

all, pits. The source of these foreign elements (that is all elements except Fe, Al, Cr, and O) is not definitively known; however, this filter was water washed and all of these foreign elements are sometimes found in regular tap water. The cause and effect relationship between the foreign elements and the pits was not determined. They may have accumulated in preexisting pits or they may have caused the pits. If the pits already existed, it is also not known if these foreign elements changed them or made them worse. Material testing in the future will be conducted on filters that are not water washed to eliminate that possible source of contamination. Specimen Tn-Ax-18, also from element 27056, had an ultimate strength and strain-to-failure near the same as specimens from other Fe₃Al elements tested after gasification operation. Examination of the failure surface of this specimen showed pits, both internal and at the surface, but they were much smaller than those seen on Tn-Ax-16 and 20. Particle size and morphology appeared the same in the pits of this specimen as away from the pits; however, EDS analysis showed many of the same foreign elements as in the other two specimens from this filter. The pits on Tn-Ax-16 and 20 were much different than those observed on the outside surface of the elements discussed in Section 3.3.4. The material inside of and surrounding the surface pits discussed previously appeared the same in particle size and morphology as the material far away from the pits.

All axial tensile stress-strain responses measured so far at room temperature for Fe₃Al elements from combustion operation are shown in [Figure 3.5-20](#). Responses measured at 1,400°F are shown in [Figure 3.5-21](#). All results are summarized in [Table 3.5-6](#). The strengths and strains-to-failure measured after operation in combustion for up to 2,780 hours were near the same as measured after gasification operation. All three of the Fe₃Al elements from combustion were in operation during at least one thermal transient. Element 034H-001, tested after 1,356 hours, was in operation during the TC03 event where a temperature increase of 320°F in 55 seconds was measured and 9 ceramic elements failed. Element 034H-004, tested after 1,424 hours, was in operation during TC04 when 6 ceramic elements (that is all ceramic elements except for IF&P REECER™) failed in a thermal transient. Element 034H-005, tested after 2,780 hours, was in operation during both of these thermal transients.

All room-temperature tensile strengths, axial and hoop, gasification, and combustion, are plotted versus hours in operation in [Figure 3.5-22](#). This plot illustrates that the strength after 2,750 hours in combustion operation was similar to the strength after much shorter operation times. Note that the strengths compared in [Figure 3.5-22](#) were measured on elements from different operating conditions, gasification (reducing) and combustion (oxidizing), and temperatures, 700 to 1,000°F for gasification and 1,350 to 1,450°F for combustion. The difference in operating environments and temperatures did not appear to affect the material properties, at least for the operating times tested so far.

3.5.2 Schumacher T10-20

Room-temperature hoop tensile strengths measured on Schumacher T10-20 element 323I178, removed after GCT3 with 183 hours in operation, are shown in [Table 3.5-7](#). An average strength of 1,230 psi was measured. Hoop tensile strengths measured on all Schumacher clay-bonded SiC elements tested so far, from combustion or gasification operation, are plotted versus

hours in operation in [Figure 3.5-23](#). The strength measured on this element was near the same as on other Schumacher clay-bonded SiC elements after operation.

3.5.3 Pall 326

Room-temperature hoop tensile strengths measured on Pall 326 element 1341-4, removed after GCT3 with 183 hours in operation, are shown in [Table 3.5-8](#). An average strength of 1,980 psi was measured including one specimen with a strength of only 1530 psi, ~25 percent lower than the other specimens. Hoop tensile strengths measured on all Pall 326 elements tested so far, from combustion or gasification operation, are plotted versus hours in operation in [Figure 3.5-24](#). Although there has been much variability in strengths measured so far, the values measured from this element are very near the average value. The low strength specimen could have resulted from local damage during the thermal transient; however, normal variability in strength on this material makes it impossible to determine if this low-strength value was because of variability or damage during the thermal transient.

3.5.4 Conclusions

Tensile strength measurements on Pall Fe₃Al elements from gasification operation at 700 to 1,000°F and combustion operation at 1,350 to 1,450°F indicated little or no strength decrease for at least up to 2,780 hours of operation. The strengths measured after operation were slightly lower than on virgin elements; however, because of the small number of elements tested so far, it is not possible to determine if this represents a slight strength decrease or element-to-element variability. The operating temperatures and environments within the range considered here did not appear to affect the properties measured. Thermal transients that have been encountered many times during operation at the PSDF, with a temperature increase of ~300°F measured during 1 minute, have not had an effect on the properties measured. However, exposure to temperatures above approximately 1,800°F, even for a short time during a thermal transient, may cause element failure. This is not surprising because the material was designed for operation below 1,470°F.

Internal pitting was seen on one element. The cause of the pitting is unknown. This element was water washed before testing and this must be considered as a possible cause of the pitting. Even if water washing was not the cause of the pitting, trace elements in the tap water used for washing may have collected and remained in pits, causing chemical and morphology changes. In the future, elements will not be water washed before testing.

The strengths of Schumacher T10-20 and Pall 326 tested after GCT03 were nearly the same as for other elements of these types tested after operation at the PSDF. The thermal transient experienced during this run did not cause any greater strength decrease than any previous runs. However, metal elements will be used for at least the next two gasification runs because similar thermal transients are possible and there is concern about cumulative damage caused by repeated transients.

Table 3.5-1

Filter Element Test Plan

Element Type	Run	Hours in Operation	Test Matrix
Pall Fe ₃ Al	GCT3	183	1
Pall Fe ₃ Al	GCT3 and 4	425	1
Pall Fe ₃ Al	GCT3 and 4 and TC06A	653	2
Pall 326	GCT3	183	2
Schumacher T10-20	GCT3	183	2
Pall Fe ₃ Al	Combustion	2,780	1

Table 3.5-2

Test Matrix 1

Test	Direction	Tests at	
		Room Temp.	1,400°F
Tension	Hoop	6	
Tension	Axial	3	3
Microstructure – microscopy, SEM,EDS, as req'd		Yes	

Note: Hoop tests not conducted on element 034H-005, 2,780 hours in combustion operation

Table 3.5-3

Test Matrix 2

Test	Direction	Tests at Room Temp
Tension	Hoop	6 (See Note)

Note: 3 tests for element 21076, 653 hours in gasification operation.

Table 3.5-4

Axial Tensile Results for Pall Fe₃Al Gasification Elements

Element	Specimen Number	Hours in Operation	Test Temperature (°F)	0.05% Yield Strength (psi)	Ultimate Strength (psi)	Young's Modulus (msi)	Strain-to-Failure (mils/in.)	Remarks
034H-002	Tn-Ax-1	virgin	RT ¹	13,400	20,200	5.26	10.1	
034H-002	Tn-Ax-3	virgin	RT	12,770	18,670	4.94	9.6	
034H-002	Tn-Ax-4	virgin	RT	12,160	18,400	5.38	9.0	
			Average	12,777	19,090	5.19	9.5	
034H-004	Tn-Ax-10	63	RT	11,390	17,770	5.63	10.5	Note 2
034H-004	Tn-Ax-12	63	RT	12,470	18,010	5.45	9.5	Note 2
034H-004	Tn-Ax-14	63	RT	11,460	17,950	5.70	10.1	Note 2
			Average	11,773	17,910	5.59	10.0	
27056	Tn-Ax-16	183	RT	12,190	12,680	5.69	2.9	Note 3
27056	Tn-Ax-18	183	RT	13,040	17,350	5.02	8.3	Note 3
27056	Tn-Ax-20	183	RT	12,440	12,440	5.92	2.6	Note 3
			Average	12,557		5.54		
27060	Tn-Ax-22	425	RT	12,800	16,250	5.47	5.8	Note 3
27060	Tn-Ax-24	425	RT	12,510	14,990	5.73	4.4	Note 3
27060	Tn-Ax-26	425	RT	12,700	16,800	5.71	6.7	Note 3
			Average	12,670	16,013	5.64	5.6	
034H-002	Tn-Ax-2	virgin	1,400	4,140	6,440	3.83	20	
034H-002	Tn-Ax-5	virgin	1,400	4,340	6,110	3.29	21	
			Average	4,240	6,275	3.56	20	
034H-004	Tn-Ax-11	63	1,400		5,200			Notes 2,4
034H-004	Tn-Ax-13	63	1,400	3,190	5,320	3.30	31	Note 2
034H-004	Tn-Ax-15	63	1,400	3,210	5,610	2.58	37	Note 2
			Average	3,200	5,377	2.94	34	
27056	Tn-Ax-17	183	1,400	3,330	5,250	2.29	24	Note 3
27056	Tn-Ax-19	183	1,400	3,250	5,320	2.53	34	Note 3
27056	Tn-Ax-21	183	1,400	3,250	5,850	2.79	43	Note 3
			Average	3,277	5,473	2.54	34	
27060	Tn-Ax-23	425	1,400	3,100	5,480	3.11	26	Note 3
27060	Tn-Ax-25	425	1,400	3,120	5,520	2.89	32	Note 3
27060	Tn-Ax-27	425	1,400	3,090	5,550	2.83	33	Note 3
			Average	3,103	5,517	2.94	30	

Notes:

1. RT = Room Temperature.
2. All operation at SCS - PSDF in gasification mode. Nominal operating temperature was 1,000°F.
3. All operation at SCS - PSDF in gasification mode. Nominal operating temperature was 700 - 800 °F.
4. Strain measurements were not obtained because the extensometers slipped during the test.

Table 3.5-5

Hoop Tensile Results for Pall Fe₃Al Gasification Elements

Element	Specimen Number	Hours in Operation	Maximum Hydrostatic Pressure (psig)	Ultimate Strength (psi)	Young's Modulus (msi)	Maximum Strain at O.D. ¹ (mils/in.)	Remarks
034H-002	Tn-Hoop-309	virgin	1,170	18,000	6.09	5.6	
034H-002	Tn-Hoop-310	virgin	1,150	17,590	7.29	4.9	
034H-002	Tn-Hoop-311	virgin	1,160	17,460	5.84	5.2	
034H-002	Tn-Hoop-312	virgin	1,110	17,100	5.96	4.9	
034H-002	Tn-Hoop-313	virgin	1,150	17,720	5.64	5.7	
034H-002	Tn-Hoop-314	virgin	1,060	16,580	5.78	4.7	
034H-002	Tn-Hoop-315	virgin	1,080	16,750	5.84	4.8	
Average			1,126	17,314	6.06	5.1	
Standard Deviation			40	483	0.52	0.37	
Coefficient of Variation (COV)			4%	3%	9%	7%	
39185	Tn-Hoop-399	virgin	1,180	15,970	4.86	5.2	
39185	Tn-Hoop-400	virgin	1,180	16,270	5.17	5.3	
39185	Tn-Hoop-401	virgin	1,160	15,980	5.29	4.4	
39185	Tn-Hoop-402	virgin	1,120	17,090	5.29	4.6	
39185	Tn-Hoop-403	virgin	1,080	16,510	5.27	4.5	
39185	Tn-Hoop-404	virgin	1,180	16,490	4.97	5.1	
Average			1,150	16,385	5.14	4.8	
Standard Deviation			38	381	0.17	0.37	
Coefficient of Variation (COV)			3%	2%	3%	8%	
034H-004	Tn-Hoop-342	63	1,100	16,700	5.34	6.0	See Note 2
034H-004	Tn-Hoop-343	63	1,120	16,800	5.59	6.3	See Note 2
034H-004	Tn-Hoop-344	63	1,090	16,210	5.46	5.5	See Note 2
034H-004	Tn-Hoop-345	63	1,070	17,190	5.72	6.8	See Note 2
034H-004	Tn-Hoop-346	63	1,180	17,680	5.74	7.6	See Note 2
034H-004	Tn-Hoop-347	63	1,140	17,220	5.70	6.5	See Note 2
Average			1,117	16,967	5.59	6.4	
Standard Deviation			36	464	0.15	0.66	
Coefficient of Variation (COV)			3%	3%	3%	10%	
27056	Tn-Hoop-348	183	1,170	15,050	4.97	5.5	See Note 3
27056	Tn-Hoop-349	183	1,160	15,230	5.00	5.4	See Note 3
27056	Tn-Hoop-350	183	1,210	16,840	5.17	6.7	See Note 3
27056	Tn-Hoop-351	183	1,230	16,470	4.88	6.8	See Note 3
27056	Tn-Hoop-352	183	1,090	14,840	4.70	4.6	See Note 3
27056	Tn-Hoop-353	183	1,080	14,620	4.97	4.1	See Note 3
Average			1,157	15,508	4.95	5.5	
Standard Deviation			56	839	0.14	0.98	
Coefficient of Variation (COV)			5%	5%	3%	18%	
27060	Tn-Hoop-354	425	1,200	15,470	4.99	5.4	See Note 3
27060	Tn-Hoop-355	425	1,210	16,530	5.37	5.4	See Note 3
27060	Tn-Hoop-356	425	1,150	15,750	5.13	4.6	See Note 3
27060	Tn-Hoop-357	425	1,170	15,810	5.21	4.7	See Note 3
27060	Tn-Hoop-358	425	1,060	15,440	5.05	4.7	See Note 3
27060	Tn-Hoop-359	425	1,140	16,100	5.15	5.3	See Note 3
Average			1,155	15,850	5.15	5.0	
Standard Deviation			49	376	0.12	0.36	
Coefficient of Variation (COV)			4%	2%	2%	7%	
21076	Tn-Hoop-366	653	1,160	15,130	5.16	6.0	See Notes 3,4
21076	Tn-Hoop-367	653	1,150	15,300	5.25	5.9	See Notes 3,4
21076	Tn-Hoop-368	653	960	12,570	5.00	3.2	See Notes 3,4
Average			1,090	14,333	5.14	5.1	
Standard Deviation			92	1,249	0.10	1.28	
Coefficient of Variation (COV)			8%	9%	2%	25%	

Notes:

1. This value does not represent the strain-to-failure. The strain was measured at the outside surface but for this test, the maximum stress occurs at the inside surface.
2. All operation was in gasification mode at a nominal temperature of 1,000°F.
3. All operation was in gasification mode at a nominal temperature of 700°F.
4. Element exposed to much higher temperature during TC06A fire.

Table 3.5-6

Axial Tensile Results for Pall Fe₃Al Combustion Elements

Candle	Specimen Number	Hours in Operation	Test Temperature (°F)	0.05% Yield Strength (psi)	Ultimate Strength (psi)	Young's Modulus (msi)	Strain-to-Failure (mils/in.)	Remarks
034H-002	Tn-Ax-1	virgin	RT	13,400	20,200	5.26	10.1	
034H-002	Tn-Ax-3	virgin	RT	12,770	18,670	4.94	9.6	
034H-002	Tn-Ax-4	virgin	RT	12,160	18,400	5.38	9.0	
			Average	12,777	19,090	5.19	9.5	
034H-001	Tn-Ax-6	1356	RT	10,820	15,680	5.36	6.71	Note 2
034H-001	Tn-Ax-7	1356	RT	10,920	15,100	5.36	5.76	Note 2
034H-001	Tn-Ax-8	1356	RT	11,040	16,440	5.28	8.32	Note 2
034H-001	Tn-Ax-9	1356	RT	11,570	16,950	4.89	8.45	Note 2
			Average	11,088	16,043	5.22	7.31	
034H-005	Tn-Ax-29	2780	RT	12,450	16,000	5.93	5.1	Note 2
034H-005	Tn-Ax-32	2780	RT	12,560	16,490	6.1	5.3	Note 2
034H-005	Tn-Ax-33	2780	RT	12,450	16,530	5.45	6.1	Note 2
			Average	12,487	16,340	5.83	5.5	
034H-002	Tn-Ax-2	virgin	1,400	4,140	6,440	3.83	20.0	
034H-002	Tn-Ax-5	virgin	1,400	4,340	6,110	3.29	21.0	
			Average	4,240	6,275	3.56		
034H-005	Tn-Ax-28	2780	1,400	3,470	5,650	2.61	26	Note 2
034H-005	Tn-Ax-30	2780	1,400	3,990	5,650	2.58	20	Note 2
034H-005	Tn-Ax-31	2780	1,400	3,950	5,410	2.78	17	Note 2
			Average	3,803	5,570	2.66	21	

Notes:

1. RT = Room Temperature.
2. All operation at SCS - PSDF in combustion mode. Nominal operating temperature was 1,350 to 1,450°F.

Table 3.5-7

Hoop Tensile Results for Schumacher T10-20 and TF20 Gasification Elements

Element	Specimen Number	Hours in Operation	Maximum Hydrostatic Pressure (psig)	Ultimate Strength (psi)	Remarks
323I178	Tn-Hoop-467	183	500	1,210	Notes 1,3
323I178	Tn-Hoop-468	183	520	1,320	Notes 1,3
323I178	Tn-Hoop-469	183	510	1,280	Notes 1,3
323I178	Tn-Hoop-470	183	470	1,210	Notes 1,3
323I178	Tn-Hoop-471	183	480	1,240	Notes 1,3
323I178	Tn-Hoop-472	183	430	1,100	Notes 1,3
Average			485	1,227	
Standard Deviation			30	69	
COV			6%	6%	
335I297	Tn-Hoop-425	218	530	1,270	Note 1
335I297	Tn-Hoop-426	218	530	1,290	Note 1
335I297	Tn-Hoop-427	218	460	1,160	Note 1
335I297	Tn-Hoop-428	218	460	1,160	Note 1
335I297	Tn-Hoop-429	218	470	1,220	Note 1
335I297	Tn-Hoop-430	218	460	1,180	Note 1
Average			485	1,213	
Standard Deviation			32	52	
COV			7%	4%	
326I121	Tn-Hoop-431	218	560	1,370	Note 1
326I121	Tn-Hoop-432	218	510	1,270	Note 1
326I121	Tn-Hoop-433	218	470	1,210	Note 1
326I121	Tn-Hoop-434	218	480	1,220	Note 1
326I121	Tn-Hoop-435	218	520	1,360	Note 1
326I121	Tn-Hoop-436	218	460	1,190	Note 1
Average			500	1,270	
Standard Deviation			34	71	
COV			7%	6%	
326I126	Tn-Hoop-455	218	510	1,230	Notes 1,2
326I126	Tn-Hoop-456	218	490	1,200	Notes 1,2
326I126	Tn-Hoop-457	218	430	1,090	Notes 1,2
326I126	Tn-Hoop-458	218	440	1,120	Notes 1,2
326I126	Tn-Hoop-459	218	410	1,050	Notes 1,2
326I126	Tn-Hoop-460	218	420	1,070	Notes 1,2
Average			450	1,127	
Standard Deviation			37	66	
COV			8%	6%	

Notes:

1. All operation at SCS - PSDF in gasification mode at a nominal operating temperature of 700 to 1,000°F.
2. Element went through cleaning process at Southern Metals Processing.
3. In operation during thermal transient.

Table 3.5-8

Hoop Tensile Results for Pall 326 Gasification Elements

Element	Specimen Number	Hours in Operation	Maximum Hydrostatic Pressure (psig)	Ultimate Strength (psi)	Remarks
1341-4	Tn-Hoop-473	183	830	2,070	Notes 2,3
1341-4	Tn-Hoop-474	183	839	2,120	Notes 2,3
1341-4	Tn-Hoop-475	183	810	2,070	Notes 2,3
1341-4	Tn-Hoop-476	183	590	1,530	Notes 2,3
1341-4	Tn-Hoop-477	183	800	2,060	Notes 2,3
1341-4	Tn-Hoop-478	183	780	2,030	Notes 2,3
Average			775	1,980	
Standard Deviation			85	203	
COV			11.0%	10.3%	
1322-2	Tn-Hoop-407	218	820	2,070	Note 2
1322-2	Tn-Hoop-408	218	840	2,120	Note 2
1322-2	Tn-Hoop-409	218	820	2,100	Note 2
1322-2	Tn-Hoop-410	218	810	2,080	Note 2
1322-2	Tn-Hoop-411	218	760	2,050	Note 2
1322-2	Tn-Hoop-412	218	740	2,010	Note 2
Average			798	2,072	
Standard Deviation			36	35	
COV			4.5%	1.7%	
1316-6	Tn-Hoop-413	218	870	2,190	Note 2
1316-6	Tn-Hoop-414	218	850	2,150	Note 2
1316-6	Tn-Hoop-415	218	790	2,030	Note 2
1316-6	Tn-Hoop-416	218	770	1,990	Note 2
1316-6	Tn-Hoop-417	218	800	2,140	Note 2
1316-6	Tn-Hoop-418	218	790	2,120	Note 2
Average			812	2,103	
Standard Deviation			36	70	
COV			4.4%	3.3%	
1339-5	Tn-Hoop-449	218	910	2,270	Notes 1,2
1339-5	Tn-Hoop-450	218	1,000	2,510	Notes 1,2
1339-5	Tn-Hoop-451	218	900	2,300	Notes 1,2
1339-5	Tn-Hoop-452	218	920	2,360	Notes 1,2
1339-5	Tn-Hoop-453	218	920	2,450	Notes 1,2
1339-5	Tn-Hoop-454	218	890	2,410	Notes 1,2
Average			923	2,383	
Standard Deviation			36	83	
COV			3.9%	3.5%	

Notes:

1. Element went through cleaning process at Southern Metals Processing.
2. All operation at SCS - PSDF in gasification mode at a nominal operating temperature of 700 to 1,000°F.
3. In operation during thermal transient.

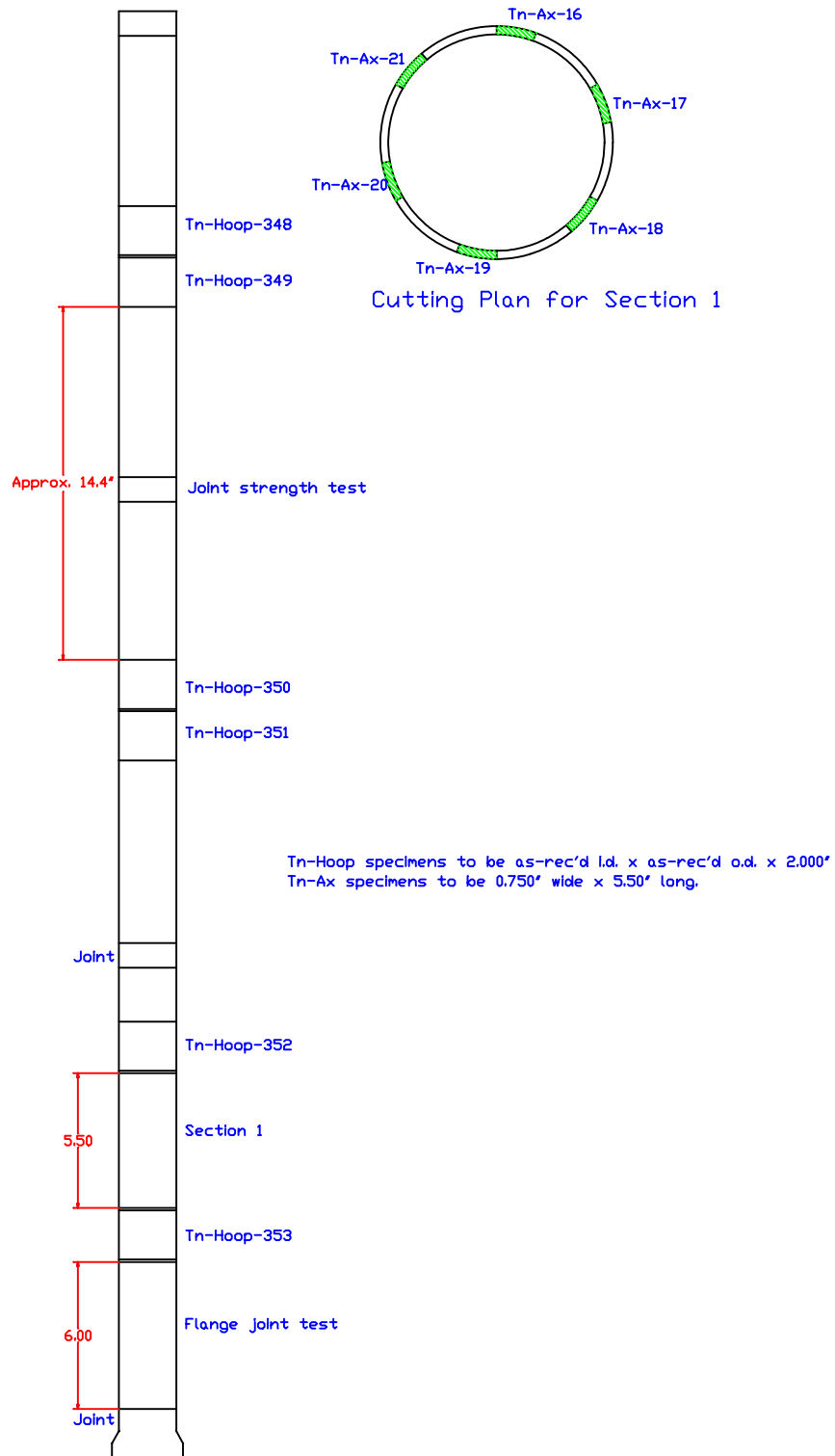


Figure 3.5-1 Cutting Plan for Pall Fe₃Al Element 27056

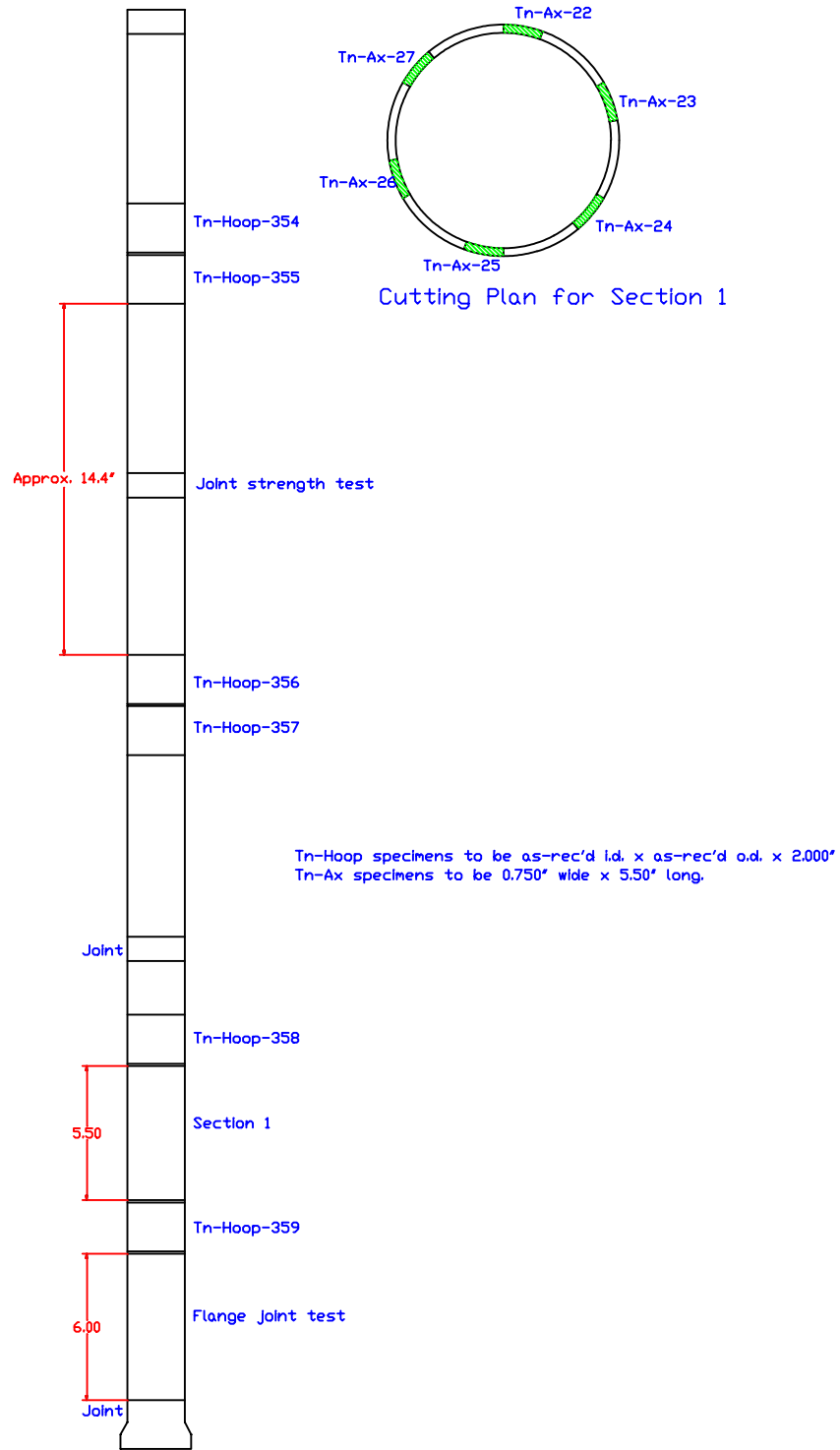


Figure 3.5-2 Cutting Plan for Pall Fe₃Al Element 27060

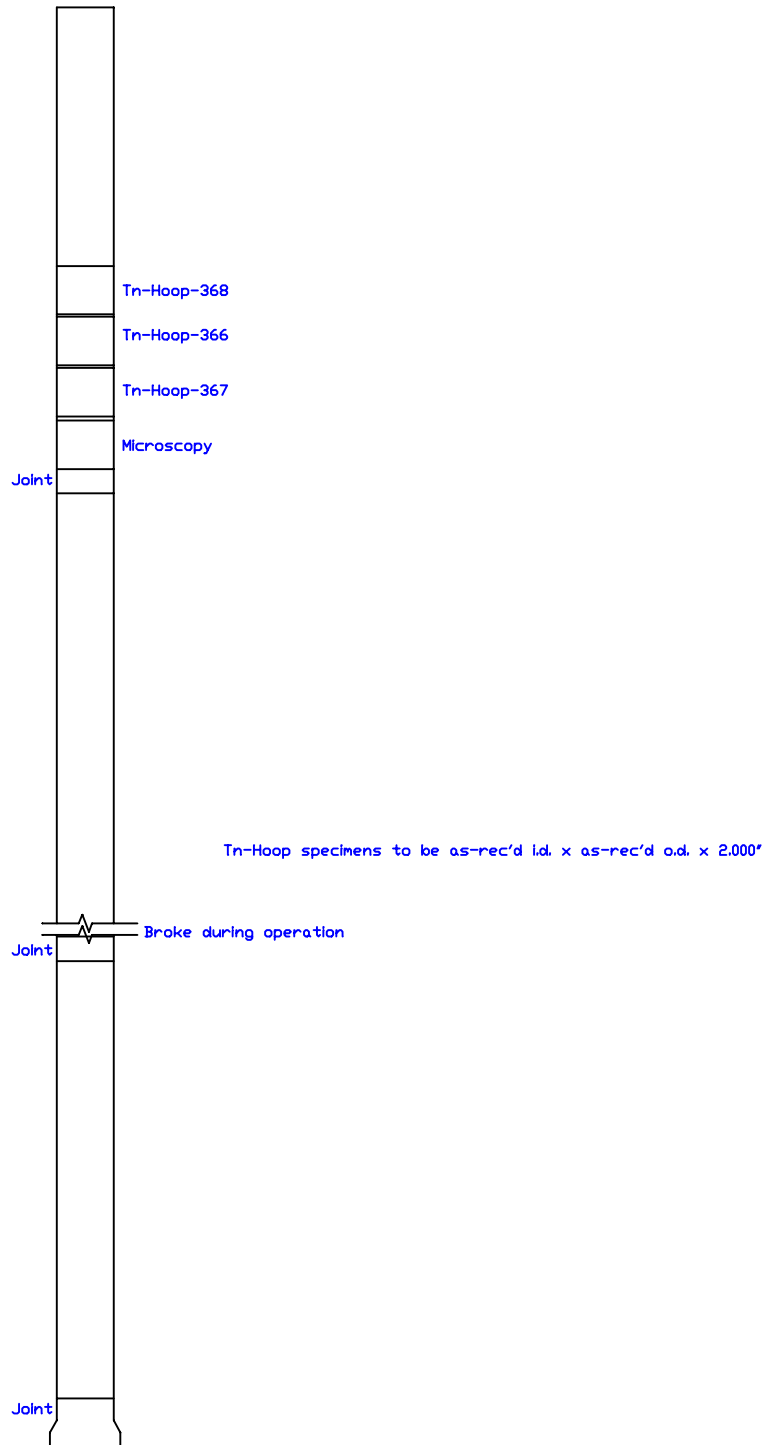


Figure 3.5-3 Cutting Plan for Pall Fe₃Al Element 21076

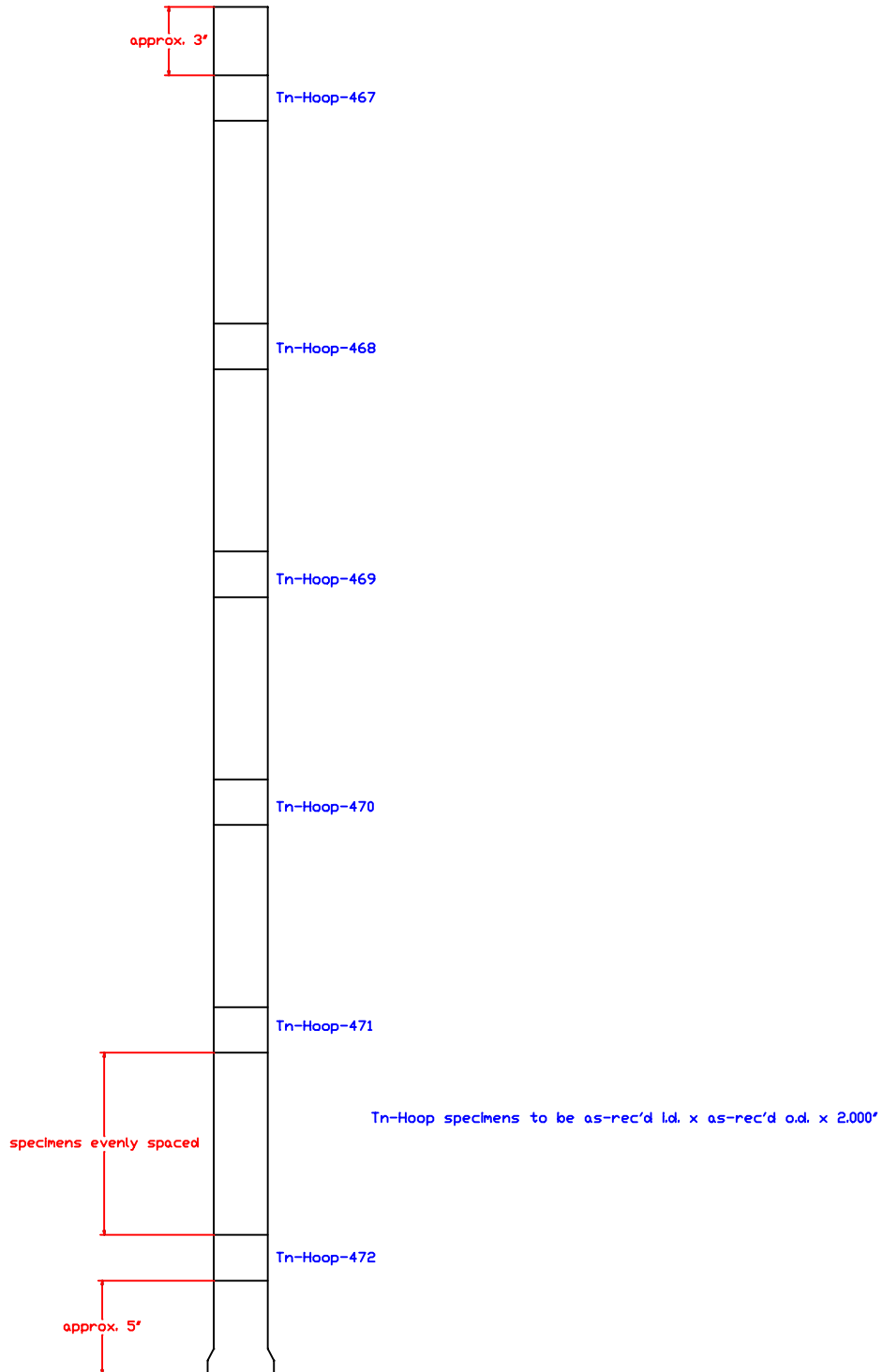


Figure 3.5-4 Cutting Plan for Schumacher T10-20 Element 3231178

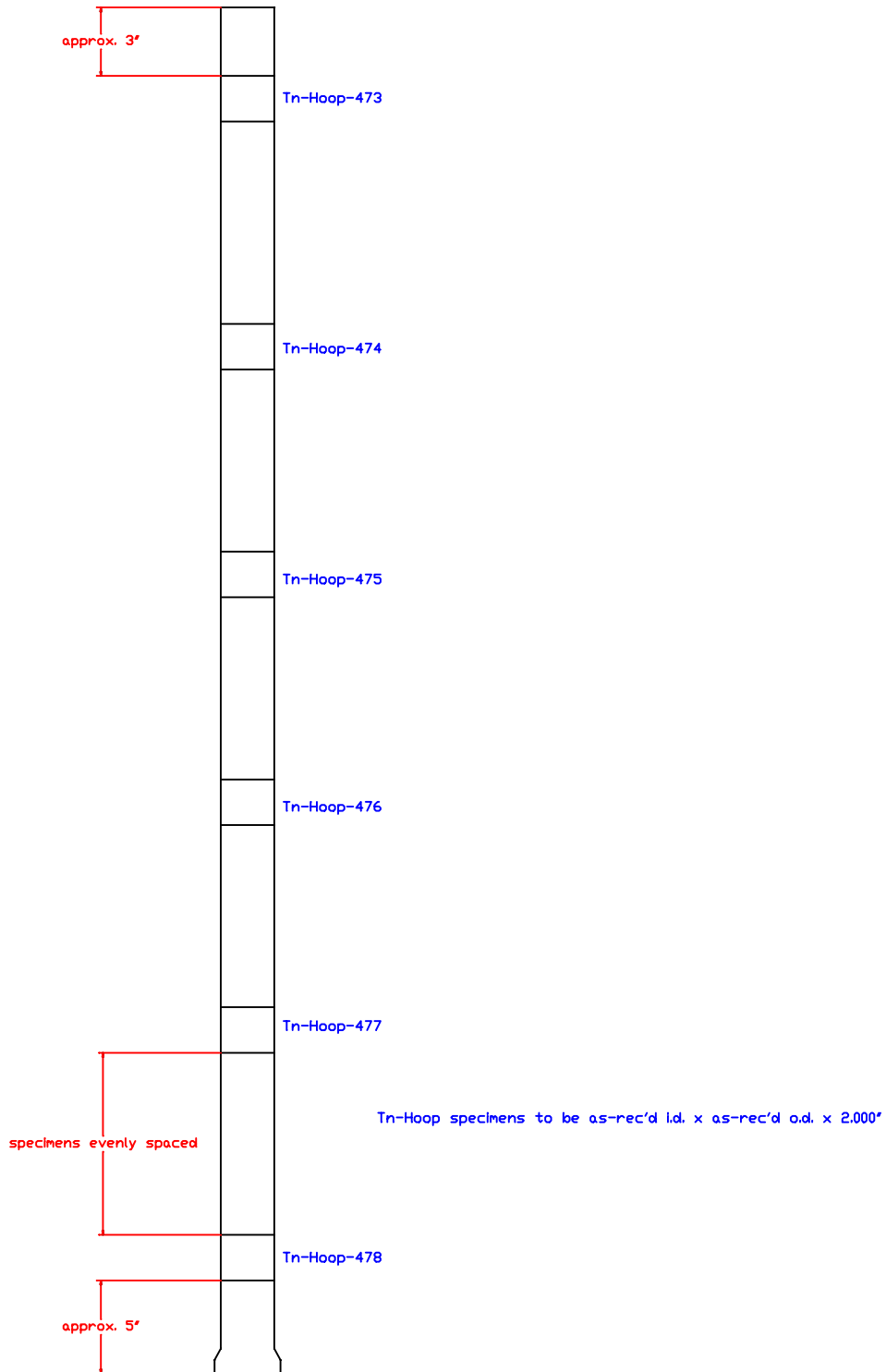


Figure 3.5-5 Cutting Plan for Pall 326 Element 1341-4

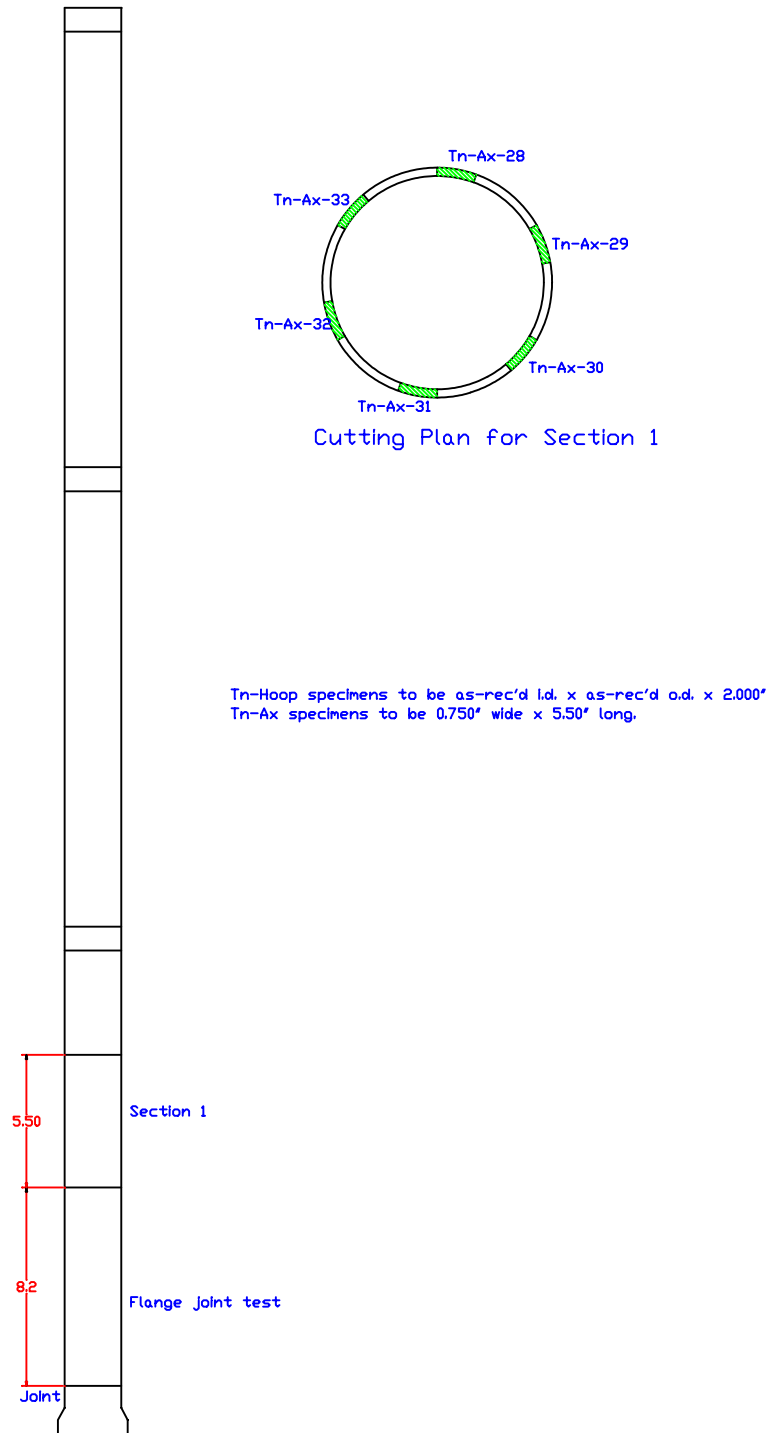


Figure 3.5-6 Cutting Plan for Pall Fe₃Al Element 034H-005

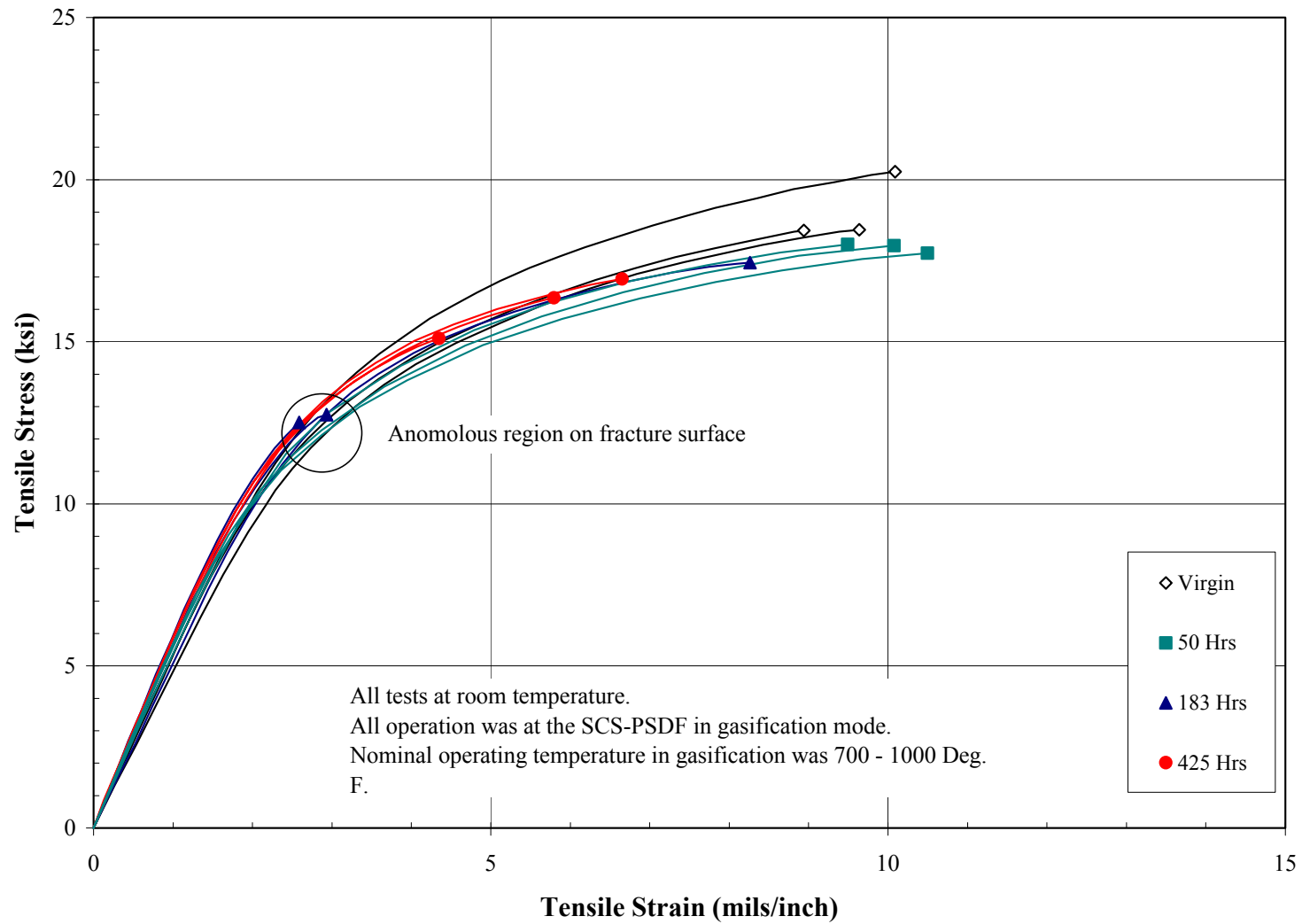


Figure 3.5-7 Axial Tensile Stress-Strain Responses for Pall Fe₃Al at Room Temperature

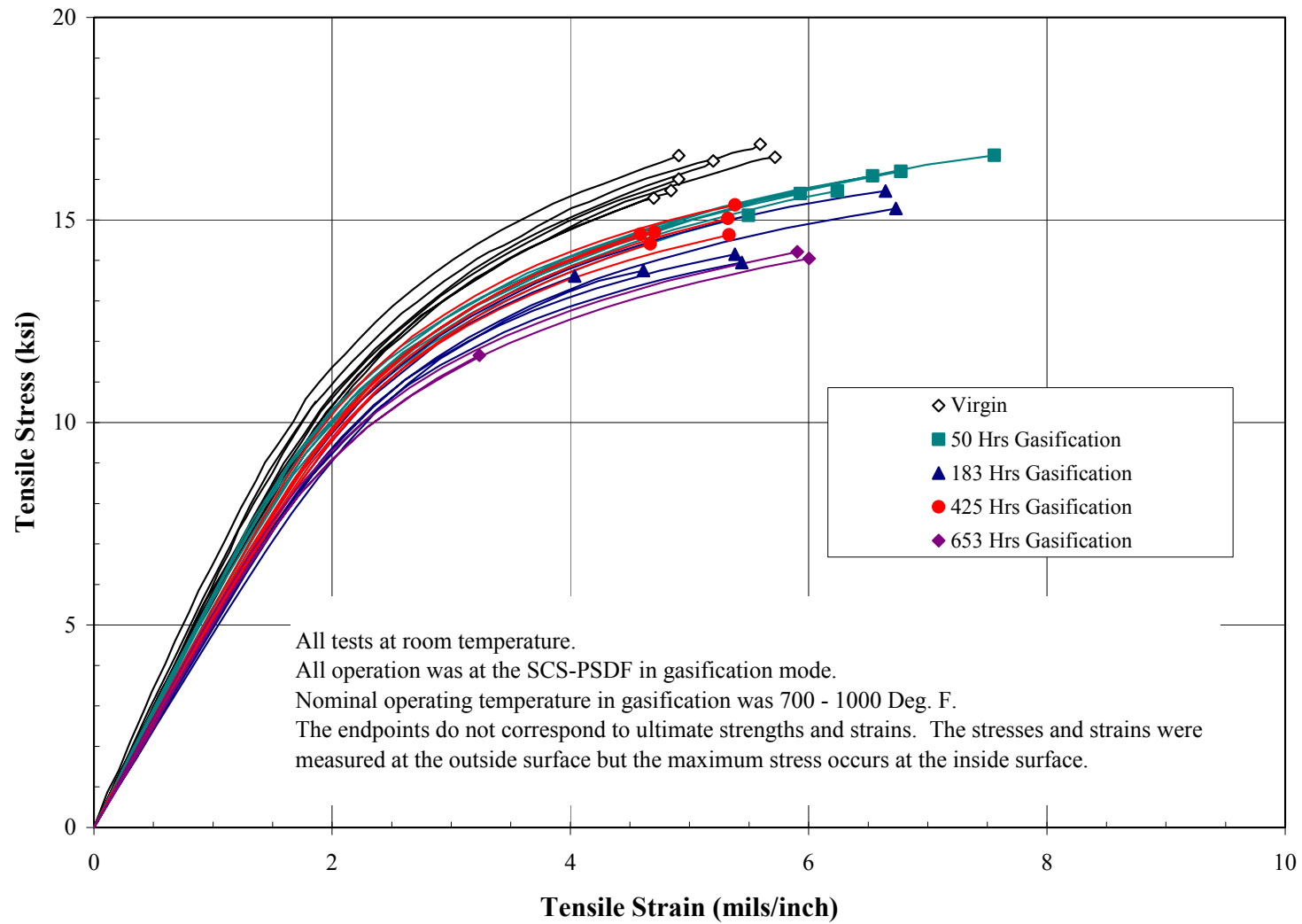


Figure 3.5-8 Hoop Tensile Stress-Strain Responses for Pall Fe₃Al at Room Temperature

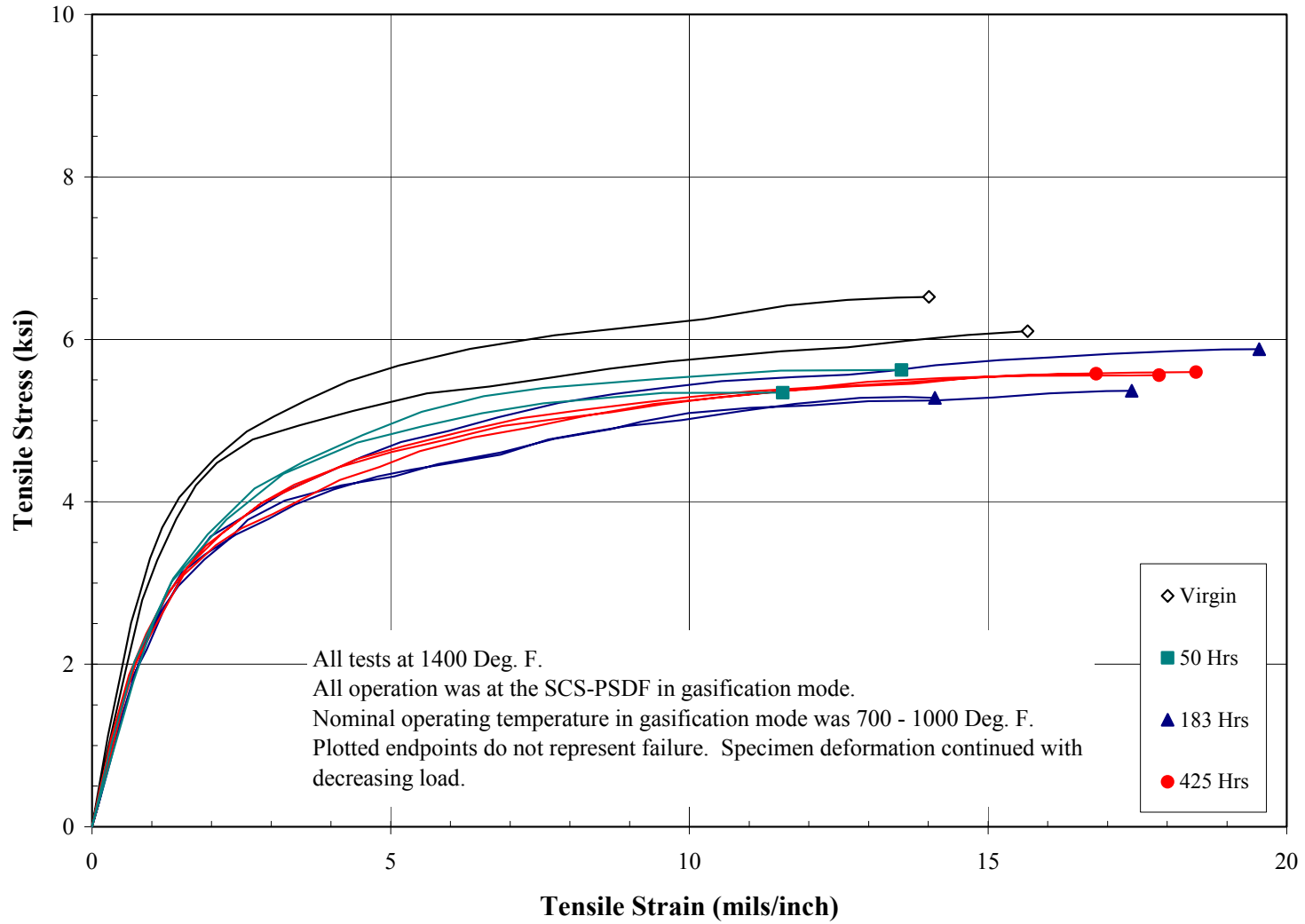


Figure 3.5-9 Axial Tensile Stress-Strain Responses for Pall Fe₃Al at 1,400°F

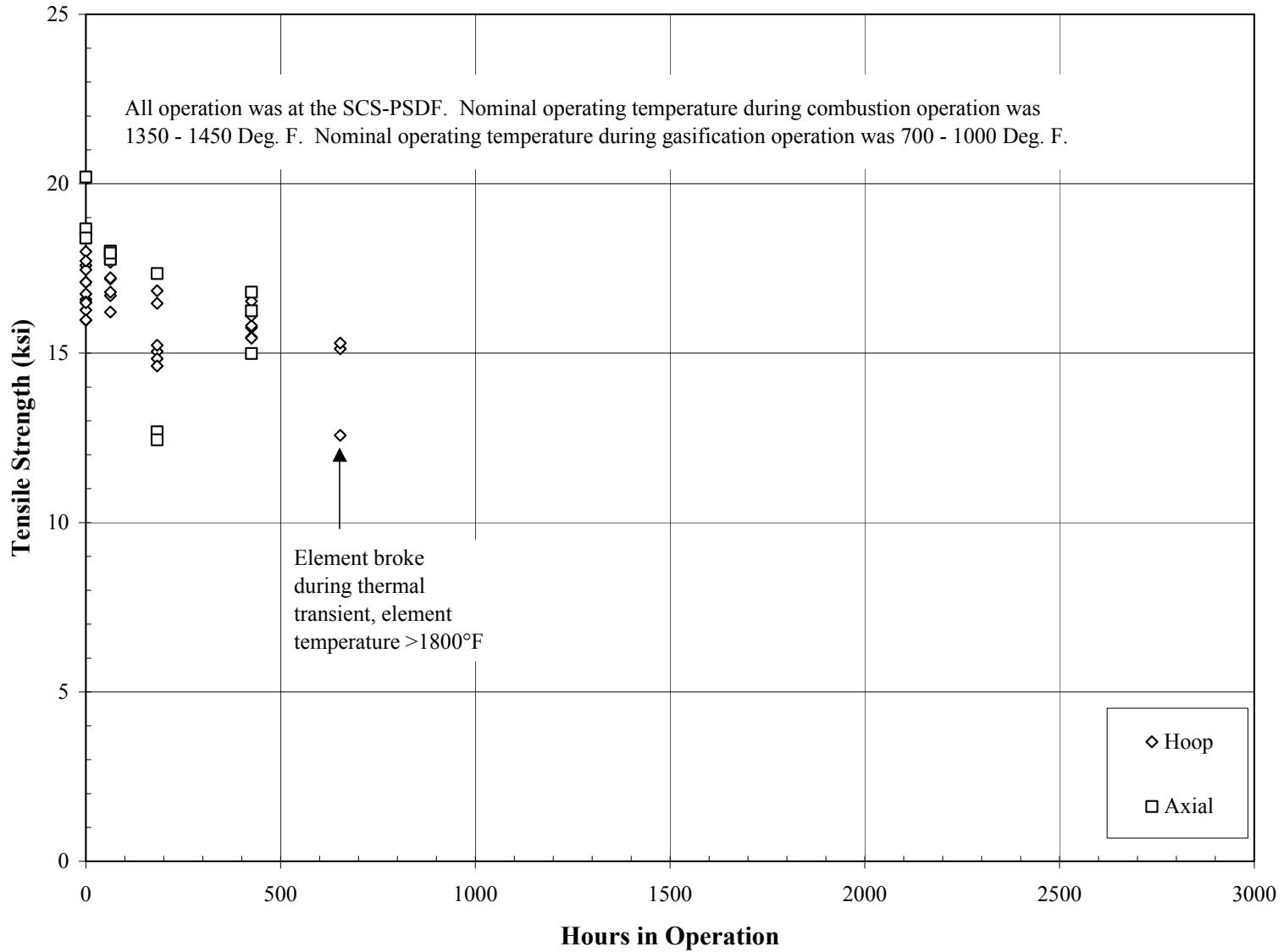


Figure 3.5-10 Tensile Strength of Pall Fe₃Al

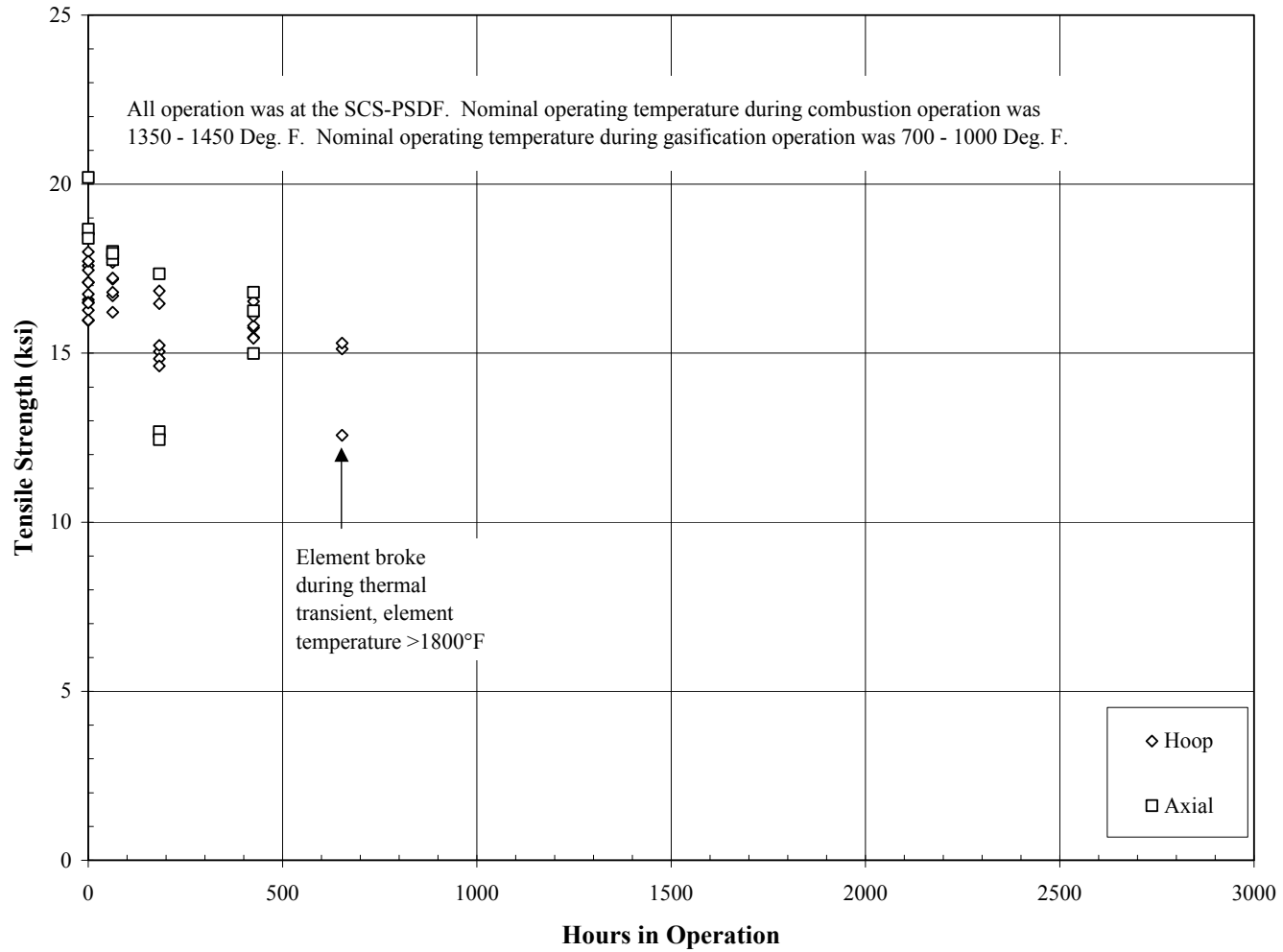


Figure 3.5-11 Failed Fe₃Al Tensile Specimen From Element 21076

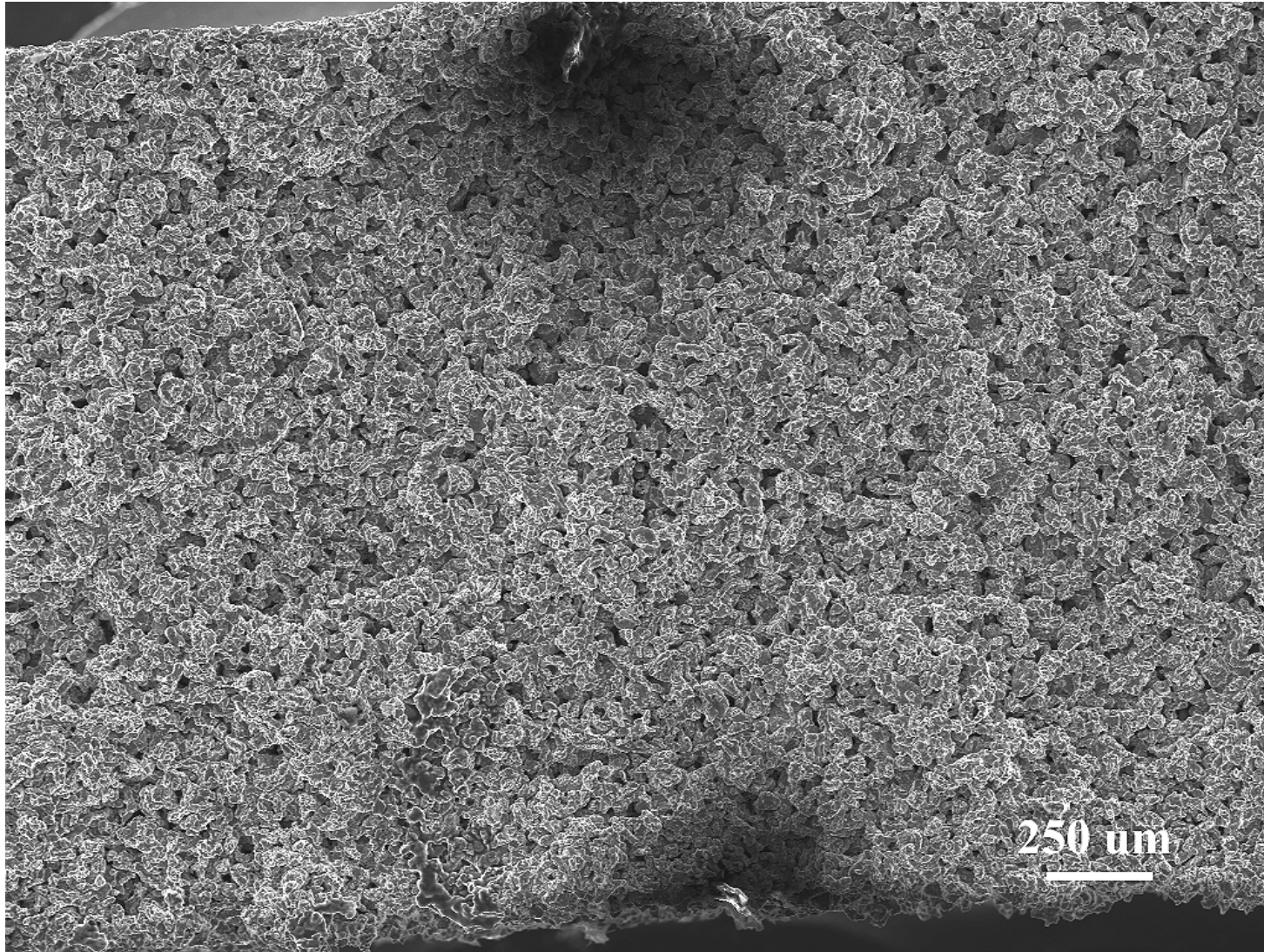


Figure 3.5-12 Fracture Surface of Fe₃Al Tensile Specimen Tn-Ax-16 – Location 1

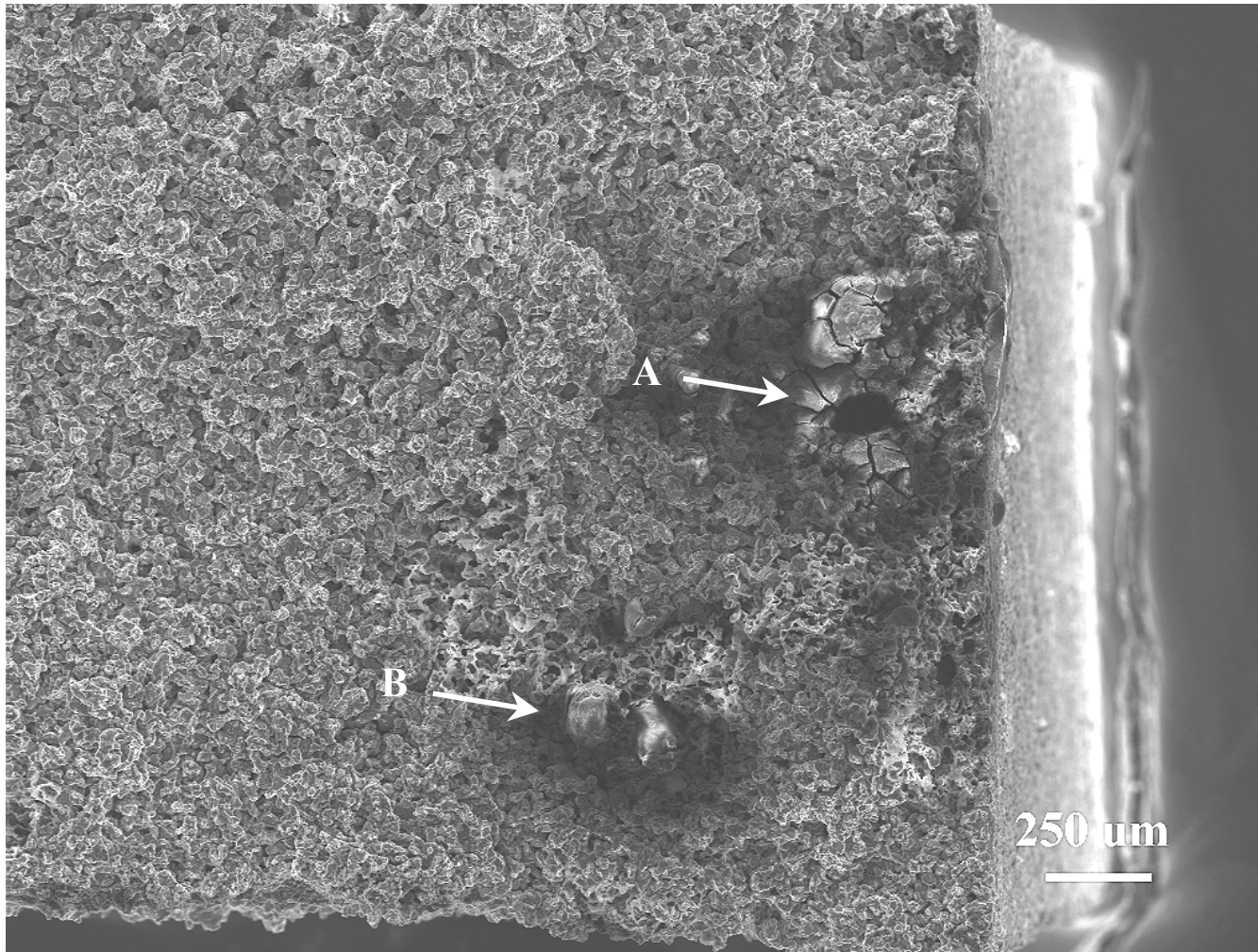


Figure 3.5-13 Fracture Surface of Fe₃Al Tensile Specimen Tn-Ax-16 – Location 2

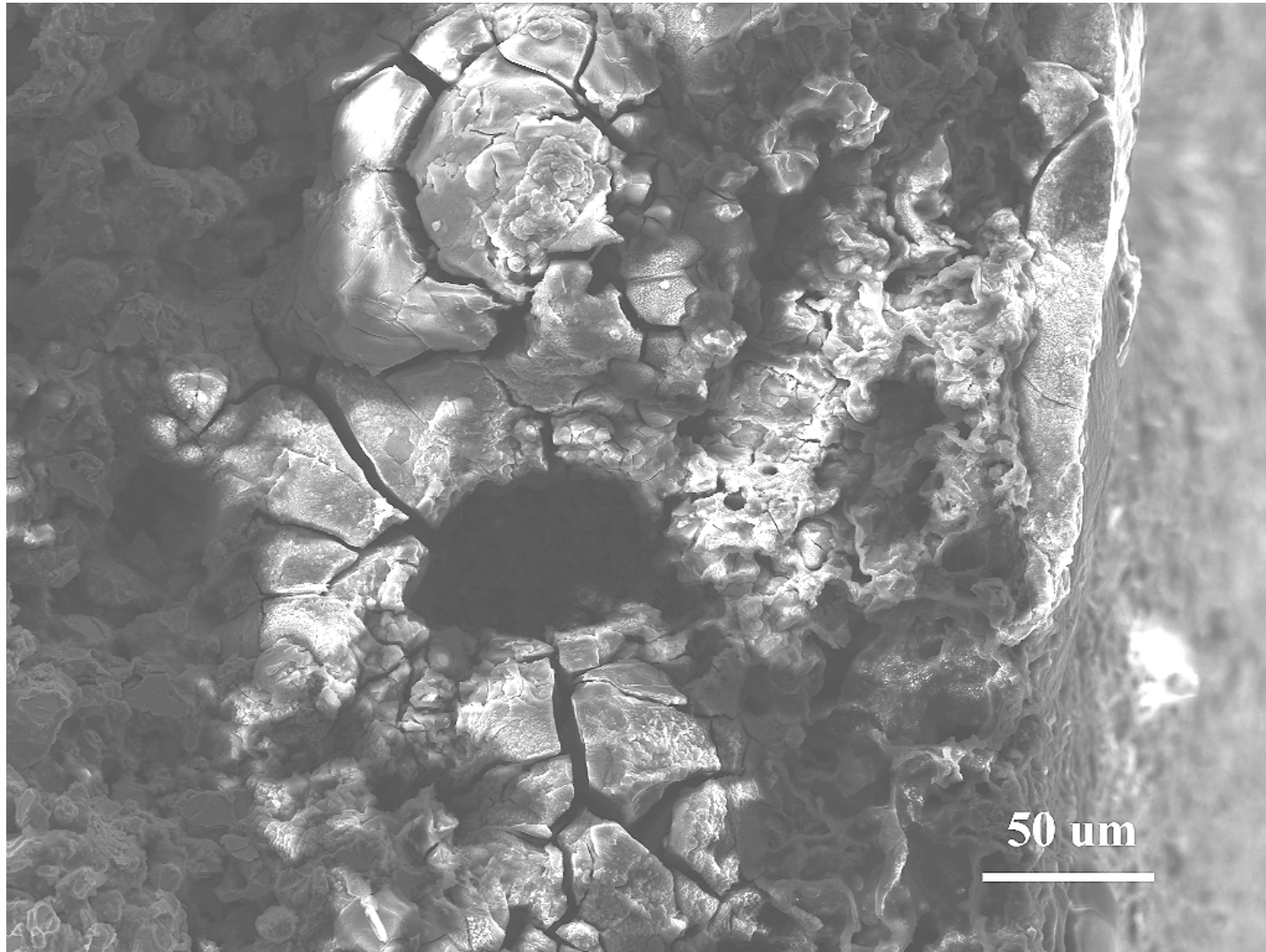


Figure 3.5-14 Area "A" of Location 2 - Fe₃Al Tensile Specimen Tn-Ax-16

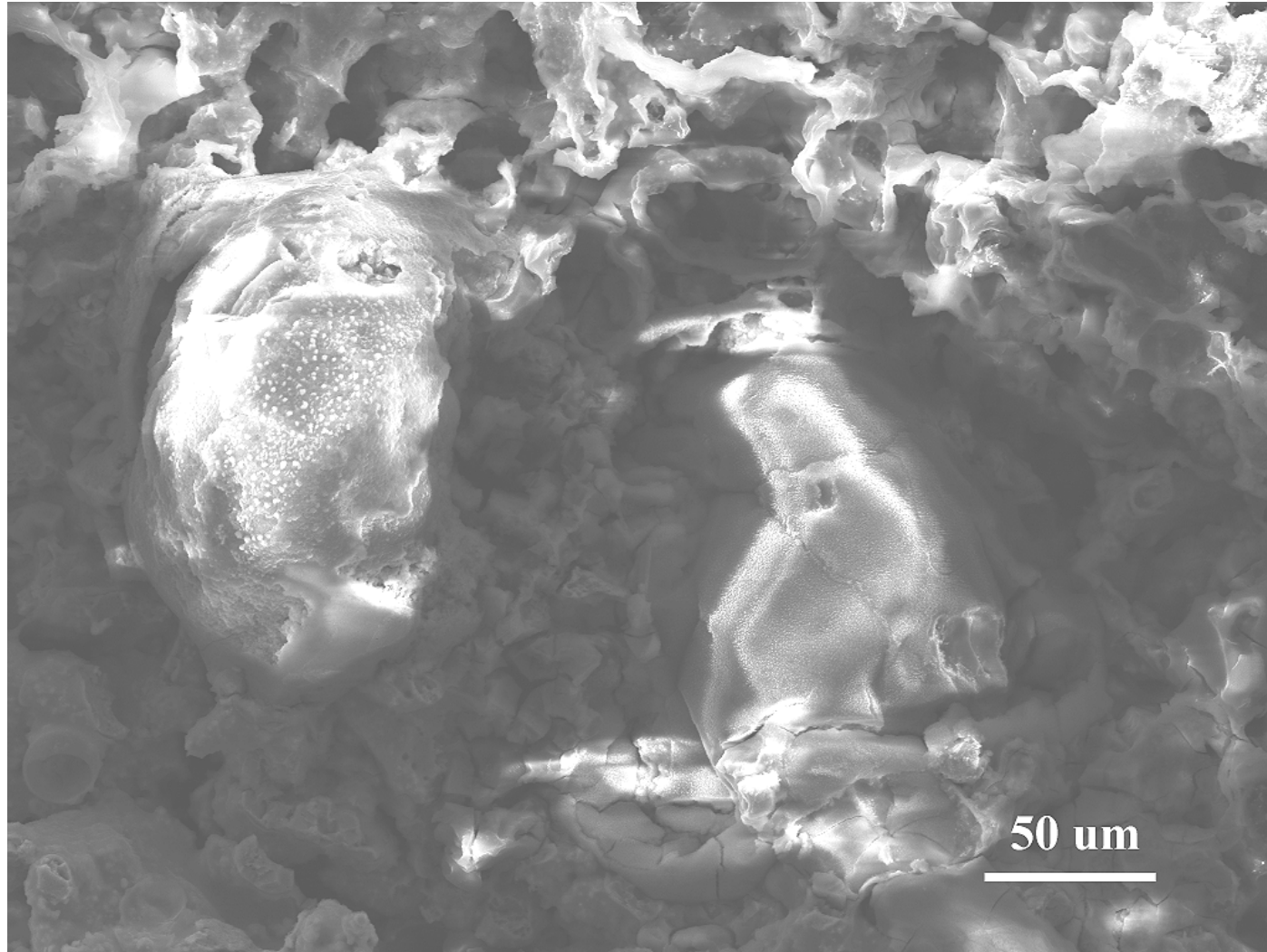


Figure 3.5-15 Area "B" of Location 2 - Fe₃Al Tensile Specimen Tn-Ax-16

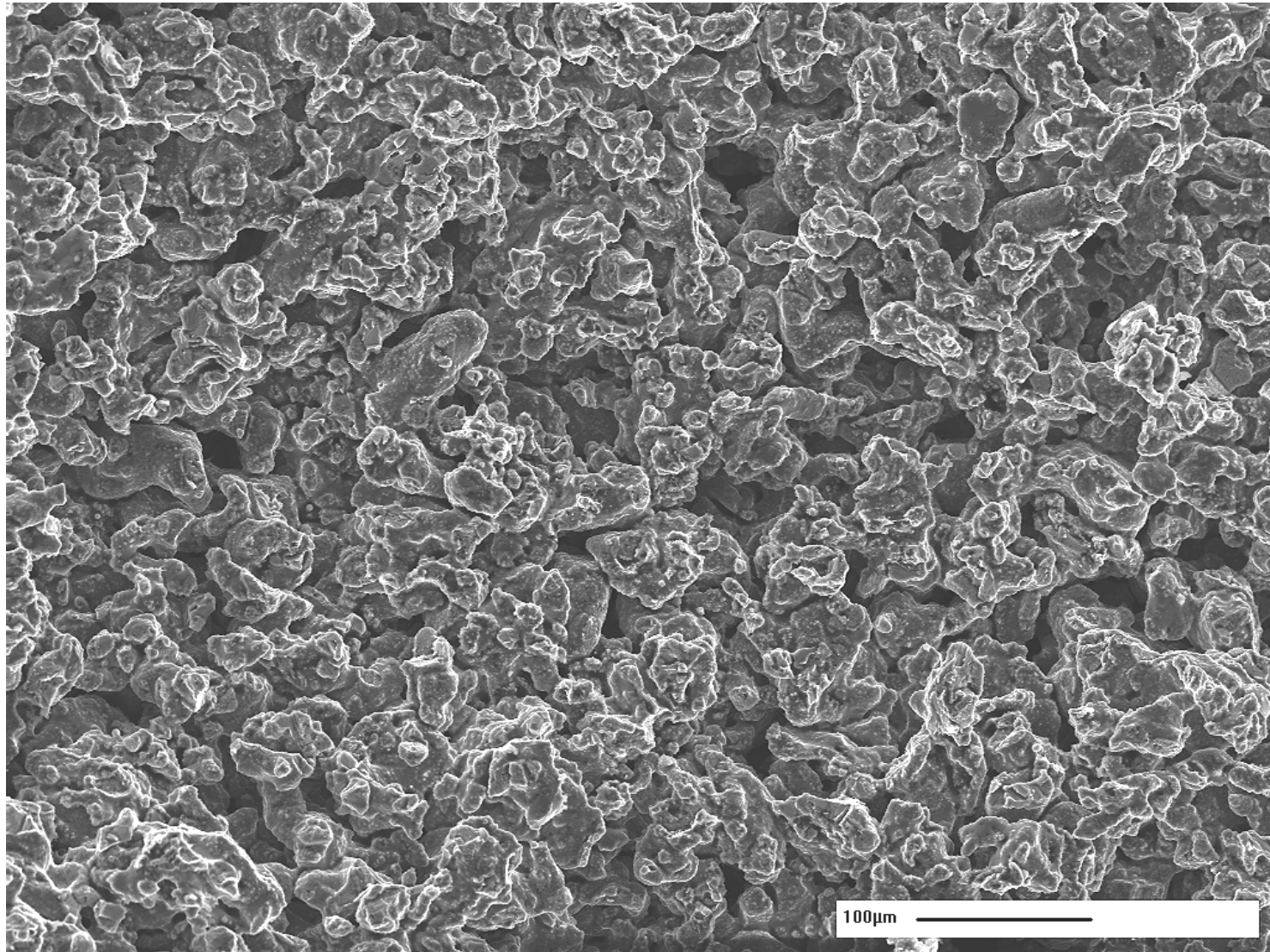


Figure 3.5-16 Fracture Surface of Fe₃Al Tensile Specimen Tn-Ax-22

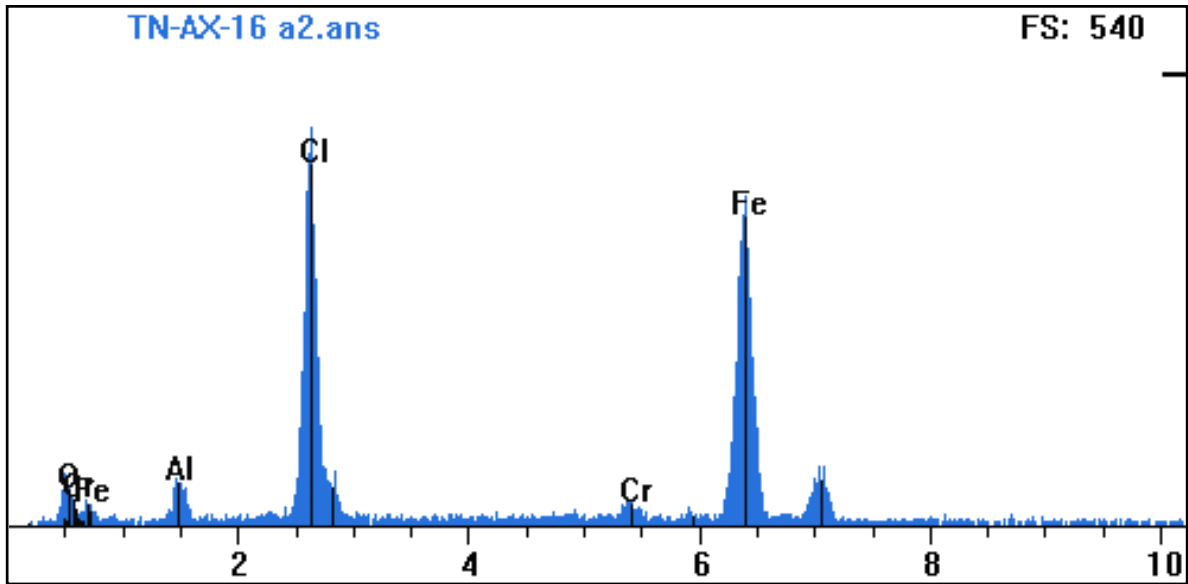


Figure 3.5-17 EDS Spectrum From Area "A" of Location 2 - Fe₃Al Tensile Specimen Tn-Ax-16

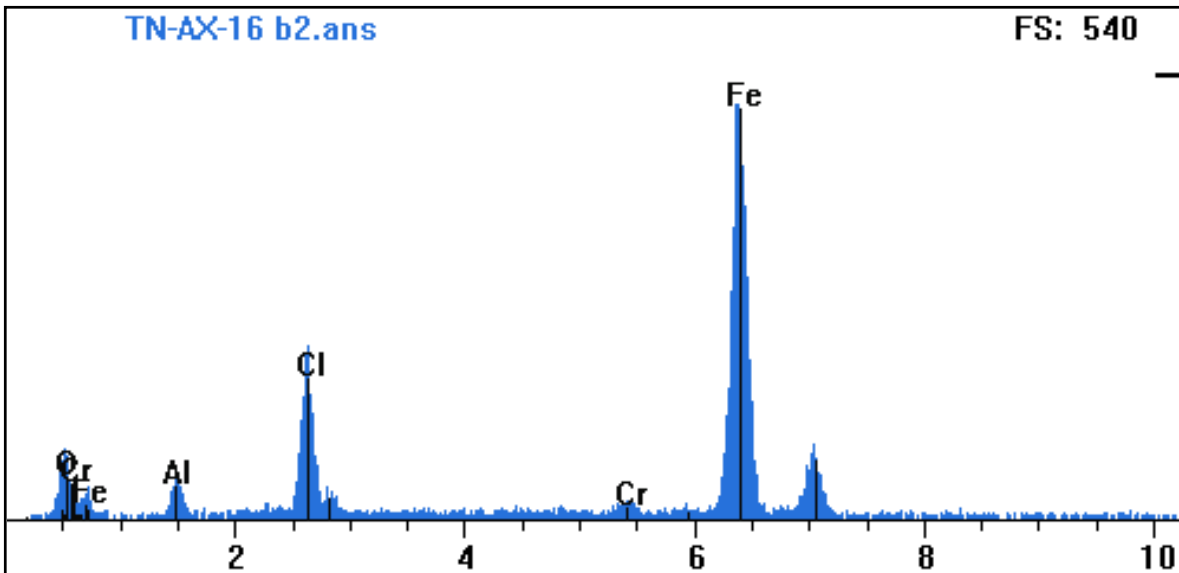


Figure 3.5-18 EDS Spectrum From Area "B" of Location 2 - Fe₃Al Tensile Specimen Tn-Ax-16

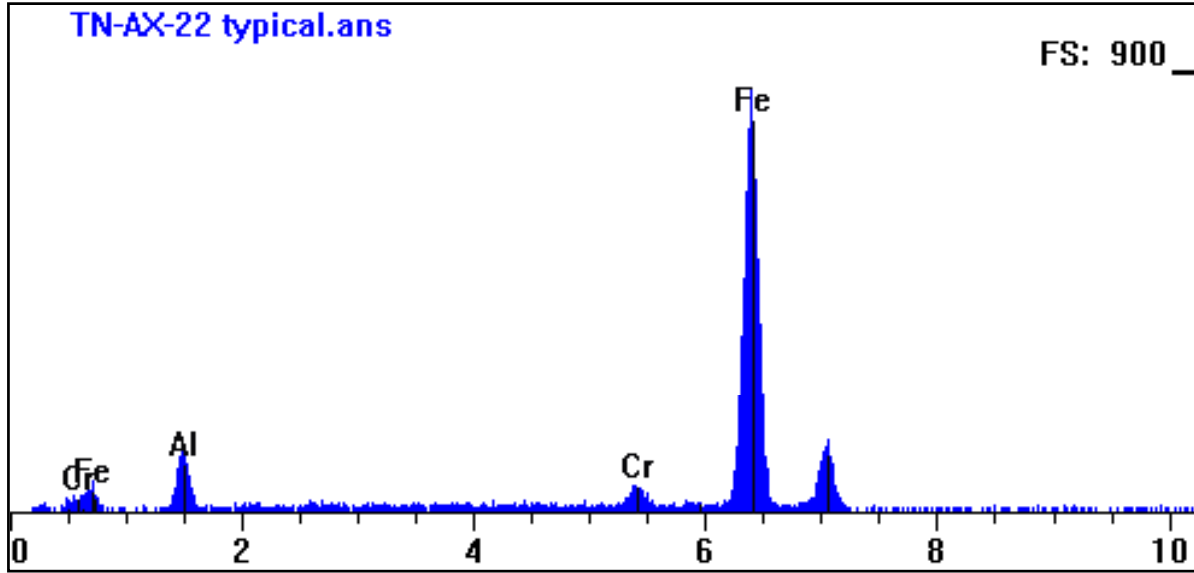


Figure 3.5-19 EDS Spectrum From Fe₃Al Tensile Specimen Tn-Ax-22

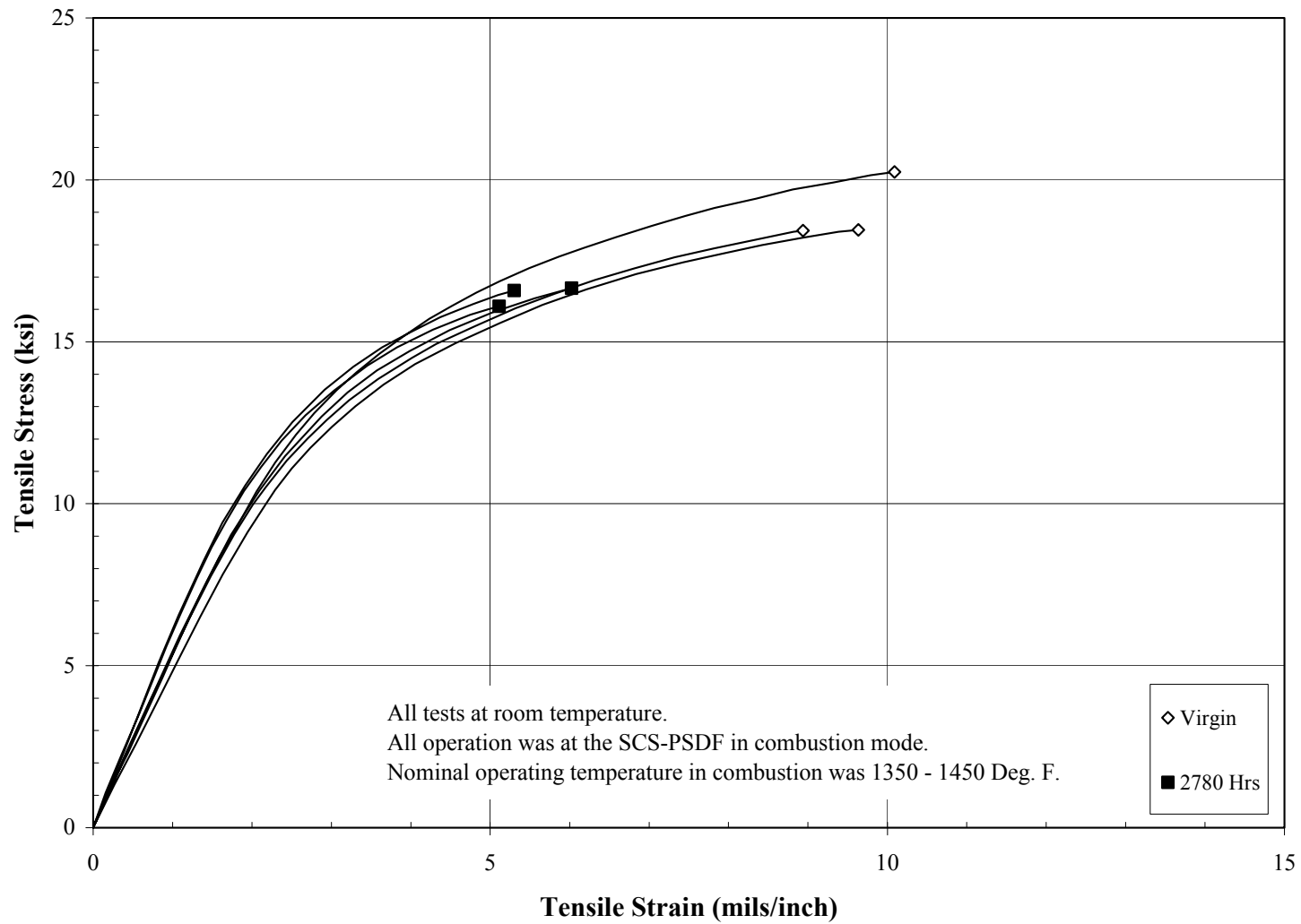


Figure 3.5-20 Axial Tensile Stress-Strain Responses at Room Temperature for Pall Fe₃Al After Combustion Operation

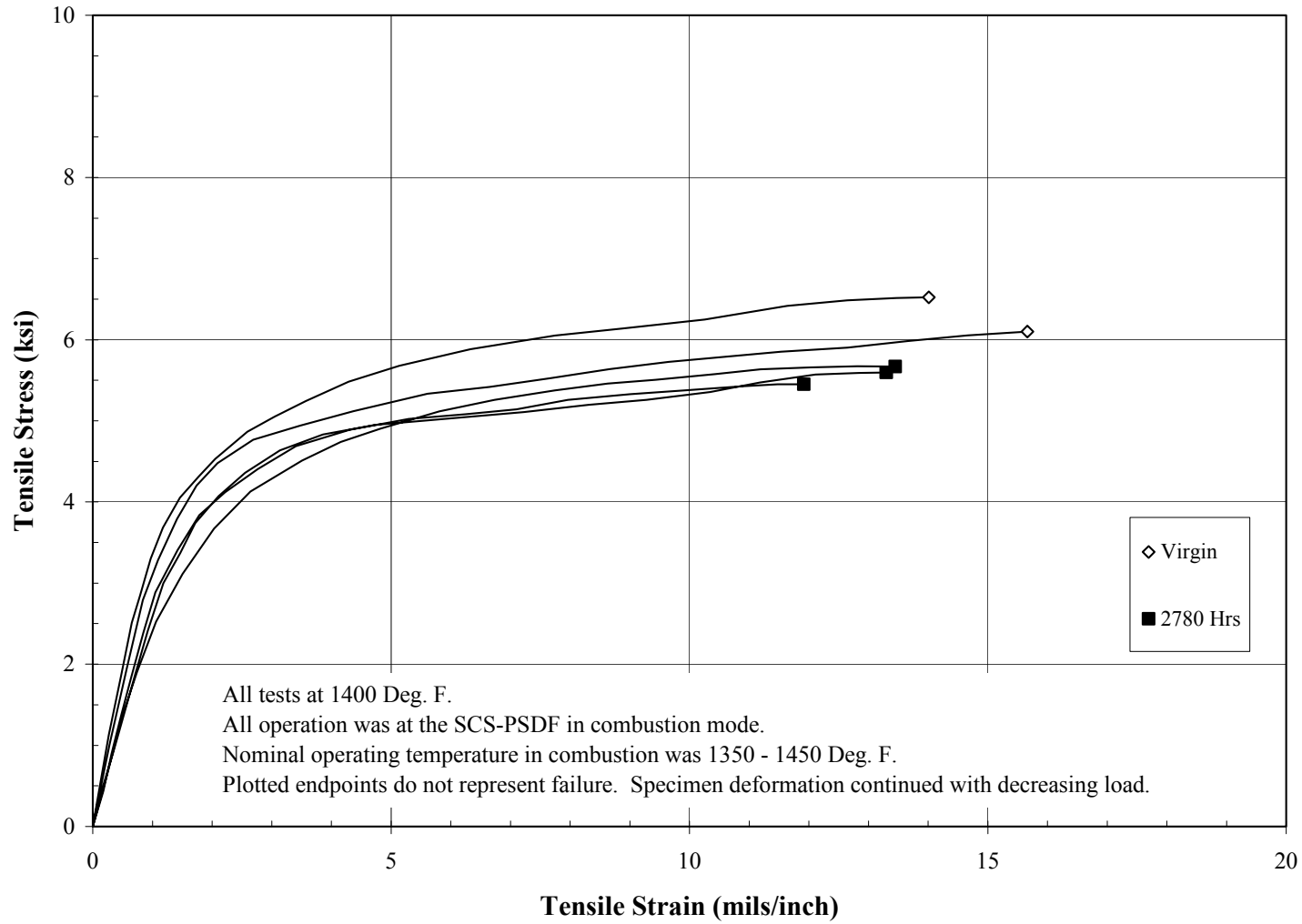


Figure 3.5-21 Axial Tensile Stress-Strain Responses at 1,400°F for Pall Fe₃Al After Combustion Operation

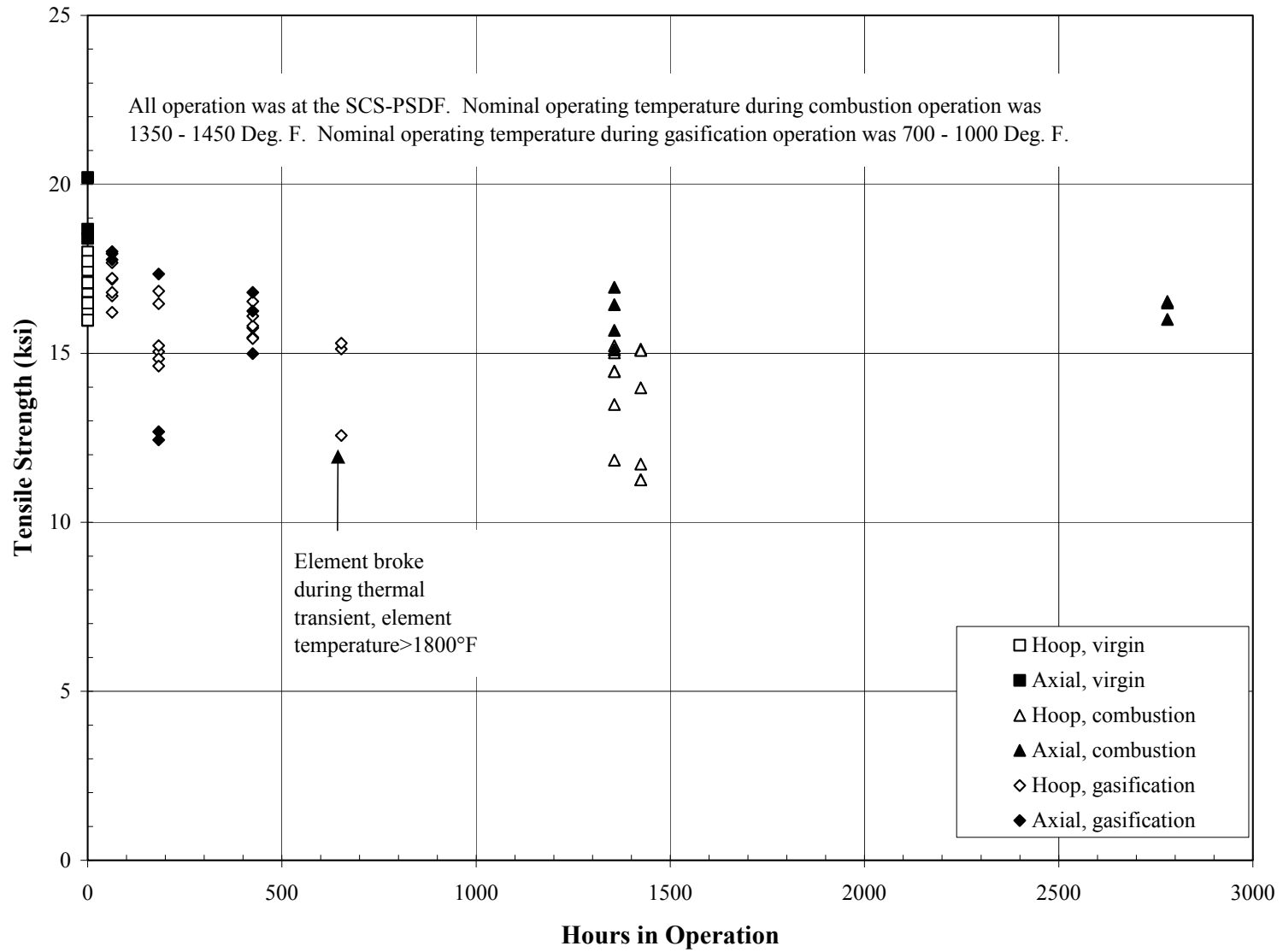


Figure 3.5-22 Room Temperature Tensile Strength of Pall Fe₃Al

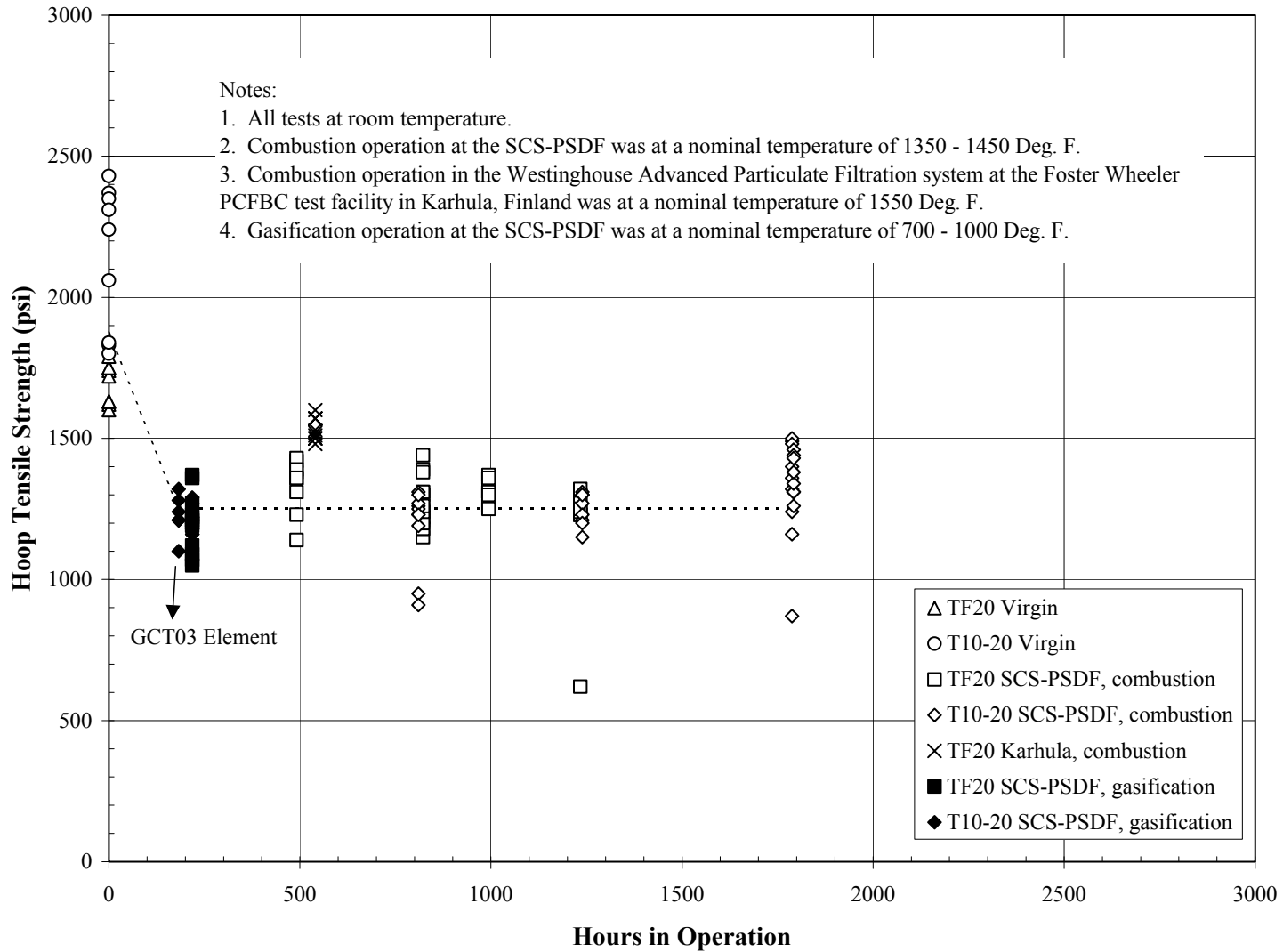


Figure 3.5-23 Room Temperature Hoop Tensile Strength of Schumacher TF20 and T10-20

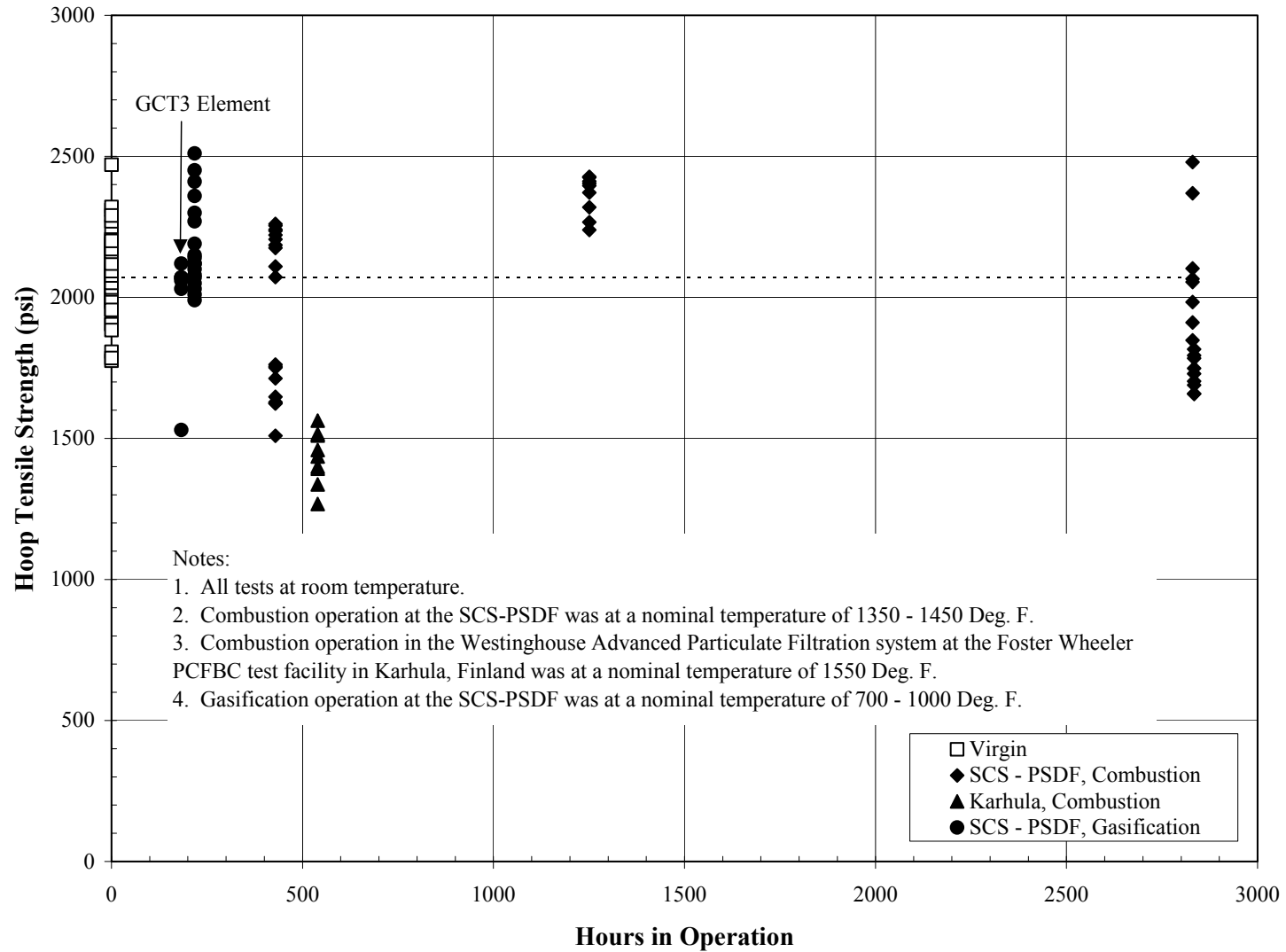


Figure 3.5-24 Room Temperature Hoop Tensile Strength of Pall 326

4.0 TRANSPORT REACTOR

4.1 TRANSPORT REACTOR TC06 RUN SUMMARY

Test run TC06 was started on July 4, 2001, with the startup of the atmospheric syngas burner fan and was completed on September 24, 2001, with an interruption in service between July 25 and August 19, due to a filter element failure in the PCD. During the outage, heat transfer fluid entered the disengager standpipe, making it necessary to remove all material from the reactor and the standpipe screw cooler. Over the course of the entire test run, the reactor temperature was varied between 1,725 and 1,825°F at pressures from 190 to 230 psig.

During the first portions of the run, the coal feeder experienced difficulty transferring coal from the lock hopper to the dispense vessel, a problem seen frequently in previous test runs. Whenever fine coal packed in the lock hopper, the dispense vessel would run out of coal, causing oxygen levels to build in the reactor and PCD. Later in the test run, operations began to feed material directly from the coal mill without allowing it to accumulate in the coal silo. This action prevented particle segregation and fine particle packing in the coal feeder lock hopper, allowing the coal feeder to run without interruption for over 278 hours.

The main air compressor also caused several reactor upsets. It surged while preheating the reactor with the start-up burner and during coal feed. Each time the compressor surged, the loss of air flow tripped all major reactor systems. To prevent more occurrences, a specialist tuned the compressor by adjusting parameters while the compressor passed air through the reactor loop. The compressor performance improved marginally.

The test run experienced a total of 1,025 hours on coal feed and 95 hours on coke breeze feed (used as a start-up fuel). Over the course of the test run, the reactor gasified 1,943 tons of Powder River Basin (PRB) coal. The sorbent used during the run was Ohio bucyrus limestone. The planned Transport Reactor operating conditions are shown in [Table 4.1-1](#). The analyses for coal and limestone feed are summarized in [Tables 4.1-2](#) and [-3](#).

The primary objective of test run TC06 was as follows:

- Operational Stability – Characterize reactor loop and PCD operations for commercial performance with long-term tests by maintaining a near-constant coal-feed rate, air/coal ratio, riser velocity, solids-circulation rate, system pressure, and air distribution.

Secondary objectives included the continuation of the following reactor characterizations:

- Reactor Operations – Study the devolatilization and tar cracking effects from transient conditions during the transition from start-up burner to coke breeze to coal. Evaluate the effect of process operations on heat release, heat transfer, and accelerated fuel particle heatup rates. Study the effect of changes in reactor conditions on transient temperature profiles, pressure balance, and product gas

- composition. Observe performance of new reactor temperature and coal-feed rate controllers.
- Effects of Reactor Conditions on Synthesis Gas Composition – Evaluate the effect of air distribution, steam/coal ratio, solids-circulation rate, and reactor temperature on CO/CO₂ ratio, synthesis gas lower heating value (LHV), carbon conversion, and cold and hot gas efficiencies.
 - Recycle Gas Compressor Commissioning in Gasification Mode – Run the recycle gas compressor in bypass mode and evaluate the performance of the new moisture removal systems.
 - Loop Seal Operations – Optimize loop seal operations and investigate increases to previously achieved maximum solids-circulation rate.

The activities that occurred during the outage preceding test run TC06 included 18 equipment revisions. Those revisions that most affected the process are listed below:

- Preparing the carbonizer coal feeder to serve as a coke breeze feeder for the Transport Reactor.
- Installing a second-level probe in the coal feeder dispense vessel to identify a loss of coal-feed situation.
- Programming a new automatic temperature controller for the Transport Reactor.

A summary of the events that occurred in TC06 is shown below.

Operations lit the atmospheric syngas burner on July 4, 2001, beginning test run TC06. On July 7, operations lit the start-up burner to preheat the reactor, while charging the reactor with sand. To bring the reactor from 1,200°F (the maximum temperature attainable by the start-up burner) to an optimum reactor temperature above the tar dew point, coke breeze was introduced as a startup fuel on July 10.

Coal feed began early on July 11, 2001, but was interrupted 2 hours later when the spent fines feeder plugged, causing material to back up into the PCD. Once maintenance cleared the line and the PCD had emptied, coal feed resumed at 09:30 on July 12 and was discontinued after less than 1 hour when the main air compressor surged, tripping all reactor systems. After experiencing difficulties with the start-up burner and the coal conveying line differential pressure, and another surge from the main air compressor, operations restored coal feed just after midnight on July 15.

The reactor ran very smoothly for 3 days at a pressure of 210 psig and a temperature between 1,750 and 1,770°F until coal packed in the feeder dispense vessel, preventing coal from entering the reactor. High oxygen levels caused a thermal event in the PCD, but the filter elements were not damaged. Coal feed resumed shortly thereafter, but reactor operations remained slightly

unstable for several hours. Once conditions stabilized, operations placed the reactor in automatic temperature control for the first time in any test run. The new controller and the reactor performed quite well, keeping the mixing zone temperature at 1,740°F except for a few coal feeder upsets in the morning of July 22, 2001.

Due to concerns about the main air compressor, a maintenance crew arrived on-site to tune the compressor on July 24, 2001. Operations stopped coal feed to prepare for the tuning procedure, which involved passing air through the reactor loop. Unfortunately, a gasification ash (g-ash) bridge that had formed on the PCD filter elements ignited as the air entered the filter vessel, causing some of the filter elements to break. Thus, operations had to shut down the entire system. During the outage, inspections revealed that heat transfer fluid had entered the reactor standpipe through a leak in the standpipe screw cooler. Maintenance had to remove all material from the reactor, repair the screw cooler, and repipe the heat transfer fluid before operations could resume.

Operations restarted the reactor burner on August 19, 2001. Coke breeze feed began on August 20, with coal feed following later that day. At the same time, a bubble formed in the standpipe that disturbed the circulation in the reactor. As fluidization flows to the reactor J-leg changed, the bubble disappeared and operations placed the reactor back into automatic temperature control.

In the next portion of the test run, the reactor ran at between 190 and 200 psig and around 1,700°F. The coal feeder generally performed poorly during this portion of the test run as fines continuously packed into the lock hopper. As a result, the coal feeder dispense vessel ran out of coal several times and coke breeze had to be used as a fuel until operations manually unpacked the lock vessel. Usually the events were short-lived, but on August 23 and on August 27, the dispense vessel ran completely out of coal, resulting in several offline hours during each occurrence.

Coal feed was again interrupted for 4 hours on August 27 when a torn spheri valve on one of the g-ash feeders caused material to accumulate in the PCD until maintenance could repair it. The reactor ran at 200 psig and around 1,715°F steadily from August 28 through September 2, when it began to experience more problems with the coal feeder. On September 12, after several more occasions of loss-of-coal feed caused by fine coal packing in the feeder lock hopper, operations began feeding ground coal continuously through the silos, not allowing coal to accumulate in the coal silos. The new feeding technique worked well and allowed the system to run very smoothly until the end of the run.

During the next portion of the test run, the reactor ran for 5 days at 200 psig and 1,700°F. Later, to test reactor stability at higher pressure, operations increased the pressure to 230 psig and 1,730°F. The test run ended on September 24, 2001, after accumulating 1,025 hours of coal feed and 1,214 hours of solids circulation.

Although several trips interrupted reactor operations, the reactor performed very well. Steady-state periods were long and reactor operations were stable, partially due to the new automatic

temperature controller. In addition, the new coal feeding technique virtually eliminated packing in the coal feeder, ensuring a steady-feed rate.

Coke breeze proved an invaluable source of fuel both during startup and whenever coal feed was interrupted. Since this material was used instead of coal to heat the reactor between 1,200 and 1,650°F, very little tar formed, and the gas analyzers were able to record the most reliable gasification data seen to date.

During TC06, the recycle gas compressor was run for the first time in gasification mode. All recycle gas flowed to the atmospheric syngas burner rather than the reactor loop. The moisture removal systems did not work as well as planned. The research team identified several improvements to attempt on the recycle gas loop.

After the test run was complete, process engineering and maintenance performed inspections on the reactor loop and the PCD. Except for some small egg-shaped deposits in the mixing zone and some soft agglomerations in the loop seal downcomer, the reactor interior appeared to be clean and the refractory in good condition. The sulfator refractory exhibited some shallow cracks that separated the refractory into small sections less than 12 inches in diameter as shown in [Figure 4.1-1](#).

Also during the inspection, the maintenance crew found that the primary gas cooler had experienced a tube failure in several tubes and had to be repaired. Upon inspecting the lower standpipe, the crews found that improvements to the HTF system had prevented any fluid from entering the reactor.

The reactor temperatures ranged from 1,725 to 1,825 °F, while the reactor operating pressure varied from 190 to 230 psig. The coal-feed rate ranged from about 3,800 to over 6,100 lb/hr. Further description of these test periods is provided in [Table 4.1-4](#).

The following test periods were selected as shown in Table 4.1-4:

TC06-I	Low operating pressure and temperature. Low coal-feed rate.
TC06-II	Low operating pressure. Low temperature. Moderate coal-feed rate.
TC06-III	Low pressure. Moderate temperature. Low coal-feed rate.
TC06-IV	Low pressure. Moderate temperature, coal-feed rate.
TC06-V	Low pressure. Moderately high temperature, feed rate.
TC06-VI	Low pressure. Moderately high temperature. High coal-feed rate.
TC06-VII	High pressure. Moderately high temperature. Low coal-feed rate.
TC06-VIII	High pressure, temperature. Low coal-feed rate.
TC06-IX	High pressure, temperature. Moderate coal-feed rate.
TC06-X	Moderate pressure. Moderately high temperature. High coal-feed rate.
TC06-XI	Moderate pressure, moderate temperature. High coal-feed rate.
TC06-XII	High pressure. High temperature. Moderate coal-feed rate.
TC06-XIII	High pressure. High temperature. High coal-feed rate.
TC06-XIV	High pressure and temperature. High coal-feed rate.

Table 4.1-1

TC06 Planned Operating Conditions for Transport Reactor

Start-up Bed Material	Sand, ~ 120 μm
Start-up Fuel	Coke Breeze
Fuel Type	Powder River Basin
Fuel Particle Size (mmd)	300 μm
Average Fuel-Feed Rate (pph)	5,000
Sorbent Type	Ohio Bucyrus Limestone
Sorbent Particle Size (mmd)	25 to 60 μm
Sorbent-Feed Rate	125 pph (Ca/S Molar Ratio of 2.0) for Sulfur Capture and Cracking Tar
Reactor Temperature (°F)	1,750 to 1,825
Reactor Pressure (psig)	240
Riser Gas Velocity (fps)	35 to 40 ft/s
Solids-Circulation Rate (pph)	100,000 to 400,000 (slip ratio = 2)
Primary Gas Cooler Bypass	0%
PCD Temperature (°F)	700 to 900
Total Gas-Flow Rate (pph)	18,000 to 26,000
Air/Coal Ratio	As Needed to Control Reactor Temperature
Primary Air Split (1 st /2 nd levels)	80/20
Steam/Coal Ratio	0.0 to 0.4
Sulfator Operating Temperature (°F)	1,500 to 1,600
Planned Duration of Coal Feed	Nominally 1,000 hours

Table 4.1-2

Coal Analyses as Fed

	PRB
Moisture	20.93
Ash	5.23
Sulfur	0.26
C	57.02
H	3.74
N	0.66
O	12.16
Vol	37.39
Fix C	36.46
Heating Value(BTU/lb)	9,391

Table 4.1-3

Sorbent Analyses

	Bucyrus Limestone From Ohio
CaCO ₃ (Wt %)	75.95
MgCO ₃ (Wt %)	17.66
CaSO ₄ (Wt %)	0.42
SiO ₂	2.58
Inerts	3.39

Table 4.1-4

Operating Periods

	Subperiods	Duration Hours	MZ Temp Deg F	Rsr Temp Deg F	Pres psig	Coal Fd ^[1] Rate lb/hr	Air Flow lb/hr	Air/Coal	Air/C
TC06-I	TC06-18	9:00	1,690	1,664	190	3,715	12,391	3.34	5.82
TC06-II	TC06-19 TC06-20 TC06-21	25:00	1,707	1,684	190	4,084	13,269	3.25	5.67
TC06-III	TC06-47 TC06-48 TC06-49 TC06-50 TC06-51	84:45	1,755	1,697	200	3,382	12,304	3.60	6.29
TC06-IV	TC06-22 TC06-23 TC06-24 TC06-25 TC06-38 TC06-39 TC06-42 TC06-45	108:00	1,733	1,701	199	4,303	14,172	3.30	5.75
TC06-V	TC06-16 TC06-26 TC06-27 TC06-28	171:45	1,751	1,718	200	4,455	14,746	3.31	5.78

Table 4.1-4

Operating Periods (continued)

	Subperiods	Duration Hours	MZ Temp Deg F	Rsr Temp Deg F	Pres psig	Coal Fd ^[1] Rate lb/hr	Air Flow lb/hr	Air/Coal	Air/C
TC06-V (continued)	TC06-29 TC06-30 TC06-31 TC06-32 TC06-33 TC06-34 TC06-35 TC06-36 TC06-37 TC06-40 TC06-43 TC06-44 TC06-46	171:45	1,751	1,718	200	4,455	14,746	3.31	5.78
TC06-VI	TC06-17 TC06-41	9:00	1,763	1,733	198	4,635	15,630	3.37	5.88
TC06-VII	TC06-52 TC06-53	18:00	1,760	1,700	220	3,294	11,937	3.64	3.65
TC06-VIII	TC06-54	19:00	1,770	1,716	220	3,648	13,161	3.61	6.30
TC06-IX	TC06-55 TC06-56 TC06-57	28:00	1,772	1,723	220	4,135	14,118	3.45	6.02

Table 4.1-4

Operating Periods (continued)

	Subperiods	Duration Hours	MZ Temp Deg F	Rsr Temp Deg F	Pres psig	Coal Fd ^[1] Rate lb/hr	Air Flow lb/hr	Air/Coal	Air/C
TC06-X	TC06-5 TC06-6 TC06-7 TC06-8 TC06-9 TC06-10 TC06-11 TC06-12 TC06-13 TC06-14	86:45	1,754	1,739	211	4,907	16,784	3.43	5.99
TC06-XI	TC06-1 TC06-2 TC06-3 TC06-4	27:45	1,746	1,757	212	4,673	16,464	3.50	6.11
TC06-XII	TC06-58 TC06-59 TC06-60 TC06-61	45:30	1,771	1,725	230	4,411	14,546	3.33	5.81
TC06-XIII	TC06-62 TC06-64	31:00	1,775	1,729	230	4,984	16,111	3.23	5.64
TC06-XIV	TC06-63	19:00	1,788	1,745	230	5,027	16,392	3.26	5.69

^[1] Coal-feed rate by carbon balance.



Figure 4.1-1 – View of Western Side of Sulfator Showing Cracks

4.2 GASIFIER OPERATIONAL ANALYSIS

The most important influence on the gasifier circulation rate is the height of the column of solids in the standpipe. A high standpipe level of fluidized solids will force solids at a rapid rate into the mixing zone, increasing the overall solids-circulation rate in the reactor loop. Figures 4.2-1, -2, and -3 show the effect of higher standpipe levels (LI339) on the pressure drop in the mixing zone and riser as an increasing mass of solids circulate through these areas, resulting in an increased holdup.

Increases in circulation rate tend to reduce the temperature extremes found in the gasifier. As the circulation rate increases, the difference in temperature between any two points should decrease. Figure 4.2-4 illustrates this effect by showing the difference in riser and mixing zone temperature as related to circulation rate, as measured by the riser differential pressure.

It has been expected that increases in the coal-feed rate would lead to an accumulation of solids in the bed. However, Figure 4.2-5, a plot of the change in LI339 over a short time and the coal-feed rate, shows that there is no appreciable change in accumulation rates as the coal-feed rate is changed. This is due to an appreciable increase in loading to PCD with an increase in coal-feed rate.

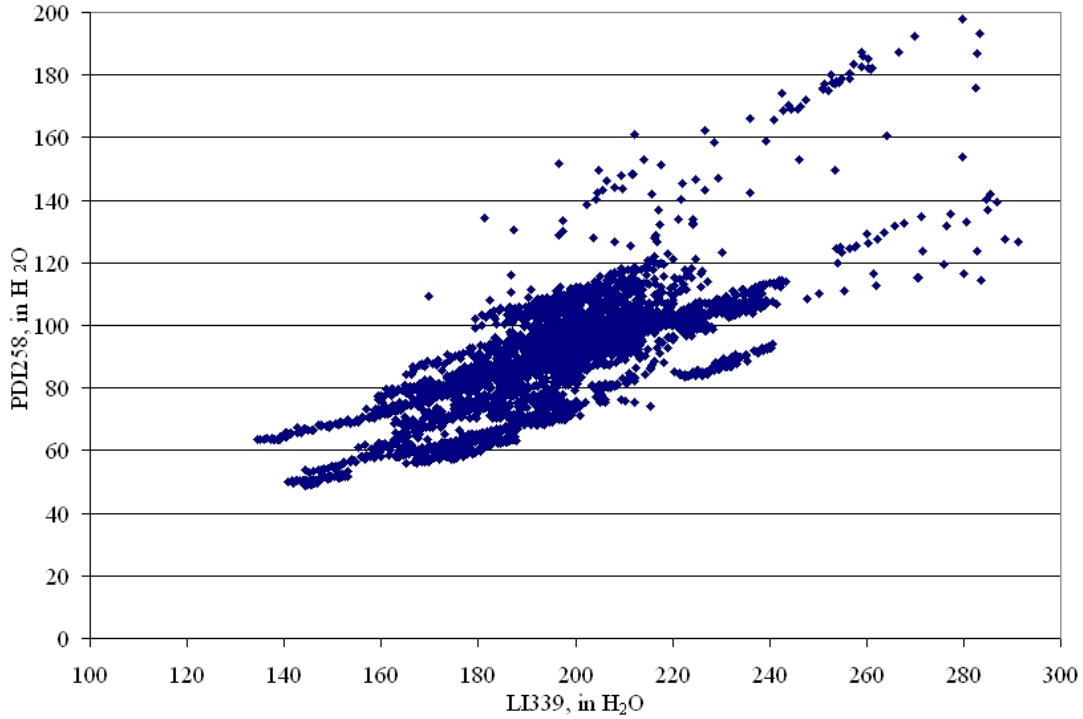


Figure 4.2-1 Effect of Standpipe Height on Riser DP

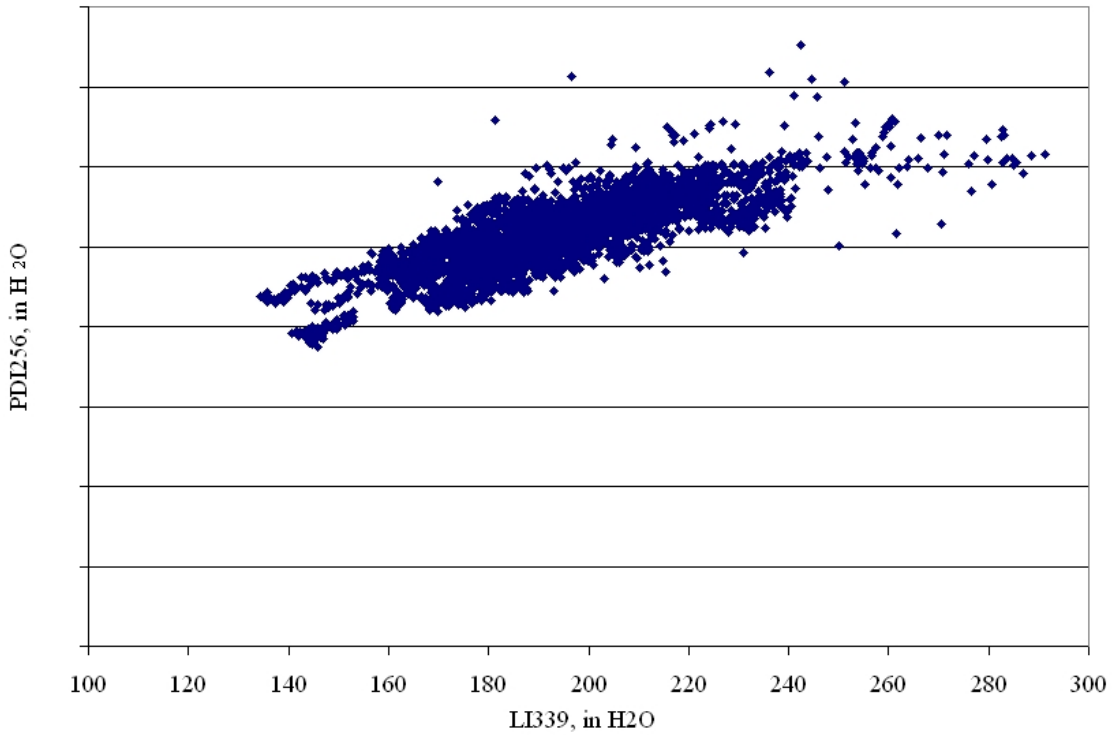


Figure 4.2-2 Effect of Standpipe Height on Mixing Zone DP

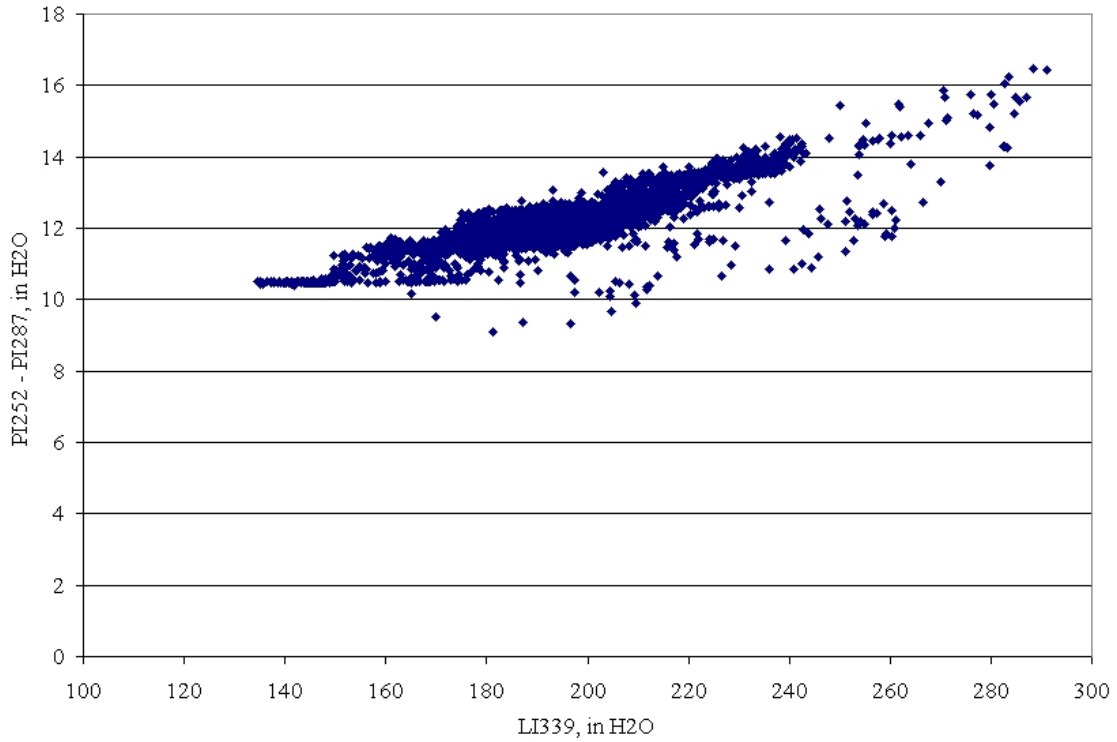


Figure 4.2-3 Effect of Standpipe Height on Combined Mixing Zone and Riser DP

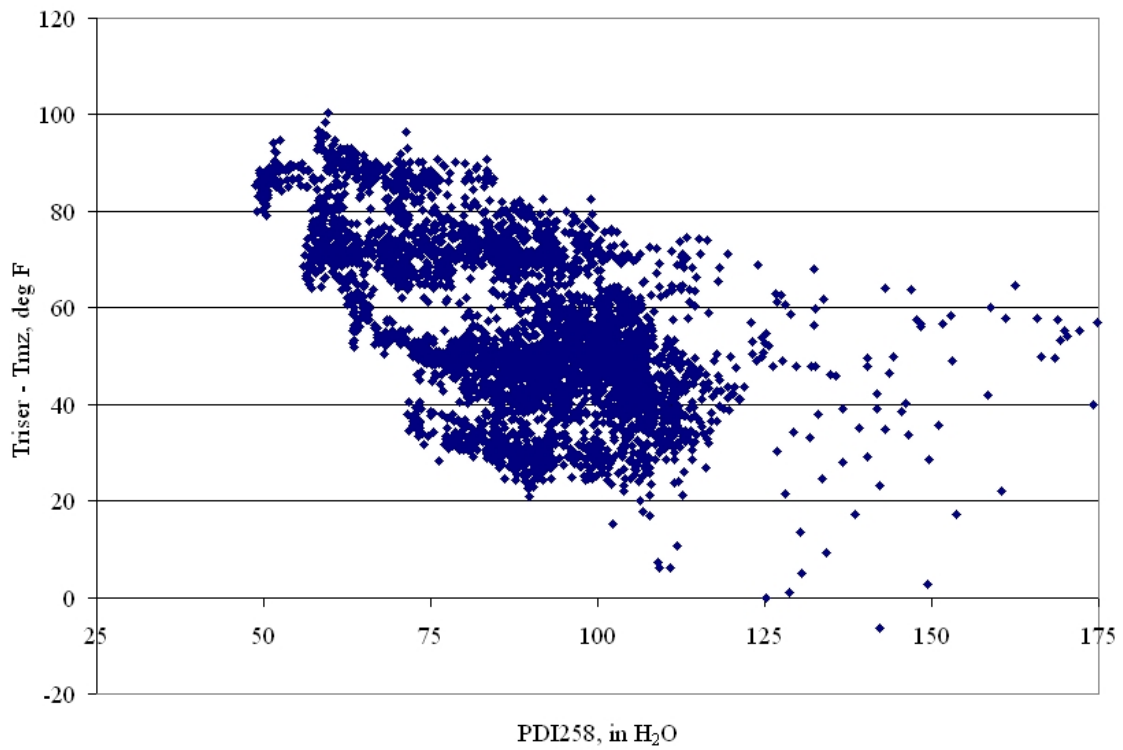


Figure 4.2-4 Effect of Circulation Rate on Temperature Difference From Mixing Zone to Riser

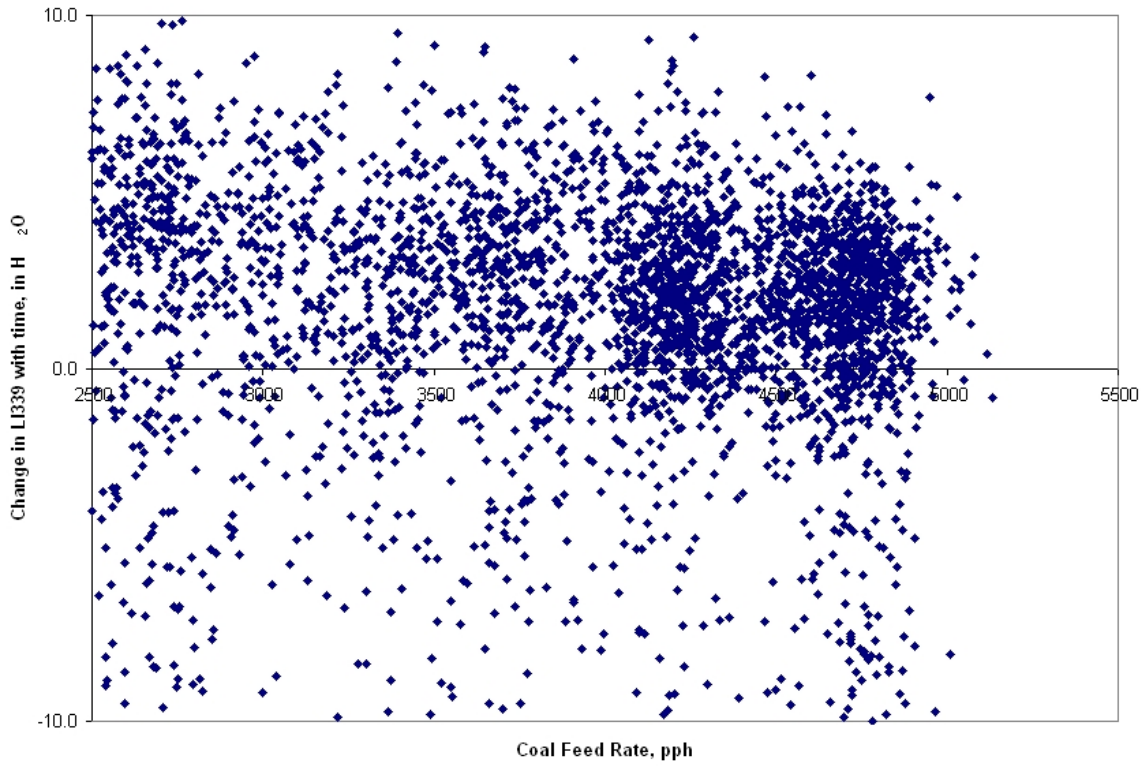


Figure 4.2-5 Effect of Coal-Feed Rate on Rate of Solids Accumulation in Standpipe

4.3 GAS ANALYSIS

During TC06, Transport Reactor and synthesis gas combustor outlet gas analyzers were continuously monitored and recorded by the plant information system (PI). Several in situ grab samples of synthesis gas moisture content were measured during the PCD outlet loading sampling. A train of gas impingers was used to measure NH_3 and HCN on two different days. This section will use gas analyzer data to show:

- Synthesis gas heating value.
- Synthesis gas molecular weight.
- Synthesis gas compositions, for CO , H_2 , CO_2 , H_2O , N_2 , CH_4 , C_2H_6^+ , NH_3 , HCN, and total reduced sulfur (H_2S , COS, and CS_2).
- Sulfur emissions.
- Equilibrium H_2S concentrations.

Run TC06 coal feed began on July 11, 2001, and ended on September 24, 2001. There was a 4-week outage (between July 24 and August 20) to replace broken filter elements. Test TC06 consisted of two periods. The first period was from July 14 to July 24, 2001. There were 14 steady periods of operation (TC06-1 to TC06-14). The steady periods of operation are shown in [Table 4.3-1](#). The second period was from August 20 to September 24, 2001. There were 50 steady periods of operation (TC06-15 to TC06-64). The only coal used during TC06 was Powder River Basin (PRB) coal, which is a mixture of four different coals. The sorbent used was Ohio Bucyrus limestone.

The TC06 hourly averages for the mixing zone temperatures, PCD (particulate control device, FL0301) temperatures and reactor pressure control valve pressures are shown in [Figure 4.3-1](#). The data for the operating periods are shown in [Table 4.3-2](#).

For the first 265 hours of TC06, the mixing zone was at about 1,750°F. At 265 hours, the temperature was decreased to about 1,700°F. After 400 hours, the mixing zone temperature was increased to 1,750°F. The temperature was then between 1,730 and 1,775°F for the remainder of the run. The brief lower temperatures on [Figure 4.3-1](#) were the periods during coal-feed trips. Usually the reactor could be maintained at pressure using the new coke breeze feeder and without depressurizing and using the start-up burner. There were no coal feeder trips from hour 763 to 986 because of improvements in the coal feeder operation strategy.

The Transport Reactor pressure was at 210 psig early in TC06 and then was decreased to 190 psig for about 150 hours. Most of TC06 was operated at 200 psig until 843 hours, when the pressure was increased to 220 psig, then 230 psig, and finally to 240 psig at the end of the run. The PCD inlet temperature slowly varied between 675 and 750°F.

TC06 hourly averages for the air rate and the nitrogen rate are shown in [Figures 4.3-2](#). The air and nitrogen rates are listed for the operating periods in [Table 4.3-2](#). The air rate was obtained from FI205. The air rate was between 16,000 to 17,500 lb/hr for the first 220 hours. After the 4-week break, the air rate increased from 14,000 to 16,000 lb/hr at hour 257. The air rate was decreased drastically to 12,500 lb/hr after a coal trip at hour 262. From hour 257 to hour 512,

the air rate slowly increased to about 14,750. At hour 760, the air rate was decreased to around 12,500 lb/hr until hour 863 to reflect a decrease in coal-flow rate. At hour 863, the air was increased until it reached 16,500 lb/hr at the end of TC06. The air rate followed the coal rate to maintain the reactor temperature constant.

The aeration-instrument nitrogen was obtained from FI609. It is estimated that about 1,000 lb/hr from FI609 does not enter the process but is used to seal valves, pressurized - depressurized feed, and ash lock hopper systems, and in the seals for the screw coolers. Values on [Figure 4.3-2](#) and [Table 4.3-2](#) assume that 1,000 lb/hr of nitrogen from FI609 does not enter the Transport Reactor. The nitrogen rate was between 5,500 and 7,750 lb/hr during the TC06. The nitrogen rate changed very gradually during the run.

The hourly synthesis gas (FI463_COMP) is plotted on [Figure 4.3-3](#). The synthesis gas rate generally follows the coal and air rates, and periods of high and low air flow result in high and low synthesis gas rates. The synthesis gas rate was from 21,000 to 30,000 lb/hr.

The gas analyzer system analyzed synthesis gas for the following gases during TC06 using the associated analyzers:

CO	AI425, AI434B, AI453G, AI464C
CO ₂	AI434C, AI464D
CH ₄	AI464E
C ₂ ⁺	AI464F
H ₂	AI464G
H ₂ O	AI7510
N ₂	AI464B

The AI464B-G analyzers use a gas chromatograph and typically have about a 6-minute delay. The other three CO analyzers (AI425, AI434B, and AI464C) and CO₂ analyzer (AI434C) are IR based and give more real-time measurements. Since all analyzers (except for the H₂O analyzer) require that the gas sample be conditioned to remove water vapor, all these analyzers report gas compositions on a dry basis.

The locations of the synthesis gas analyzers are shown in [Figure 4.3-4](#). All of the gas analyzers obtain gas samples from between the secondary gas cooler and the pressure letdown valve. The H₂O analyzer AI7510 obtains gas samples from between the pressure letdown valve and the syngas combustor. The GC analyzer AI464 normally samples between the PCD and the secondary gas cooler. This sample line plugged and the AI464 sample was taken between the secondary gas cooler and the pressure letdown valve during TC06.

The raw synthesis gas analyzer data was adjusted to produce the best estimate of the actual gas composition in three steps:

1. Choice of CO and CO₂ analyzer data to use.
2. Normalization of dry gas compositions (force to 100 percent total).
3. Conversion of dry compositions to wet compositions.

There is a measure of self-consistency when all or several of the four analyzers read the same value. There is also the choice of which analyzer to use when problems arise due to solids plugging the gas sampling lines. The TC06 hourly averages for the four CO analyzers are shown in [Figure 4.3-5](#). For the first 64 hours of TC06, only AI434B was giving reasonable results. At hour 64, both AI434B and AI464C agreed with each other and remained in agreement with each other until the end of TC06. For the first 220 hours AI453G read zero and AI425 had wide variations. After a 4-week break at hour 220, all four CO analyzers agreed with each other until the end of TC06. The close agreement between the CO analyzers gives good confidence to the accuracy of the data. The low-CO measurements are either periods when the gas analyzers were being calibrated or are measurements during coal feeder trips. The CO compositions used in calculations were interpolated for times when the gas analyzers were being calibrated. The dry CO concentrations varied between 12 and 14 percent during TC06.

TC06 hourly averages data for the CO₂ analyzers are shown in [Figure 4.3-6](#). Analyzer AI454D was not operating properly for the first 220 hours of TC06, while AI434C was giving reasonable results. After the 4-week break both analyzers agreed very well with each other. The low CO₂ measurements are either periods when the gas analyzers were being calibrated or are measurements made during coal feeder trips. The CO₂ compositions used in calculations were interpolated for times when the gas analyzers were being calibrated. The dry CO₂ concentrations varied between 8 and 9.5 percent during TC06. For the last 700 hours of TC06, the CO₂ concentration was very steady at 8 percent.

The TC06 hourly average gas analyzer data for H₂, CH₄, and C₂⁺ are shown in [Figure 4.3-7](#). For the first 60 hours of TC06 (TC06-1 to TC06-5), the hydrogen analyzer AI464G was not operating properly. Once the hydrogen analyzer was operating, it gave reasonable results until the end of the run. The hydrogen concentration varied between 6 and 8 percent, with most of the run at about 7.5-mole percent. Thermodynamic data (the water gas shift equilibrium constant) was used to estimate the hydrogen concentration for the first five operating periods from other gas analyzer data and the mixing zone temperature.

For the first 220 hours of TC06 (TC06-1 to -14), the methane analyzer AI464E was out of service. Once it was put in service, it gave reasonable results for the remainder of TC06. The methane concentration averaged 1.37 percent during the operating periods TC06-15 to -64, therefore that value was used for the first 14 operating periods.

The C₂⁺ analyzer AI464F read 0.0 percent after 220 hours except when coke breeze was being fed to the Transport Reactor. During the first 220 hours, AI464F gave erratic readings, so for the first 220 hours of TC06 it was assumed that the C₂⁺ was 0.0 percent.

The nitrogen analyzer AI464B was not giving reasonable results for TC06-3 to -5, so the nitrogen content was estimated by difference for these operating periods.

The hourly averages of the sum of the dry gas analyses are shown in [Figure 4.3-8](#) for all the operating periods except the first five. The majority of the remaining 59 operating periods have the sum of dry gas compositions close to 99 percent indicating that the data is consistent. There is a concern on what is in the missing 1 percent of the gas or whether there is a consistent

1 percent error in the gas analyzers. There is no backup analyzer for the hydrogen, nitrogen, methane, or C_2^+ concentrations, so some of the error could be there. It is planned to have backup hydrogen, nitrogen, methane, and C_2^+ analyzers for the next gasification run. The first 14 operating periods have the sum of the dry compositions at 97 to 99 percent, which indicate that the gas composition data for those periods is not as good as the gas composition data for the operating periods TC06-15 to -64.

The AI7510 water analyzer data for the operating periods are shown in [Figure 4.3-9](#) where they are compared with the in situ synthesis gas moisture measurement made during PCD outlet particulate sampling. The location of the water analyzer is between the pressure letdown valve and the synthesis gas combustor inlet. The location of the in situ H_2O measurement is between the PCD exit and the inlet of the secondary gas cooler. The locations of both sampling points are shown in [Figure 4.3-4](#). The in situ measurement and gas analyzer data agreed well between hour 58 and 278, both before and after the 4-week break. From hour 296 to hour 586, AI7510 measured about 1 percent higher than the in situ analyses. Then from hour 608 to hour 760, the two H_2O measurements agreed with each other if one of the in situ measurements was excluded. From hour 787 to the end of TC06, half of the in situ measurements agreed with each and the other half the in situ data were again 1 to 2 percent below AI7510. These results are surprising since in the previous gasification runs AI7510 usually agreed well with the in situ data.

The steam feed rate is also shown in [Figure 4.3-9](#). Both H_2O measurements were consistent with the increase and then decrease in stream rates in the first 100 hours of TC06. Both H_2O measurements increased from hour 500 to the hour 900, which would be consistent with a steam leak from HX0202. Between hour 900 and the end of TC06, the H_2O measurements slightly decreased due to increases in the air rate.

In previous gasification runs, the water-gas shift (WGS) reaction was used to interpolate H_2O measurements between in situ H_2O measurements and to check the consistency of the H_2O analyzer. The water-gas shift equilibrium constant should be a function of a Transport Reactor mixing zone or riser temperature. Plotted in [Figure 4.3-9](#) are the H_2O concentrations calculated from the water-gas shift equilibrium constant based on the mixing zone temperature TI344 and using the measured H_2 , CO, and CO_2 concentrations. The water-gas shift H_2O should give some guidance as to which H_2O measurement is more correct. There is no reactor temperature that correctly predicts the trends of either the in situ or the H_2O analyzer data. The in situ H_2O measurements analyzer readings will be used for further data analyses since oxygen and hydrogen balances agree better for the in situ measurements than the H_2O analyzer measurements. The H_2O compositions used in further calculations are based on interpolation between the in situ measurements.

The water-gas shift reaction and equilibrium constant:



$$K_p = \frac{(H_2)(CO_2)}{(H_2O)(CO)} \quad (2)$$

The water-gas shift equilibrium constant was used to estimate the hydrogen concentration using TI344 as the equilibrium temperature for operating periods TC06-1 to -5, since the equilibrium constant predicted the H₂O concentration very well for test periods TC06-6 (hour 74) to -18 (hour 270).

The best estimates of the wet gas compositions for the TC06 operating periods are shown in [Table 4.3-3](#) and shown in [Figure 4.3-10](#). Also shown in [Table 4.3-3](#) are the synthesis gas molecular weights for each operating period. The CO concentration increased from 10 to 12 percent during the first 255 hours of TC06. After decreasing to 9 percent at hour 270, the CO concentration was constant at about 12 percent from hour 336 to hour 719. The CO concentration then dipped down to 11 percent from hour 711 to hour 859 during the period of low coal flow. As the coal rate was steadily increased from hour 829 to the end of the run, the CO concentration steadily increased up to 13.5 percent at the end of TC06.

The H₂ concentration was steady at about 7 percent during most of TC06. From hour 244 to hour 306, the H₂ concentration was about 6 percent. During the low coal flow from hour 760 to hour 859, the H₂ concentration also decreased to 6 percent. When the coal-feed rate was increased at hour 829, the H₂ concentration slowly increased to 7.5 percent at the end of TC06.

The CO₂ concentration was steady for the entire run at about 7.5 percent. The CH₄ concentration was steady at about 1.3 percent until the coal rate decreased at hour 760 when it decreased to 1.0 percent. When the coal rate increased at hour 829, the CH₄ increased to 1.5 percent.

The water-gas shift (WGS) equilibrium constant and the CO/CO₂ ratio, which were calculated from the gas data for each operating period, are listed in [Table 4.3-3](#), and plotted in [Figure 4.3-11](#). The water-gas shift equilibrium constant is not shown for the first five operating periods because there were no hydrogen data for those periods. For operating periods TC06-6 to -14, the water-gas shift was steady at between 0.60 and 0.65. From hour 244 to hour 400, the equilibrium constant was steady at between 0.7 and 0.8. From hour 400 to hour 873, the equilibrium constant decreased from 0.80 to 0.55. From hour 873 to the end of the run, the equilibrium constant was steady at between 0.5 and 0.6. The variation in equilibrium constant is surprising since the reactor temperature was held constant during TC06 and the equilibrium constant should only be a function of temperature. During the post-TC06 outage, it was discovered that the primary gas cooler (HX0202) was leaking steam into the synthesis gas. The extra H₂O in the synthesis gas would tend to lower the water-gas shift constant. It would appear that the steam leaks became significant at about hour 500, when the WGS constant started to decrease, and the H₂O content of the synthesis gas increased from about 7 to 9 percent (about 350 more lb/hr H₂O).

The CO/CO₂ ratio is varied from 1.1 to 1.6 during the first 308 hours of TC06. The CO/CO₂ ratio was then constant at about 1.6 from hour 308 to hour 719. During the lower coal-rate operation between hour 760 and hour 829, the CO/CO₂ ratio dropped to between 1.4 to 1.5. When the coal rate was increased between hour 829 to hour 926, the CO/CO₂ ratio increased to 1.8. For the last 60 hours of the run, the CO/CO₂ ratio was constant at 1.8.

The water-gas shift equilibrium, calculated from the mixing zone temperature TI344, is shown in Table 4.3-3 and plotted in Figure 4.3-12 against the measured water-gas shift equilibrium. The agreement was very good for the first 296 hours of TC06. Between hour 244 and hour 498, the measured equilibrium constant was consistently higher than the equilibrium constant calculated from the mixing zone temperature. From hour 505 to hour 586, the two equilibrium constants were the same. Between hour 608 and the end of TC06, the measured equilibrium constant was consistently lower than the equilibrium constant calculated from the mixing zone temperature. The mixing zone temperature equilibrium constant was unchanged during the run at 0.65, except between hour 254 and hour 419 when it increased to 0.7, and at the end of the run from hour 859 on when it was at 0.63. The low measured equilibrium constants produce a higher equilibrium temperature (around 1,900°F) than the maximum temperature in the reactor. The steam leakage from HX0202 that began around 500 hours was the probable cause of the decrease in measured water-gas shift constant.

The temperature at which the water gas-shift reaction data is at equilibrium is calculated from thermodynamic data and shown in Table 4.3-3 and varied from 1,639 to 1,978°F. This demonstrated that the water-gas shift reaction essentially "freezes" at the reactor temperatures and does not further react at the lower temperatures in the primary gas cooler or the PCD. This is surprising since gas-gas reactions like the water-gas shift reaction should be fast reactions. In order to have the water-gas shift reaction to proceed at lower temperatures than the Transport Reactor, a catalyst is required.

The lower heating value (LHV) for each gas composition was calculated and is shown in Table 4.3-3 and plotted in Figure 4.3-13. The LHV value was calculated using the formula:

$$\text{LHV(Btu/SCF)} = \left\{ \begin{array}{l} 275 \times (\text{H}_2 \%) + 322 \times (\text{CO}\%) + \\ 913 \times (\text{CH}_4 \%) + 1641 \times (\text{C}_2\text{H}_6 \%) \end{array} \right\} / 100 \quad (3)$$

The raw LHV was from 57 to 77 Btu/SCF. The LHV were generally constant, about 65 to 70 Btu/SCF for the first 719 hours. As the coal rate decreased, the LHV decreased down to about 60 Btu/SCF. At the end of TC06, when the coal rate was increased, the LHV increased up to 76 Btu/SCF.

The PSDF Transport Reactor adds more N₂ per lb synthesis gas than a commercial reactor because of the additional PSDF sampling purges, additional PSDF instrument purges, and the need to aerate the lower portion of the reactor. Instrument purges would be proportionally smaller in a commercial design due to the scale factor (number of instruments stay the same size as plant size increases). Any additional N₂ added to the riser requires additional fuel to bring the additional N₂ up to operating temperatures. This additional fuel then requires additional air, which then adds additional N₂ to the reactor and further dilutes the synthesis gas. The aeration gas will be supplied by recycle gas in a commercial-sized reactor. The PSDF Transport Reactor heat loss per lb of coal fed is much greater than the heat loss from a commercial-sized reactor. To correct for the lower heat loss per lb of coal fed, the additional coal required to compensate

for the heat loss is subtracted from the coal-feed rate. To estimate the commercial synthesis LHV, the following components are deleted from the raw synthesis gas:

- All aeration nitrogen ("nonair" nitrogen).
- Air nitrogen that is required for burning additional coal that is used for heating aeration nitrogen to the reactor process temperature.
- Carbon dioxide from burning the additional coal required for heating aeration nitrogen.
- Water vapor from burning the additional coal required for heating aeration nitrogen.
- Air nitrogen required for burning additional coal that is required to compensate for the reactor heat loss of 1.5×10^6 Btu/hr.
- Carbon dioxide from burning the additional coal required for the reactor heat loss.
- Water vapor from burning the additional coal required for the reactor heat loss.

The sum of all these corrections is the adiabatic nitrogen-corrections LHV. The aeration nitrogen was determined by subtracting the air nitrogen from the synthesis gas nitrogen. Note that these corrections change the water-gas shift equilibrium constant, the CO/CO₂ ratio, and the air-to-coal ratio. These calculations are an oversimplification of the gasification process. A more sophisticated model is required to correctly predict the effect of decreasing aeration nitrogen and reactor heat loss. The adiabatic N₂ corrected LHV for each operating period are shown in [Table 4.3-4](#) and plotted in [Figure 4.3-13](#). All the N₂ corrected LHV were between 104 and 124 Btu/SCF and follow the trends of the raw gas LHV.

The synthesis gas compositions and synthesis gas-flow rate can be checked by an oxygen balance around the synthesis gas combustor (SGC) since the synthesis gas combustor exit O₂ is measured by AIT8775. The synthesis gas combustor oxygen balance was calculated for each operating period by using the following thermal oxidizer process tags:

- Primary air flow, FI8773.
- Secondary air flow, FIC8772.
- Quench air flow, FI8771.
- Propane flow, FI8753.
- Oxygen concentration, AIT8775.

During TC06, it was discovered that temperature- and pressure-compensated flow rates for FIC8772 and FI8771 were calculated by the DCS but were not being stored in PI. At 14:00 September 4, 2001, the temperature and pressure compensated flow rates for FIC8772 and FI8771 were added to PI and could be used in synthesis gas combustor calculations. A correlation factor was developed from post-September 4 data to estimate the compensated pre-September 4 FIC8772 and FI8771 values and these values were used for pre-September 4 data analysis.

The measured and mass balance calculated O₂ values are shown in [Figure 4.3-14](#) and [Table 4.3-5](#). The measured- and calculated-O₂ concentrations agreed well with each other for nearly all the operating periods. Both were around 6-percent O₂ for most of the run. The agreement is good for up to the first nine operating periods (hour 124). The agreement is poor for the next five periods until the 4-week break in operations with the calculated oxygen about

1 percent less than the measured oxygen. The agreement is then excellent from the 4-week break until hour 760, even when the oxygen content increased from 6 to 8 percent. From hour 711 to hour 850, the calculated oxygen was from 0.5 to 1.0 percent below the measured oxygen. After hour 873 until the end of TC06, the agreement was excellent between the measured and calculated oxygen. The operating periods when the calculated oxygen was lower than the measured oxygen were typically when one of the air flow meters to the synthesis gas combustor was reading low. The agreement between measured and calculated oxygen concentration was about the same whether the analyzer H₂O or the in situ H₂O measurement was used.

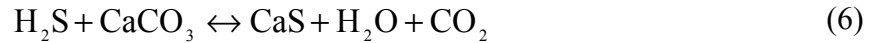
The synthesis gas LHV can be estimated by doing an energy balance around the synthesis gas combustor. The synthesis gas combustor energy balance is done by estimating the synthesis gas combustor heat loss to make the synthesis gas LHV calculated by the synthesis gas combustor energy balance agree with LHV calculated from the synthesis gas analyzer data. In GCT2, the synthesis gas combustor heat loss was usually between 1.5 and 4.0 x 10⁶ Btu/hr to obtain agreement. In GCT3, the best fit was 1.0 x 10⁶ Btu/hr. The best fit for the GCT4 data was 2.25 x 10⁶ Btu/hr. The best fit of the TC06 data was also 2.25 x 10⁶ Btu/hr. A comparison between the measured LHV and the synthesis gas combustor energy balance LHV using a synthesis gas combustor heat loss of 2.25 x 10⁶ Btu/hr is shown in [Figure 4.3-15](#). The SGC combustor energy balance LHV was close to the analyzer measured value for the first 220 hours. From hour 234 to hour 336, the gas analysis LHV was less than the synthesis gas combustor LHV. After hour 336, the two LHV had excellent agreement with each other.

Since the Transport Reactor H₂S analyzer was not working during TC06, the H₂S concentration and sulfur emissions from the Transport Reactor were not directly measured. The synthesis gas combustor SO₂ analyzer (AI534A) measures the total sulfur emissions from the Transport Reactor. The total sulfur emissions consists of H₂S, COS, and CS₂. The main sulfur species in coal gasification are considered to be H₂S and carbon oxysulfide (COS). There should also be only a minor amount of carbon disulfide (CS₂). Waltz Mills KRW gasifier data indicates that the majority of the gaseous sulfur is present as H₂S, with the balance COS. KRW typically measured concentrations of 100 to 200 ppm COS for 0.6 to 1.0 percent sulfur fuels. The sulfur emissions for the operating periods of TC06 are plotted in [Figure 4.3-16](#) and listed in [Table 4.3-5](#). Since the synthesis gas combustor exit-gas-flow rate is about twice that of the synthesis gas rate, the synthesis gas total reduced sulfur concentration is about twice that of the measured synthesis gas combustor SO₂ concentration.

The sulfur emissions were from 155 to 230 ppm for the beginning of TC06 up to hour 255. At hour 270, the sulfur emissions dropped to between 100 and 150 ppm until hour 587 when the sulfur emissions increased to above 150 ppm. After hour 648 the sulfur emissions dropped below 150 ppm and were between 100 to 150 ppm to the end of the run.

The equilibrium H₂S concentration in coal gasification using limestone is governed by three reversible reactions:





Reaction (4) is the limestone calcination reaction. At thermodynamic equilibrium, the CO_2 partial pressure should be a function of only the system temperature as long as there are both CaCO_3 and CaO present according to the equilibrium constant:

$$K_1 = P_{\text{CO}_2}^o \quad (7)$$

where $P_{\text{CO}_2}^o$ is the partial pressure of CO_2 . A plot of the partial pressure of CO_2 and temperature is shown in [Figure 4.3-15](#) of the GCT1 report. At thermodynamic equilibrium, CaCO_3 and CaO only coexist on the equilibrium curve, while above the curve only CaCO_3 exists, and below the curve only CaO exists. Typically, there are both CaCO_3 and CaO present in the PCD solids. This is because of kinetic limitations and the quick cooling down of the solids in the fuel gas from the reactor temperatures to PCD temperatures. This quick cooling down tends to “freeze” reactions at higher equilibrium temperatures than would be indicated by the actual system exit temperature.

The H_2S equilibrium is governed by reactions (5) and (6), with the associated equilibrium constants:

$$K_2 = \frac{P_{\text{H}_2\text{O}}^o}{P_{\text{H}_2\text{S}}^o} \quad (8)$$

$$K_3 = \frac{P_{\text{H}_2\text{O}}^o P_{\text{CO}_2}^o}{P_{\text{H}_2\text{S}}^o} \quad (9)$$

Equations (8) and (9) state that the equilibrium H_2S concentrations in the CaCO_3 - CaO - CaS system is a function of the system temperature and the CO_2 and H_2O partial pressures. As the CO_2 and H_2O partial pressures increase, so would H_2S partial pressures. The equilibrium constants are all functions of temperature and can be determined using thermodynamic data with Aspen simulations. A more detailed description of the H_2S equilibrium calculations is provided (starting on page 4.3-7) in the GCT1 final report.

The minimum thermodynamic H_2S concentrations for each operating period were calculated from the measured partial pressures of CO_2 and H_2O and are shown in [Table 4.3-5](#). The measured total reduced sulfur and minimum H_2S concentrations are compared in [Figure 4.3-16](#). The measured total reduced sulfur emissions had a lot of scatter as compared to the measured sulfur emissions. For the first 700 hours of TC06, the measured emissions seemed to follow the equilibrium concentrations, either above or below them in a random pattern. After 700 hours, the equilibrium H_2S concentrations were consistently below the measured sulfur emissions, usually by about 50 ppm. These observations are consistent with observations from operation at Beijing Research Institute of Coal Chemistry in the early 1990's (Guohai Liu, personal communications). This is surprising since the total reduced sulfur consists of not only H_2S , but also COS and CS_2 and should be higher than the equilibrium H_2S . The choice of the in situ H_2O

measurement increases the equilibrium H_2S since the in situ H_2O measurements were generally higher than the H_2O analyzer measurements.

The temperature at which the equilibrium H_2S concentration is determined is about $1,650^\circ F$, indicating that all the H_2S removal takes place in the Transport Reactor and not in the primary gas cooler or the PCD. Therefore, limestone addition after the reactor will not produce any additional H_2S removal. Thermodynamics also predicts that increasing the reactor temperature should increase H_2S emissions, while lowering the reactor temperature will decrease H_2S emissions.

Ammonia and HCN concentration data were taken by extracting synthesis gas and collecting NH_3 and HCN in liquid solutions. The solutions were then analyzed for NH_3 and HCN. The data was taken on July 17, 2001, (hour 67 to 71, TC06-6) and July 24 (hour 224 to 227, right after the end of TC06-14). The results are shown in [Table 4.3-6](#). The ammonia was from 1,296 to 1,910 ppm and the HCN was from 42 to 72 ppm. The NH_3 and HCN concentrations increased during the July 17 sampling periods, while the NH_3 and HCN concentrations were constant during the July 24 sampling.

Table 4.3-1 Operating Periods

Operating Period	Start Time	End Time	Duration Hours	Operating Period	
				Average Time	Relative Hours
TC06-1	7/15/01 17:45	7/16/01 02:30	8:45	7/15/01 22:07	21
TC06-2	7/16/01 04:30	7/16/01 08:30	4:00	7/16/01 6:30	29
TC06-3	7/16/01 08:30	7/16/01 12:30	4:00	7/16/01 10:30	34
TC06-4	7/16/01 12:30	7/16/01 23:30	11:00	7/16/01 18:00	41
TC06-5	7/17/01 03:30	7/17/01 11:30	8:00	7/17/01 7:30	55
TC06-6	7/17/01 21:00	7/18/01 09:00	12:00	7/18/01 3:00	74
TC06-7	7/18/01 09:00	7/18/01 17:00	8:00	7/18/01 13:00	84
TC06-8	7/18/01 17:00	7/18/01 22:15	5:15	7/18/01 19:37	91
TC06-9	7/19/01 21:45	7/20/01 13:00	15:15	7/20/01 5:22	124
TC06-10	7/21/01 00:15	7/21/01 05:15	5:00	7/21/01 2:45	146
TC06-11	7/21/01 05:30	7/21/01 14:30	9:00	7/21/01 10:00	153
TC06-12	7/22/01 16:45	7/23/01 03:45	11:00	7/22/01 22:15	189
TC06-13	7/23/01 03:45	7/23/01 12:45	9:00	7/23/01 8:15	199
TC06-14	7/24/01 05:00	7/24/01 09:15	4:15	7/24/01 7:07	222
TC06-15	8/20/01 20:30	8/21/01 00:30	4:00	8/20/01 22:30	234
TC06-16	8/21/01 00:30	8/21/01 17:15	16:45	8/21/01 8:52	244
TC06-17	8/21/01 17:15	8/21/01 22:15	5:00	8/21/01 19:45	255
TC06-18	8/22/01 23:15	8/23/01 08:15	9:00	8/23/01 3:45	270
TC06-19	8/23/01 10:45	8/23/01 16:45	6:00	8/23/01 13:45	280
TC06-20	8/24/01 17:30	8/24/01 21:30	4:00	8/24/01 19:30	297
TC06-21	8/25/01 00:00	8/25/01 15:00	15:00	8/25/01 7:30	309
TC06-22	8/26/01 00:00	8/26/01 21:00	21:00	8/26/01 10:30	336
TC06-23	8/26/01 23:30	8/27/01 11:30	12:00	8/27/01 5:30	354
TC06-24	8/28/01 01:30	8/28/01 08:30	7:00	8/28/01 5:00	374
TC06-25	8/28/01 11:00	8/29/01 07:00	20:00	8/28/01 21:00	390
TC06-26	8/29/01 07:00	8/30/01 22:00	39:00	8/30/01 2:30	420
TC06-27	8/31/01 00:00	8/31/01 16:00	16:00	8/31/01 8:00	449
TC06-28	9/1/01 02:00	9/1/01 07:00	5:00	9/1/01 4:30	470
TC06-29	9/1/01 09:00	9/1/01 15:00	6:00	9/1/01 12:00	477
TC06-30	9/1/01 15:00	9/2/01 03:00	12:00	9/1/01 21:00	486
TC06-31	9/2/01 03:00	9/2/01 07:00	4:00	9/2/01 5:00	494
TC06-32	9/2/01 07:00	9/2/01 11:00	4:00	9/2/01 9:00	498

Table 4.3-1 Operating Periods (continued)

Operating Period	Start Time	End Time	Duration Hours	Operating Period	
				Average Time	Relative Hours
TC06-33	9/2/01 13:45	9/2/01 18:45	5:00	9/2/01 16:15	505
TC06-34	9/3/01 02:00	9/3/01 12:00	10:00	9/3/01 7:00	520
TC06-35	9/3/01 18:00	9/4/01 01:00	7:00	9/3/01 21:30	534
TC06-36	9/4/01 09:00	9/4/01 14:00	5:00	9/4/01 11:30	548
TC06-37	9/4/01 16:00	9/4/01 21:00	5:00	9/4/01 18:30	555
TC06-38	9/4/01 23:00	9/5/01 18:00	19:00	9/5/01 8:30	569
TC06-39	9/5/01 18:00	9/6/01 09:00	15:00	9/6/01 1:30	586
TC06-40	9/6/01 19:15	9/7/01 03:15	8:00	9/6/01 23:15	608
TC06-41	9/8/01 07:45	9/8/01 11:45	4:00	9/8/01 9:45	643
TC06-42	9/8/01 11:45	9/8/01 18:45	7:00	9/8/01 15:15	648
TC06-43	9/9/01 08:45	9/9/01 16:45	8:00	9/9/01 12:45	670
TC06-44	9/10/01 06:15	9/10/01 21:15	15:00	9/10/01 13:45	695
TC06-45	9/11/01 02:15	9/11/01 09:15	7:00	9/11/01 5:45	711
TC06-46	9/11/01 11:15	9/11/01 17:15	6:00	9/11/01 14:15	719
TC06-47	9/13/01 04:15	9/13/01 09:30	5:15	9/13/01 6:52	760
TC06-48	9/13/01 09:30	9/15/01 10:30	49:00	9/14/01 10:00	787
TC06-49	9/15/01 12:00	9/15/01 22:00	10:00	9/15/01 17:00	818
TC06-50	9/15/01 22:00	9/16/01 10:30	12:30	9/16/01 4:15	829
TC06-51	9/16/01 11:00	9/16/01 19:00	8:00	9/16/01 15:00	840
TC06-52	9/16/01 19:15	9/17/01 07:15	12:00	9/17/01 1:15	850
TC06-53	9/17/01 07:15	9/17/01 13:15	6:00	9/17/01 10:15	859
TC06-54	9/17/01 14:00	9/18/01 9:00	19:00	9/17/01 23:30	873
TC06-55	9/18/01 13:00	9/19/01 9:00	20:00	9/18/01 23:00	896
TC06-56	9/19/01 09:00	9/19/01 13:00	4:00	9/19/01 11:00	908
TC06-57	9/19/01 13:45	9/19/01 17:45	4:00	9/19/01 15:45	913
TC06-58	9/19/01 19:15	9/20/01 15:15	20:00	9/20/01 5:15	926
TC06-59	9/20/01 16:15	9/21/01 00:15	8:00	9/20/01 20:15	941
TC06-60	9/21/01 00:30	9/21/01 06:30	6:00	9/21/01 3:30	949
TC06-61	9/21/01 09:30	9/21/01 21:00	11:30	9/21/01 15:15	960
TC06-62	9/21/01 21:00	9/22/01 13:00	16:00	9/22/01 5:00	974
TC06-63	9/22/01 19:00	9/23/01 14:00	19:00	9/23/01 4:30	998
TC06-64	9/23/01 15:00	9/24/01 06:00	15:00	9/23/01 22:30	1,016

Table 4.3-2 Operating Conditions

Operating Periods	Average Relative Hours	Mixing Zone Temperature TI344 °F	Pressure PI287 psig	PCD Inlet Temperature TI458 °F	Air Rate lb/hr	Synthesis Gas Rate lb/hr	Nitrogen Rate ¹ lb/hr
TC06-1	21	1,756	212	752	16,201	28,356	6,697
TC06-2	29	1,733	212	743	15,773	27,784	6,684
TC06-3	34	1,737	212	754	16,627	29,080	6,117
TC06-4	41	1,746	212	752	16,865	29,532	6,308
TC06-5	55	1,748	212	752	16,721	29,426	6,313
TC06-6	74	1,750	212	749	16,868	29,686	6,494
TC06-7	84	1,748	212	748	16,726	29,321	6,598
TC06-8	91	1,759	212	753	17,252	30,154	6,740
TC06-9	124	1,755	210	752	16,690	29,207	6,777
TC06-10	146	1,757	210	756	17,259	30,206	6,961
TC06-11	153	1,756	210	755	17,163	30,009	6,950
TC06-12	189	1,756	210	752	16,233	28,487	6,730
TC06-13	199	1,759	210	755	16,799	29,276	6,613
TC06-14	222	1,766	210	759	16,575	28,916	6,753
TC06-15	234	1,717	196	737	14,830	26,589	7,254
TC06-16	244	1,739	196	757	15,226	26,858	6,750
TC06-17	255	1,751	196	757	15,775	27,328	6,774
TC06-18	270	1,690	190	732	12,391	23,618	7,776
TC06-19	280	1,702	190	735	13,318	24,328	7,046
TC06-20	297	1,701	200	709	13,213	23,760	6,623
TC06-21	309	1,711	190	713	13,265	23,969	6,749
TC06-22	336	1,720	196	710	13,625	24,226	6,474
TC06-23	354	1,721	196	712	14,080	24,772	6,546
TC06-24	374	1,723	200	716	13,880	24,490	6,441
TC06-25	390	1,726	200	718	14,093	24,694	6,502
TC06-26	420	1,748	200	726	14,461	24,986	6,497
TC06-27	449	1,745	200	725	14,464	25,051	6,426
TC06-28	470	1,748	200	728	14,573	25,354	6,573
TC06-29	477	1,742	200	723	14,286	25,032	6,465
TC06-30	486	1,744	200	727	14,613	25,384	6,402
TC06-31	494	1,747	200	728	14,525	25,308	6,512
TC06-32	498	1,752	200	727	14,080	25,240	6,620

1. Feed Nitrogen was determined by subtracting 1,000 lb/hr from FI609 reading to account for nitrogen losses.

Table 4.3-2 Operating Conditions (continued)

Operating Periods	Average Relative Hours	Mixing Zone Temperature TI344 °F	Pressure PI287 psig	PCD Inlet Temperature TI458 °F	Air Rate lb/hr	Synthesis Gas Rate lb/hr	Nitrogen Rate ¹ lb/hr
TC06-33	505	1,750	200	730	14,914	25,660	6,386
TC06-34	520	1,751	200	730	14,969	25,936	6,623
TC06-35	534	1,753	200	728	14,767	25,553	6,626
TC06-36	548	1,756	200	732	14,999	26,668	6,491
TC06-37	555	1,756	200	729	14,957	25,692	6,332
TC06-38	569	1,740	200	723	14,456	25,212	6,447
TC06-39	586	1,745	200	723	14,416	25,127	6,451
TC06-40	608	1,756	200	727	14,578	25,439	6,333
TC06-41	643	1,778	200	729	15,449	26,691	6,413
TC06-42	648	1,756	200	712	14,520	25,486	6,341
TC06-43	670	1,770	200	721	15,228	26,374	6,402
TC06-44	695	1,770	200	721	15,231	26,429	6,389
TC06-45	711	1,752	200	708	14,353	25,608	6,786
TC06-46	719	1,760	200	711	14,923	25,959	6,261
TC06-47	760	1,753	200	675	12,176	22,001	6,200
TC06-48	787	1,755	200	679	12,450	22,284	6,028
TC06-49	818	1,755	200	674	12,213	22,018	6,106
TC06-50	829	1,755	200	673	12,032	21,843	6,167
TC06-51	840	1,755	200	672	12,027	21,741	6,297
TC06-52	850	1,756	220	670	11,841	21,331	6,297
TC06-53	859	1,768	220	679	12,129	21,456	6,115
TC06-54	873	1,770	220	692	13,161	23,013	6,047
TC06-55	896	1,772	220	700	14,009	24,166	5,866
TC06-56	908	1,770	220	705	14,309	24,370	5,938
TC06-57	913	1,772	220	705	14,471	24,906	5,933
TC06-58	926	1,770	230	698	14,087	24,021	5,577
TC06-59	941	1,772	230	704	14,419	24,578	5,571
TC06-60	949	1,774	230	711	15,055	25,582	5,715
TC06-61	960	1,772	230	713	15,167	25,913	5,902
TC06-62	974	1,773	230	727	16,099	27,491	6,129
TC06-63	998	1,788	230	733	16,392	27,579	6,043
TC06-64	1016	1,776	230	725	16,124	27,376	6,019

Note: Feed Nitrogen was determined by subtracting 1,000 pounds per hour from FI609 reading to account for nitrogen losses

Table 4.3-3 Gas Compositions, Molecular Weight, and Heating Value

Operating Period	Average Relative Hour	H ₂ O Mole %	CO Mole %	H ₂ ¹ Mole %	CO ₂ Mole %	CH ₄ ² Mole %	C ₂ H ₆ ⁺² Mole %	N ₂ ³ Mole %	Total Mole %	Measured WGS K _p	WGS Eqm. Temp. °F	Calculated WGS K _p @ TI344	Syngas MW lb./Mole	Syngas CO/CO ₂ Ratio	Syngas LHV Btu/SCF
TC06-1	21	10.9	10.4	10.2	7.1	1.2	0.0	60.2	100.0			0.64	25.2	1.5	73
TC06-2	29	10.9	10.0	10.1	7.1	1.2	0.0	60.7	100.0			0.66	25.3	1.4	71
TC06-3	34	10.9	9.4	9.5	7.2	1.2	0.0	61.8	100.0			0.66	25.4	1.3	68
TC06-4	41	10.7	10.0	9.8	7.2	1.2	0.0	61.1	100.0			0.65	25.4	1.4	70
TC06-5	55	10.4	9.7	9.1	7.2	1.2	0.0	62.4	100.0			0.65	25.6	1.3	67
TC06-6	74	9.8	10.3	7.1	8.3	1.2	0.0	63.2	100.0	0.58	1,829	0.65	26.4	1.2	64
TC06-7	84	9.5	10.2	7.1	8.4	1.3	0.0	63.5	100.0	0.62	1,782	0.65	26.4	1.2	64
TC06-8	91	9.2	10.8	7.2	8.2	1.3	0.0	63.4	100.0	0.60	1,809	0.64	26.4	1.3	66
TC06-9	124	7.8	10.5	7.1	7.9	1.3	0.0	65.4	100.0	0.69	1,707	0.64	26.5	1.3	65
TC06-10	146	7.5	11.1	7.1	8.0	1.3	0.0	65.0	100.0	0.68	1,714	0.64	26.5	1.4	67
TC06-11	153	7.4	11.3	7.1	7.9	1.3	0.0	65.0	100.0	0.66	1,736	0.64	26.5	1.4	68
TC06-12	189	7.2	11.6	6.7	7.5	1.3	0.0	65.7	100.0	0.61	1,799	0.64	26.6	1.6	68
TC06-13	199	7.1	11.6	7.0	7.8	1.3	0.0	65.3	100.0	0.66	1,742	0.64	26.6	1.5	68
TC06-14	222	7.9	11.4	6.9	7.6	1.3	0.0	65.0	100.0	0.58	1,831	0.63	26.5	1.5	67
TC06-15	234	6.7	11.0	5.2	8.7	1.7	0.0	66.6	100.0	0.61	1,789	0.68	27.1	1.3	66
TC06-16	244	6.7	11.2	6.2	9.2	1.5	0.0	65.2	100.0	0.76	1,649	0.66	27.0	1.2	67
TC06-17	255	6.7	12.0	7.4	8.1	1.4	0.0	64.4	100.0	0.75	1,653	0.65	26.5	1.5	72
TC06-18	270	6.7	9.0	5.7	8.1	1.3	0.0	69.1	100.0	0.77	1,639	0.71	27.0	1.1	57
TC06-19	280	6.7	10.4	6.3	8.2	1.5	0.0	67.0	100.0	0.75	1,654	0.70	26.8	1.3	64
TC06-20	297	6.5	10.7	6.2	8.1	1.5	0.0	67.0	100.0	0.72	1,678	0.70	26.8	1.3	66
TC06-21	309	6.4	10.6	6.1	7.9	1.4	0.0	67.6	100.0	0.72	1,677	0.69	26.9	1.3	64
TC06-22	336	6.1	11.9	6.5	7.4	1.5	0.0	66.6	100.0	0.68	1,722	0.68	26.7	1.6	70
TC06-23	354	5.9	12.1	6.6	7.5	1.5	0.0	66.4	100.0	0.70	1,699	0.68	26.7	1.6	71
TC06-24	374	5.8	11.8	6.7	7.7	1.4	0.0	66.5	100.0	0.75	1,652	0.67	26.8	1.5	70
TC06-25	390	5.8	12.0	6.9	7.8	1.5	0.0	66.0	100.0	0.77	1,638	0.67	26.7	1.5	71
TC06-26	420	5.8	12.2	6.9	7.7	1.3	0.0	66.1	100.0	0.75	1,653	0.65	26.7	1.6	70
TC06-27	449	6.2	11.9	6.9	7.7	1.4	0.0	65.8	100.0	0.72	1,675	0.65	26.6	1.5	70
TC06-28	470	6.3	11.7	6.9	7.7	1.2	0.0	66.1	100.0	0.71	1,687	0.65	26.7	1.5	68
TC06-29	477	6.4	11.6	6.9	7.8	1.4	0.0	65.8	100.0	0.74	1,665	0.66	26.6	1.5	69
TC06-30	486	6.4	12.0	7.0	7.7	1.4	0.0	65.5	100.0	0.71	1,687	0.65	26.6	1.5	70
TC06-31	494	6.4	11.7	6.9	7.7	1.3	0.0	66.0	100.0	0.71	1,686	0.65	26.7	1.5	68
TC06-32	498	6.4	11.2	6.7	7.8	1.1	0.0	66.9	100.0	0.73	1,670	0.65	26.7	1.4	64

Notes:

1. TC06-1 to TC06-5: H₂ determined from water-gas shift reaction and thermodynamic equilibrium data.
2. TC06-1 to TC06-14: CH₄ and C₂⁺ determined from the average of TC06-15 to TC06-64 data.
3. TC06-3 to TC06-5: N₂ data determined by difference.

Table 4.3-3 Gas Compositions, Molecular Weight, and Heating Value (continued)

Operating Period	Average Relative Hour	H ₂ O Mole %	CO Mole %	H ₂ Mole %	CO ₂ Mole %	CH ₄ Mole %	C ₂ H ₆ ⁺ Mole %	N ₂ Mole %	Total Mole %	Measured WGS K _p	WGS Eqm. Temp. °F	Calculated WGS K _p @ T1344	Syngas MW lb./Mole	Syngas CO/CO ₂ Ratio	Syngas LHV Btu/SCF
TC06-33	505	6.4	12.3	7.1	7.7	1.3	0.0	65.2	100.0	0.69	1,709	0.65	26.6	1.6	71
TC06-34	520	6.4	12.0	6.9	7.6	1.3	0.0	65.8	100.0	0.67	1,727	0.65	26.6	1.6	69
TC06-35	534	6.5	12.1	6.8	7.4	1.2	0.0	66.0	100.0	0.64	1,764	0.65	26.6	1.6	69
TC06-36	548	6.5	12.3	6.9	7.4	1.2	0.0	65.8	100.0	0.64	1,763	0.64	26.6	1.7	69
TC06-37	555	6.6	12.5	7.2	7.5	1.3	0.0	64.9	100.0	0.65	1,752	0.64	26.5	1.7	72
TC06-38	569	6.9	12.0	7.0	7.7	1.3	0.0	65.1	100.0	0.65	1,747	0.66	26.5	1.6	70
TC06-39	586	7.0	12.0	7.0	7.6	1.3	0.0	65.2	100.0	0.63	1,772	0.65	26.5	1.6	70
TC06-40	608	7.4	12.0	6.9	7.5	1.2	0.0	65.0	100.0	0.59	1,824	0.64	26.5	1.6	69
TC06-41	643	8.1	12.3	7.1	7.5	1.2	0.0	63.7	100.0	0.54	1,887	0.62	26.4	1.6	70
TC06-42	648	8.0	11.9	7.0	7.6	1.3	0.0	64.1	100.0	0.56	1,855	0.64	26.4	1.6	70
TC06-43	670	7.7	12.2	7.1	7.6	1.2	0.0	64.1	100.0	0.58	1,837	0.63	26.4	1.6	70
TC06-44	695	7.5	12.1	7.0	7.6	1.3	0.0	64.6	100.0	0.58	1,828	0.63	26.5	1.6	70
TC06-45	711	8.1	11.1	6.6	7.6	1.2	0.0	65.4	100.0	0.55	1,871	0.65	26.5	1.5	65
TC06-46	719	8.2	12.0	7.1	7.6	1.3	0.0	63.7	100.0	0.54	1,882	0.64	26.4	1.6	70
TC06-47	760	8.5	10.6	6.2	7.5	1.0	0.0	66.2	100.0	0.51	1,926	0.65	26.6	1.4	61
TC06-48	787	7.8	11.2	6.4	7.5	1.1	0.0	66.1	100.0	0.55	1,877	0.64	26.6	1.5	63
TC06-49	818	7.8	11.1	6.3	7.4	1.0	0.0	66.3	100.0	0.54	1,886	0.64	26.7	1.5	63
TC06-50	829	8.0	10.6	6.1	7.5	0.9	0.0	66.9	100.0	0.54	1,888	0.64	26.7	1.4	59
TC06-51	840	8.2	10.9	6.4	7.4	1.0	0.0	66.1	100.0	0.53	1,894	0.64	26.6	1.5	62
TC06-52	850	8.3	11.0	6.2	7.4	1.0	0.0	66.1	100.0	0.50	1,941	0.64	26.6	1.5	62
TC06-53	859	8.5	11.0	6.2	7.3	0.9	0.0	66.1	100.0	0.48	1,978	0.63	26.6	1.5	61
TC06-54	873	8.4	11.6	6.5	7.4	1.0	0.0	65.0	100.0	0.49	1,962	0.63	26.5	1.6	64
TC06-55	896	7.8	12.3	6.9	7.4	1.2	0.0	64.4	100.0	0.52	1,910	0.63	26.5	1.7	69
TC06-56	908	7.3	12.6	7.0	7.4	1.2	0.0	64.5	100.0	0.56	1,856	0.63	26.5	1.7	71
TC06-57	913	7.3	12.6	6.9	7.4	1.2	0.0	64.7	100.0	0.56	1,861	0.63	26.5	1.7	70
TC06-58	926	7.3	13.0	7.0	7.3	1.3	0.0	64.1	100.0	0.54	1,882	0.63	26.5	1.8	73
TC06-59	941	7.5	13.2	7.1	7.3	1.3	0.0	63.6	100.0	0.53	1,906	0.63	26.4	1.8	74
TC06-60	949	7.6	13.1	7.1	7.3	1.4	0.0	63.5	100.0	0.52	1,915	0.63	26.4	1.8	75
TC06-61	960	7.7	13.1	7.1	7.4	1.4	0.0	63.4	100.0	0.52	1,915	0.63	26.4	1.8	74
TC06-62	974	7.5	13.1	7.2	7.5	1.4	0.0	63.3	100.0	0.55	1,876	0.63	26.4	1.7	75
TC06-63	998	7.3	13.5	7.3	7.4	1.4	0.0	63.1	100.0	0.55	1,879	0.62	26.4	1.8	76
TC06-64	1016	7.2	13.3	7.5	7.5	1.5	0.0	63.0	100.0	0.58	1,825	0.63	26.3	1.8	77

1. TC06-1 to TC06-5: H₂ determined from water-gas shift reaction and thermodynamic equilibrium data.
2. TC06-1 to TC06-14: CH₄ and C₂⁺ determined from the average of TC06-15 to TC06-64 data.
3. TC06-3 to TC06-5: N₂ data determined by difference.

Table 4.3-4 Corrected² Gas Compositions, Molecular Weight, and Heating Value

Operating Period	Average Relative Hour	H ₂ O Mole %	CO Mole %	H ₂ Mole %	CO ₂ Mole %	CH ₄ Mole %	C ₂ H ₆ ⁺ Mole %	N ₂ Mole %	Total Mole %	Syngas MW lb./Mole	Syngas LHV Btu/SCF
TC06-1	21	14.9	16.4	16.0	7.7	1.9	0.0	43.1	100.0	23.3	114
TC06-2	29	15.1	16.0	16.2	7.8	1.9	0.0	43.0	100.0	23.3	114
TC06-3	34	15.2	15.2	15.3	8.0	2.0	0.0	44.2	100.0	23.5	109
TC06-4	41	14.8	15.9	15.5	8.0	1.9	0.0	43.8	100.0	23.5	112
TC06-5	55	14.6	15.9	14.9	8.1	2.0	0.0	44.5	100.0	23.7	110
TC06-6	74	13.6	16.8	11.5	9.9	2.0	0.0	46.2	100.0	25.0	104
TC06-7	84	13.2	16.5	11.6	10.0	2.1	0.0	46.6	100.0	25.0	104
TC06-8	91	12.5	17.4	11.7	9.6	2.0	0.0	46.7	100.0	25.0	107
TC06-9	124	10.6	17.8	12.1	9.4	2.2	0.0	48.0	100.0	25.0	110
TC06-10	146	10.0	18.6	11.9	9.5	2.2	0.0	47.8	100.0	25.1	113
TC06-11	153	9.9	19.0	11.9	9.3	2.2	0.0	47.7	100.0	25.1	114
TC06-12	189	9.6	19.8	11.5	8.7	2.2	0.0	48.1	100.0	25.1	116
TC06-13	199	9.4	19.4	11.7	9.1	2.2	0.0	48.2	100.0	25.2	115
TC06-14	222	10.7	19.0	11.5	8.8	2.2	0.0	47.9	100.0	25.1	113
TC06-15	234	8.9	19.2	9.1	10.9	3.0	0.0	48.7	100.0	26.1	115
TC06-16	244	8.7	18.7	10.3	11.5	2.5	0.0	48.3	100.0	26.0	112
TC06-17	255	8.6	19.7	12.2	9.5	2.3	0.0	47.7	100.0	25.2	118
TC06-18	270	9.8	18.3	11.6	10.7	2.7	0.0	47.0	100.0	25.4	115
TC06-19	280	9.1	19.0	11.6	10.2	2.7	0.0	47.3	100.0	25.3	118
TC06-20	297	8.7	19.4	11.3	9.9	2.8	0.0	48.0	100.0	25.4	119
TC06-21	309	8.6	19.5	11.3	9.8	2.6	0.0	48.2	100.0	25.4	118
TC06-22	336	7.9	21.1	11.6	8.7	2.7	0.0	48.1	100.0	25.2	124
TC06-23	354	7.5	21.3	11.6	8.7	2.6	0.0	48.4	100.0	25.3	124
TC06-24	374	7.4	20.8	11.7	9.2	2.5	0.0	48.4	100.0	25.4	122
TC06-25	390	7.3	20.8	11.9	9.2	2.6	0.0	48.3	100.0	25.3	123
TC06-26	420	7.3	20.8	11.8	8.9	2.2	0.0	49.0	100.0	25.3	120
TC06-27	449	7.9	20.3	11.8	9.0	2.3	0.0	48.6	100.0	25.3	119
TC06-28	470	8.1	20.1	11.8	9.1	2.1	0.0	48.8	100.0	25.3	117
TC06-29	477	8.2	20.1	11.9	9.3	2.4	0.0	48.1	100.0	25.2	120
TC06-30	486	8.1	20.3	11.9	9.0	2.3	0.0	48.3	100.0	25.2	119
TC06-31	494	8.2	20.1	11.9	9.1	2.2	0.0	48.5	100.0	25.3	118
TC06-32	498	8.5	20.2	12.1	9.4	1.9	0.0	47.9	100.0	25.3	116

Notes:

1. See Table 4.3-3 for assumptions on gas compositions.
2. Correction is to assume that only air nitrogen is in the synthesis gas and that the reactor is adiabatic.

Table 4.3-4 Corrected² Gas Compositions, Molecular Weight, and Heating Value (continued)

Operating Period	Average Relative Hour	H ₂ O Mole %	CO Mole %	H ₂ Mole %	CO ₂ Mole %	CH ₄ Mole %	C ₂ H ₆ ⁺ Mole %	N ₂ Mole %	Total Mole %	Syngas MW lb./Mole	Syngas LHV Btu/SCF
TC06-33	505	8.1	20.5	11.8	8.8	2.2	0.0	48.5	100.0	25.2	119
TC06-34	520	8.3	20.4	11.6	8.8	2.2	0.0	48.7	100.0	25.3	117
TC06-35	534	8.4	20.7	11.5	8.4	2.1	0.0	48.8	100.0	25.2	118
TC06-36	548	8.6	21.4	12.0	8.6	2.0	0.0	47.5	100.0	25.1	120
TC06-37	555	8.5	20.7	11.9	8.5	2.1	0.0	48.3	100.0	25.1	119
TC06-38	569	9.1	20.1	11.9	8.9	2.3	0.0	47.8	100.0	25.1	118
TC06-39	586	9.2	20.3	11.8	8.7	2.2	0.0	47.9	100.0	25.1	117
TC06-40	608	9.9	20.2	11.7	8.5	2.0	0.0	47.6	100.0	25.1	116
TC06-41	643	10.8	19.9	11.6	8.5	2.0	0.0	47.3	100.0	25.0	114
TC06-42	648	10.9	19.7	11.7	8.7	2.2	0.0	46.7	100.0	25.0	116
TC06-43	670	10.2	20.0	11.7	8.7	2.0	0.0	47.4	100.0	25.1	115
TC06-44	695	10.0	20.0	11.6	8.7	2.1	0.0	47.6	100.0	25.1	115
TC06-45	711	11.3	19.4	11.4	8.8	2.1	0.0	47.0	100.0	25.0	113
TC06-46	719	11.1	19.7	11.5	8.7	2.2	0.0	46.9	100.0	25.0	115
TC06-47	760	12.3	19.4	11.3	8.7	1.8	0.0	46.5	100.0	25.0	110
TC06-48	787	10.9	20.2	11.4	8.6	1.9	0.0	46.9	100.0	25.1	114
TC06-49	818	11.1	20.2	11.4	8.6	1.9	0.0	46.7	100.0	25.1	114
TC06-50	829	11.6	19.7	11.3	8.9	1.7	0.0	46.9	100.0	25.1	110
TC06-51	840	11.7	19.8	11.6	8.6	1.9	0.0	46.4	100.0	25.0	113
TC06-52	850	12.0	19.9	11.2	8.6	1.9	0.0	46.5	100.0	25.0	112
TC06-53	859	12.1	19.7	11.0	8.3	1.6	0.0	47.3	100.0	25.1	108
TC06-54	873	11.7	19.9	11.2	8.3	1.7	0.0	47.2	100.0	25.0	110
TC06-55	896	10.4	20.5	11.4	8.2	1.9	0.0	47.6	100.0	25.1	115
TC06-56	908	9.5	20.7	11.4	8.3	1.9	0.0	48.3	100.0	25.2	115
TC06-57	913	9.6	20.8	11.5	8.3	2.0	0.0	48.0	100.0	25.1	116
TC06-58	926	9.5	21.1	11.4	8.1	2.1	0.0	47.8	100.0	25.1	119
TC06-59	941	9.6	21.2	11.4	8.0	2.1	0.0	47.6	100.0	25.1	119
TC06-60	949	9.8	20.9	11.3	8.1	2.2	0.0	47.7	100.0	25.1	119
TC06-61	960	9.9	20.9	11.3	8.1	2.2	0.0	47.5	100.0	25.1	119
TC06-62	974	9.7	20.7	11.4	8.3	2.3	0.0	47.5	100.0	25.1	119
TC06-63	998	9.3	21.0	11.4	8.1	2.1	0.0	48.0	100.0	25.1	118
TC06-64	1016	9.1	20.9	11.7	8.3	2.4	0.0	47.6	100.0	25.1	121

Notes:

1. See Table 4.3-3 for assumptions on gas compositions.
2. Correction is to assume that only air nitrogen is in the synthesis gas and that the reactor is adiabatic.

Table 4.3-5 Synthesis Gas Combustor Calculations

Operating Period	Average Relative Hour	AIT8775 SGC Exit O ₂ M %	Calculated SGC Exit O ₂ M %	Gas Analyzer LHV Btu/SCF	Energy Balance LHV ¹ Btu/SCF	Combustor SO ₂ AI534A ppm	Syngas Total Reduced Sulfur ² ppm	Thermo. Equilibrium H ₂ S ppm
TC06-1	21	6.0	5.4	73	68	74	155	223
TC06-2	29	6.0	5.2	71	66	85	175	223
TC06-3	34	6.0	5.9	68	68	107	228	224
TC06-4	41	6.1	5.6	70	67	94	198	221
TC06-5	55	6.0	5.5	67	65	98	205	214
TC06-6	74	6.0	6.1	64	67	87	184	214
TC06-7	84	6.1	6.1	64	68	76	163	208
TC06-8	91	6.2	6.4	66	69	73	160	198
TC06-9	124	6.1	6.3	65	67	85	186	166
TC06-10	146	6.1	5.6	67	65	91	189	160
TC06-11	153	6.1	5.8	68	67	90	191	158
TC06-12	189	6.4	5.7	68	65	85	179	149
TC06-13	199	6.1	5.6	68	66	86	179	150
TC06-14	222	6.1	5.5	67	65	80	165	165
TC06-15	234	7.5	7.7	66	72	68	165	143
TC06-16	244	6.6	6.6	67	70	86	193	147
TC06-17	255	5.8	5.7	72	72	99	212	140
TC06-18	270	7.6	7.7	57	63	48	112	138
TC06-19	280	7.8	7.9	64	69	41	101	138
TC06-20	297	7.7	7.9	66	71	40	99	136
TC06-21	309	7.4	7.5	64	69	65	154	130
TC06-22	336	6.8	6.9	70	73	63	147	123
TC06-23	354	6.1	6.3	71	73	66	146	119
TC06-24	374	5.6	5.5	70	71	48	101	120
TC06-25	390	7.3	7.4	71	73	56	136	120
TC06-26	420	6.0	5.9	70	70	43	93	120
TC06-27	449	6.1	5.9	70	70	59	126	129
TC06-28	470	6.1	5.7	68	67	52	109	131
TC06-29	477	6.1	5.9	69	70	63	136	132
TC06-30	486	6.1	6.0	70	71	59	128	132
TC06-31	494	6.0	5.6	68	68	68	142	132
TC06-32	498	5.8	5.3	64	62	67	134	133

Notes:

1. Energy LHV calculated assuming the sythesis gas combustor heat loss was 2.25×10^6 Btu/hr.
2. Synthesis gas total reduced sulfur (TRS) estimated from Synthesis gas combustor SO₂ analyzer data.

Table 4.3-5 Synthesis Gas Combustor Calculations (continued)

Operating Period	Average Relative Hour	AIT8775 SGC Exit O ₂ M %	Calculated SGC Exit O ₂ M %	Gas Analyzer LHV Btu/SCF	Energy Balance LHV ¹ Btu/SCF	Combustor SO ₂ AI534A ppm	Syngas Total Reduced Sulfur ² ppm	Thermo. Equilibrium H ₂ S ppm
TC06-33	505	6.3	6.2	71	72	48	105	132
TC06-34	520	6.1	5.8	69	69	58	124	132
TC06-35	534	6.1	5.9	69	69	49	105	132
TC06-36	548	6.1	5.7	69	67	55	116	132
TC06-37	555	6.3	6.4	72	72	47	106	136
TC06-38	569	6.1	6.1	70	70	67	146	143
TC06-39	586	6.0	6.0	70	69	75	161	144
TC06-40	608	6.0	6.0	69	69	75	161	151
TC06-41	643	6.2	6.2	70	70	89	196	166
TC06-42	648	6.1	6.1	70	70	80	176	165
TC06-43	670	6.1	6.1	70	70	64	140	159
TC06-44	695	6.1	6.1	70	69	70	153	155
TC06-45	711	6.1	5.6	65	65	69	141	166
TC06-46	719	6.2	6.1	70	71	56	122	170
TC06-47	760	6.1	5.9	61	62	62	127	172
TC06-48	787	6.1	5.5	63	63	65	133	158
TC06-49	818	6.1	5.4	63	62	65	131	159
TC06-50	829	6.0	5.1	59	58	56	109	163
TC06-51	840	6.1	5.5	62	60	73	148	166
TC06-52	850	6.1	5.2	62	60	54	108	175
TC06-53	859	6.6	6.1	61	60	57	118	177
TC06-54	873	6.5	6.2	64	64	65	138	177
TC06-55	896	6.5	6.4	69	70	58	128	164
TC06-56	908	6.5	6.3	71	71	63	139	154
TC06-57	913	6.3	6.1	70	69	65	142	153
TC06-58	926	6.6	6.5	73	73	60	136	155
TC06-59	941	6.6	6.3	74	74	54	122	158
TC06-60	949	6.3	6.0	75	74	41	92	161
TC06-61	960	6.2	5.9	74	74	58	127	163
TC06-62	974	6.0	5.7	75	74	56	121	162
TC06-63	998	6.4	6.2	76	75	57	128	157
TC06-64	1016	6.1	5.9	77	77	54	120	154

Notes:

1. Energy LHV calculated assuming the sythesis gas combustor heat loss was 2.25×10^6 Btu/hr.
2. Synthesis gas total reduced sulfur (TRS) estimated from Synthesis gas combustor SO₂ analyzer data.

Table 4.3-6 Ammonia & Hydrogen Cyanide Data

Operating Period	Relative Hour	Date	Time Start	Time End	NH ₃ ppm	HCN ppm
	67	7/17/01	19:52	20:01	1,296	
	68	7/17/01	20:49	20:55		42.1
TC06-6	69	7/17/01	21:55	22:01	1,476	
TC06-6	70	7/17/01	22:30	22:36		51.4
TC06-6	71	7/17/01	23:33	23:41	1,770	
TC06-6	71	7/18/01	00:06	00:10		72.1
(1)	224	7/24/01	09:03	09:11	1,845	
(1)	225	7/24/01	09:34	09:39	1,910	
(1)	225	7/24/01	09:57	10:02	1,823	
(1)	225	7/24/01	10:20	10:24	1,770	
(1)	226	7/24/01	10:45	10:48		72.0
(1)	226	7/24/01	11:07	11:11		69.0
(1)	226	7/24/01	11:28	11:33		72.0
(1)	227	7/24/01	11:46	11:49		70.1

Note:1. Data obtained just after the end of Operating Period TC06-14.

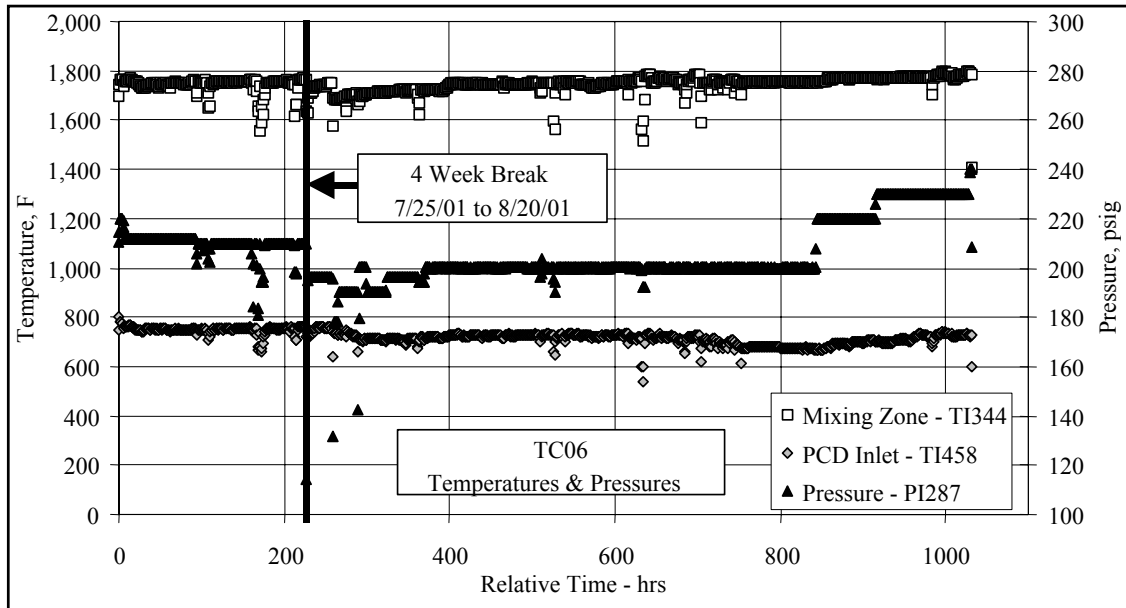


Figure 4.3-1 Temperatures & Pressures

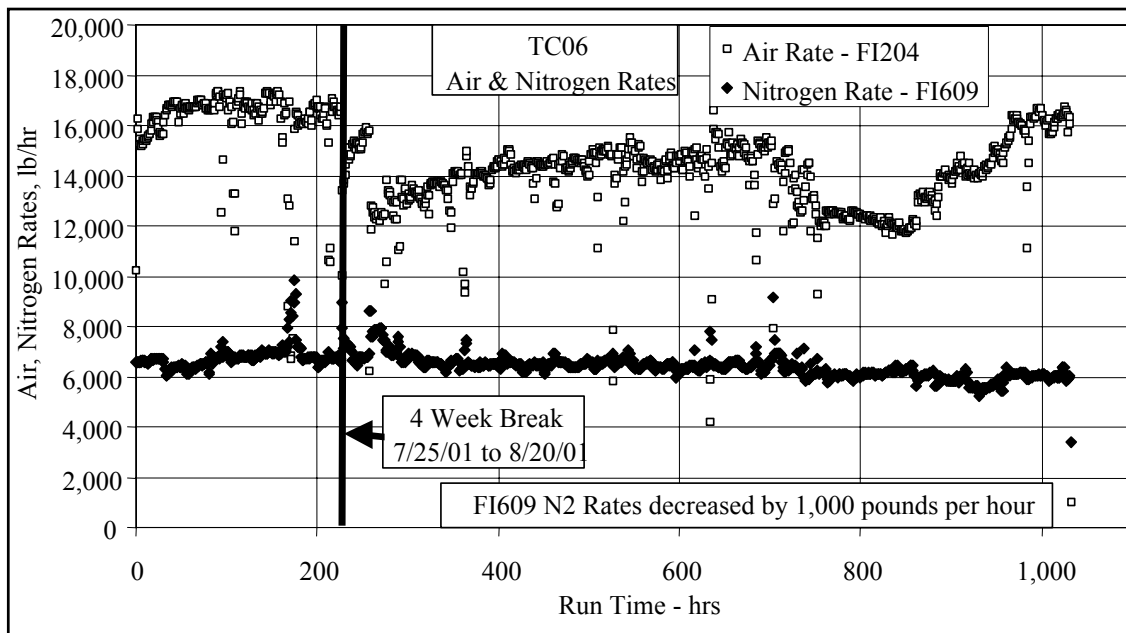


Figure 4.3-2 Air & Nitrogen Rates

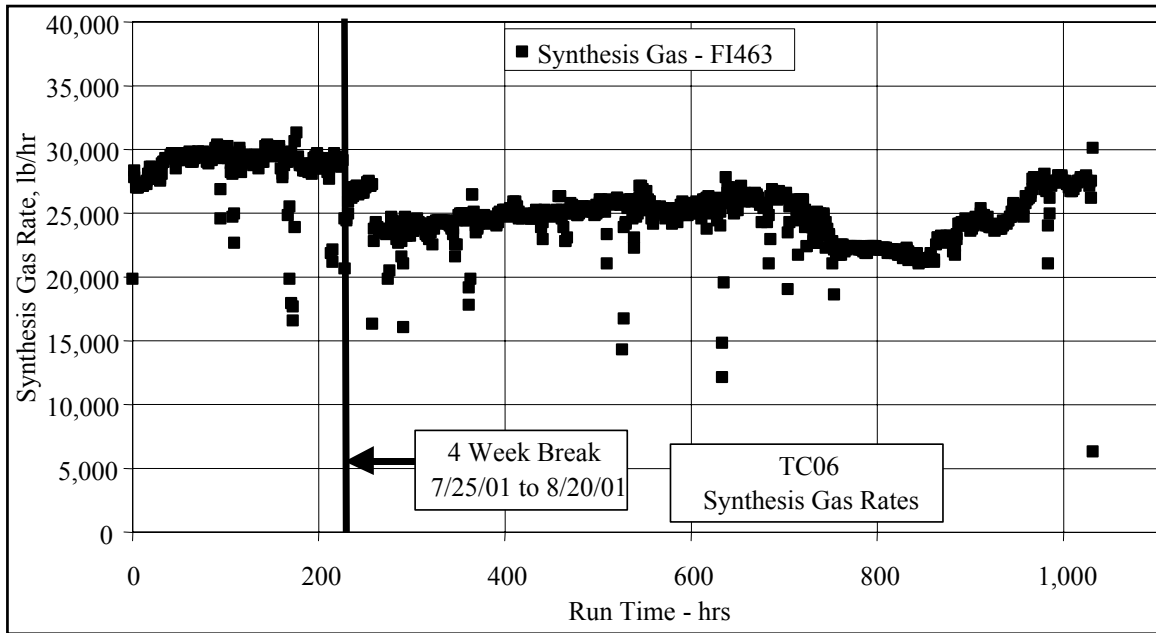


Figure 4.3-3 Synthesis Gas Rates

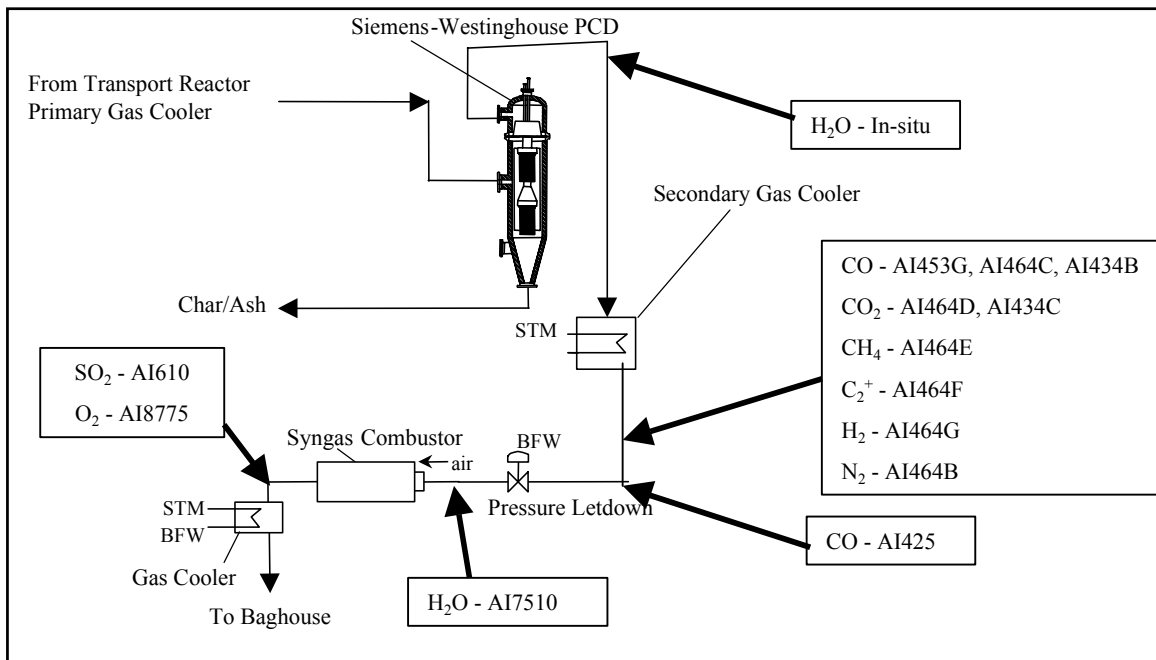


Figure 4.3-4 Gas Sampling Locations

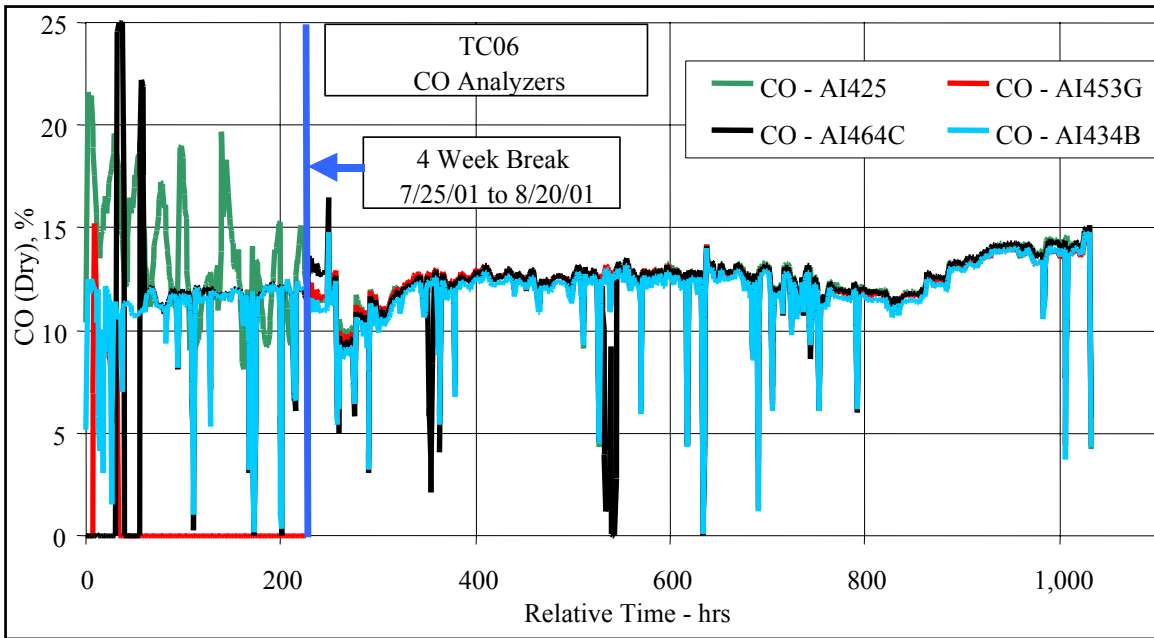


Figure 4.3-5 CO Analyzer Data

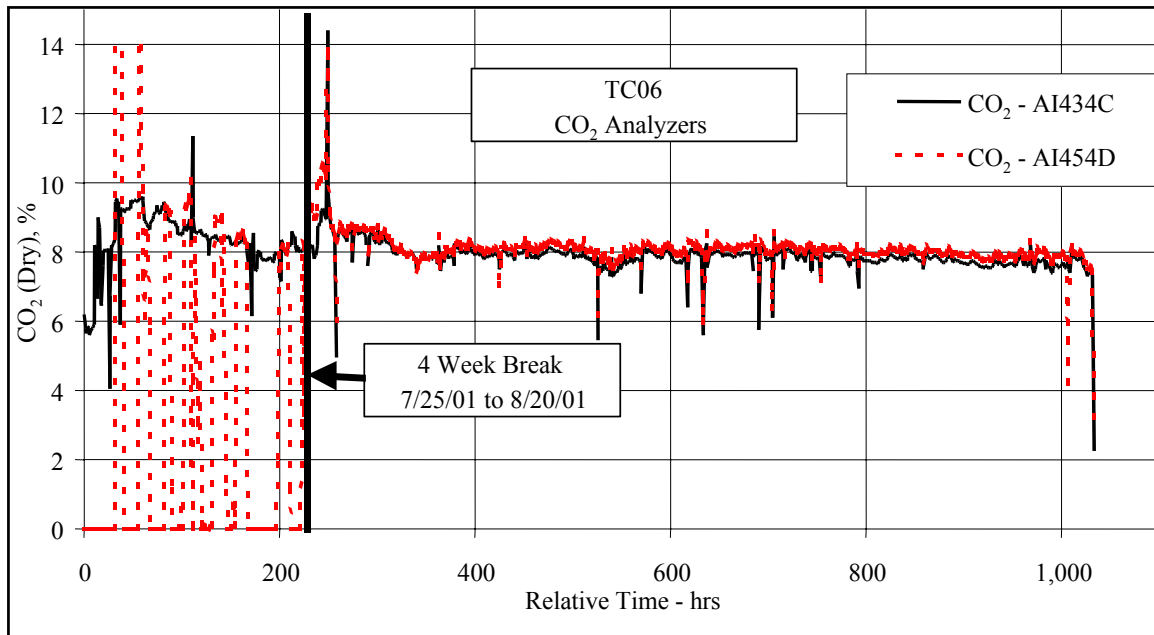


Figure 4.3-6 CO₂ Analyzer Data

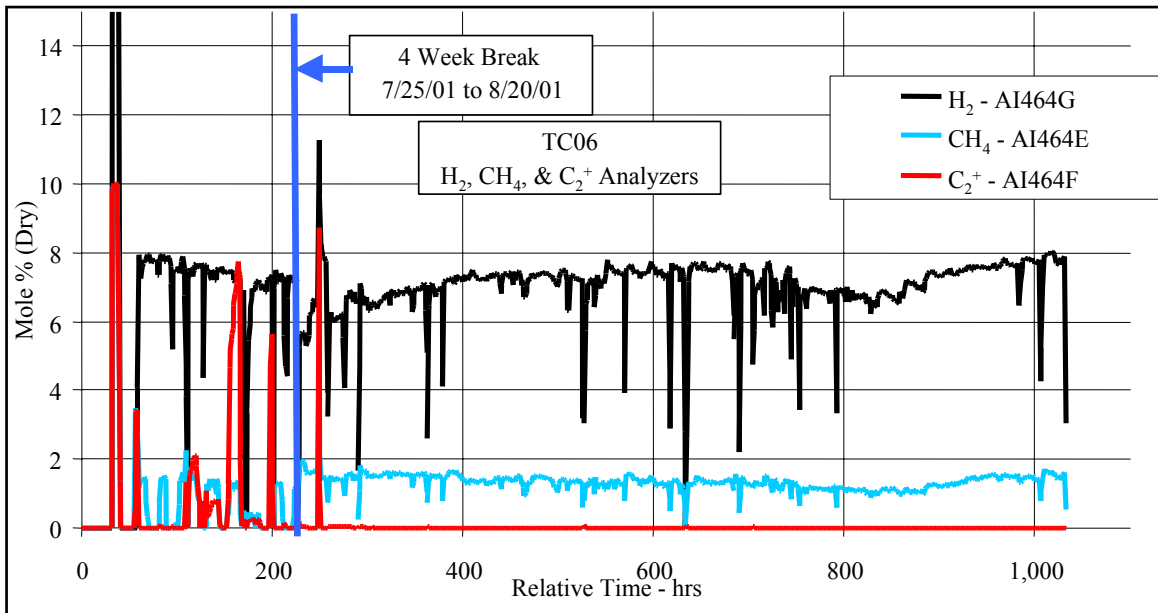


Figure 4.3-7 Analyzer H₂, CH₄, C₂⁺ Data

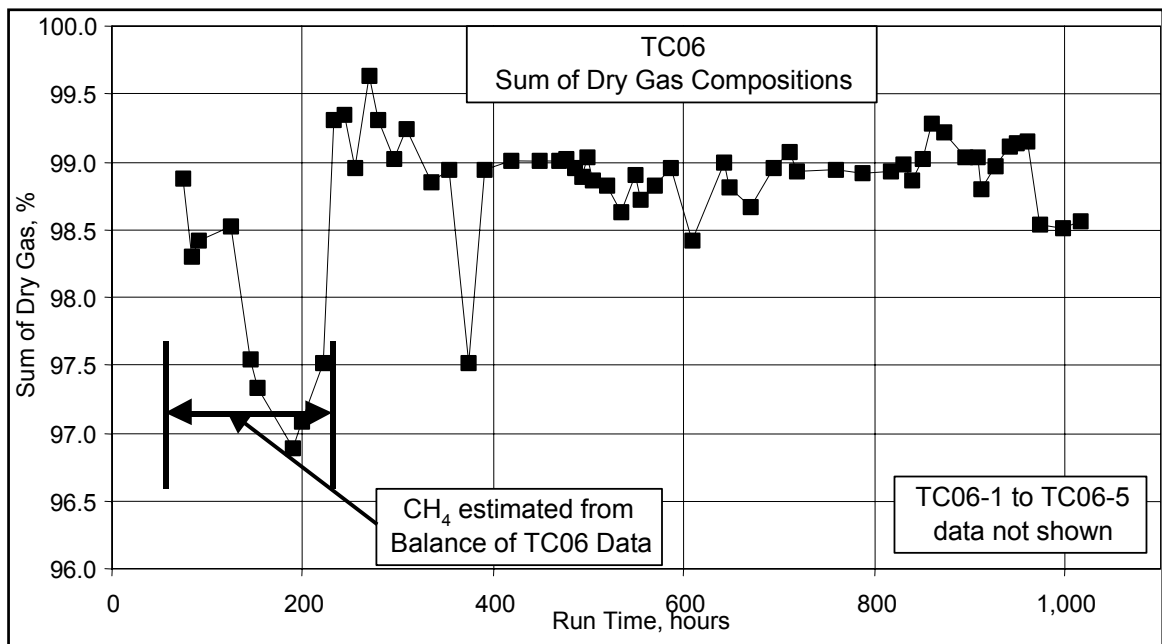


Figure 4.3-8 Sum of Dry Gas Compositions