-Butene		0.002%	
i-Butene		0.002%	
trans-2-Butene		0.002%	
cis-2-Butene		0.002%	
1,3-Butadiene		0.002%	
i-Pentane		0.002%	
n-Pentane		0.002%	
neo-Pentane		0.002%	
1-Pentene		0.002%	
Hexane Plus	0.005%	0.002%	0.016%
Hydrogen Sulfide	0.090%	0.001%	0.114%
Carbonyl Sulfide	0.007%	0.001%	0.016%
Total	100.0%		100.0%

Calculated Real Gas Properties per ASTM D3588-98

Temp. (°F) =	60.0	60.0
Press. (psia) =	14.696	14.73
Compressibility Factor [z] (Dry) =	0.99946	0.99946
Compressibility Factor [z] (Sat.) =	0.99928	0.99927
Relative Density (Dry) =	0.9361	0.9361
Gross HV (Dry) (Btu/ft3) =	85.2	85.4
Gross HV (Sat.) (Btu/ft3) =	83.8	84.0
Wobbe Index =	88.1	88.3
Net HV (Dry) (Btu/ft3) =	78.5	78.7
Net HV (Sat.) (Btu/ft3) =	77.1	77.3

Notes: All blank values are below detection limit
N.A. - Not Analyzed

6. Syngas Bulk Composition and Sulfur Analyses (CF-R Outlet at G-13)

Major Component Gas Analysis By Gas Chromatography

Report Date: 24-Mar-05
Client Name: **15352.1.05**
GTI Sample Number: **051143-041**
Sample Description: **NGC-OPT2 G13 CFR Outlet 3/24/05 11:45**
Date Analyzed: 24-Mar-05 **Analyst:** RJB

Component	Mol %	Det. Limit	Weight %
Helium		0.1%	
Hydrogen	**10.0%**	0.1%	**0.74%**
Carbon Dioxide	**12.3%**	0.03%	**19.9%**
Oxygen/Argon	**0.70%**	0.03%	**0.83%**
Nitrogen	**65.6%**	0.03%	**67.5%**
Carbon Monoxide	**9.60%**	0.03%	**9.89%**
Methane	**1.76%**	0.002%	**1.04%**
Ethane		0.002%	
Ethene		0.002%	
Ethyne		0.002%	
Propane		0.002%	
Propene		0.002%	
Propadiene		0.002%	
Propyne		0.002%	
i-Butane		0.002%	
n-Butane		0.002%	
1-Butene		0.002%	
i-Butene		0.002%	
trans-2-Butene		0.002%	
cis-2-Butene		0.002%	
1,3-Butadiene		0.002%	
i-Pentane		0.002%	
n-Pentane		0.002%	
neo-Pentane		0.002%	
1-Pentene		0.002%	
Hexane Plus	**0.015%**	0.002%	**0.046%**
Hydrogen Sulfide	**0.0700%**	0.001%	**0.088%**
Carbonyl Sulfide	**0.0052%**	0.001%	**0.011%**
Total	**100.0%**		**100.0%**

Calculated Real Gas Properties per ASTM D3588-98

Temp. (°F) =	**60.0**	**60.0**
Press. (psia) =	**14.696**	**14.73**
Compressibility Factor [z] (Dry) =	0.99945	0.99945
Compressibility Factor [z] (Sat.) =	0.99926	0.99926
Relative Density (Dry) =	0.9396	0.9396
Gross HV (Dry) (Btu/ft3) =	82.2	82.3
Gross HV (Sat.) (Btu/ft3) =	80.7	80.9
Wobbe Index =	84.8	85.0
Net HV (Dry) (Btu/ft3) =	75.3	75.4
Net HV (Sat.) (Btu/ft3) =	74.0	74.1

Notes: All blank values are below detection limit
N.A. - Not Analyzed

7. Conditioned Syngas Bulk Composition and Sulfur Analyses (TF-R Inlet at G-14)

Major Component Gas Analysis By Gas Chromatography

Report Date: 25-Mar-05
Client Name: **15352.1.05**
GTI Sample Number: **051143-060**
Sample Description: **NGC-OPT2 G14 TF-R Inlet 3/24/05 19:05**
Date Analyzed: 24-Mar-05 **Analyst:** RJB

Component	Mol %	Det. Limit	Weight %
Helium		0.1%	
Hydrogen	**12.6%**	0.1%	**0.94%**
Carbon Dioxide	**15.2%**	0.03%	**24.7%**
Oxygen/Argon	**0.68%**	0.03%	**0.81%**
Nitrogen	**63.6%**	0.03%	**66.0%**
Carbon Monoxide	**6.18%**	0.03%	**6.41%**
Methane	**1.78%**	0.002%	**1.06%**
Ethane		0.002%	
Ethene		0.002%	
Ethyne		0.002%	
Propane		0.002%	
Propene		0.002%	
Propadiene		0.002%	
Propyne		0.002%	
i-Butane		0.002%	
n-Butane		0.002%	
1-Butene		0.002%	
i-Butene		0.002%	
trans-2-Butene		0.002%	
cis-2-Butene		0.002%	
1,3-Butadiene		0.002%	
i-Pentane		0.002%	
n-Pentane		0.002%	
neo-Pentane		0.002%	
1-Pentene		0.002%	
Hexane Plus	**0.016%**	0.002%	**0.051%**
Hydrogen Sulfide	**0.000170%**	0.000005%	**0.00021%**
Carbonyl Sulfide	**0.000023%**	0.000005%	**0.00005%**
Total	**100.0%**		**100.0%**

Calculated Real Gas Properties per ASTM D3588-98

Temp. (°F) =	**60.0**	**60.0**
Press. (psia) =	**14.696**	**14.73**
Compressibility Factor [z] (Dry) =	0.99940	0.99940
Compressibility Factor [z] (Sat.) =	0.99920	0.99920
Relative Density (Dry) =	0.9324	0.9324
Gross HV (Dry) (Btu/ft3) =	79.3	79.5
Gross HV (Sat.) (Btu/ft3) =	77.9	78.1
Wobbe Index =	82.1	82.3
Net HV (Dry) (Btu/ft3) =	71.1	71.3
Net HV (Sat.) (Btu/ft3) =	69.9	70.1

Notes: All blank values are below detection limit
N.A. - Not Analyzed
Thiophene detected at 0.68ppmv