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APPENDIX A

**DEVELOPMENT OF
A COAL-FIRED COMBUSTION SYSTEM FOR
INDUSTRIAL PROCESS HEATING APPLICATIONS**

PHASE III FINAL REPORT

CONTRACT DE-AC22-91PC91161

NOVEMBER 1992 TO DECEMBER 1994

PREPARED FOR

**U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER**

PREPARED BY

**VORTEC CORPORATION
3770 RIDGE PIKE
COLLEGEVILLE, PA 19426**

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**Vortec CMS™ Test Facility
Test 93 Log**

Date	Time	Comments
9/12	0834	Completed blending feedstock in tank. 7,242 lbs. feedstock in tank.
	0850	Established ≈ 3.7 MMBtu/hr natural gas thermal input to CRV combustor.
	0943	Initiated feedstock flow to CRV combustor.
	0945	Computer Monitor shows feedstock flow rate @ 1100#/hr.
	1000	Feedstock flow falling off - increasing set point to obtain 900-1000#/hr feedstock flow rate.
	1130	Increasing feedstock flow rate to maintain between 1000 - 1200 #/hr flow rate.
	1140	Viewport on Cyclone Melter (CM) needs cleaning. Terminating feedstock flow to clean viewport.
	1149	Viewport cleaned off. Feedstock flow back on.
	1214	Flue gas analyzers on. Adjusting air to get 4% O ₂ in flue gas.
	1233	Comprehensive Safety Compliance, Inc. (CSC) is starting Method 5 flue gas sampling.
	1411	Method 5 completed. Shutting off feedstock flow to clean out CM view port, and change over to feedstock Tank "B".
	1457	Feedstock flow turned back on.
	1607	Glass not flowing smoothly from separator/reservoir tap hole due to glass build up around hole. Stopped feedstock flow to allow cleanout of tap hole.
	1615	Tap hole clear. Feedstock flow restarted.
	1828	Feedstock Tank "B" empty. Turned of feeder.
	1841	Switched over from feedstock Tank "B" to Tank "A". Started feedstock flow on Tank "A".
	1907	Stopped feedstock flow to initiate co-firing of natural gas with coal.
	2013	Initiated coal flow and increased coal thermal input to ≈ 1.8 million Btu/hr (≈ 150 lb/hr). Decreased natural gas thermal input to ≈ 0.8 million Btu/hr.
	2138	Terminated coal flow. Increased natural gas thermal input to ≈ 2.25 million Btu/hr.
	2310	Particulate carryover in flue gas built up in flue gas quench channel (spray channel). Shutting down system to clean out channel.
9/13	0030	Restarted system on natural gas.
	0049	Initiated coal feed and increased to ≈ 2 million Btu/hr thermal input (200 lb/hr). Decreased natural gas input to ≈ 1 million Btu/hr.
	0131	Starting feedstock flow to CRV combustor.
	0619	Glass built up around separator/reservoir tap hole. Terminating batch flow to clean out tap hole.
	0631	Tap hole clean. Restarting feedstock flow to CRV combustor.
	0736	Feedstock tank empty. Turned feeder off. Shut down system to clean spray channel duct of carryover buildup.
	0815	Data recorder turned off.
	0843	Duct work and spray channel cleaned out. Started back up with ≈ 3 million Btu/hr coal and ≈ 1 million Btu/hr natural gas.
	0854	Gas and coal on - at idle - system cold - CM temperature at $\approx 1800^{\circ}\text{F}$.
	0927	Data recorder turned on.
	0954	Started feedstock flow on Tank "B". 5,890 lb feedstock in Tank "B".

	1226	CSC started Method 5 flue gas sampling.
	1310	Carryover particulate accumulating in water drain pipes from spray channel to recirculation tank causing blockage. Feedstock turned off and system shut down to clean piping. 2,614 lbs feedstock remaining in Tank "B".
	1400	Turned data recorder off until after restarting system.
	1414	Started combustion air blower.
	1429	Initiated natural gas flow to CRV combustor. CM temperature $\approx 1580^{\circ}\text{F}$.
	1559	CM temperature up to $\approx 2600^{\circ}\text{F}$. Started feedstock flow from Tank "A" (wt = 9105#). Turned data recorder on.
	1735	Terminated coal flow; increased natural gas flow.
	1850	Restarted coal flow; decreased natural gas flow.
	2030	Shut down system to remove carryover particulate accumulation in spray channel duct.
	2150	Turned of data recorder until restart.
9/14	0300	Turned on data recorder. System operating on natural gas firing at ≈ 2.75 million Btu/hr. Temperature increasing. Coal flow initiated; decreased natural gas flow.
	0342	Started feedstock flow from Tank "A" (5,237 lbs feedstock in tank).
	0555	Switch from feedstock Tank "A" to Tank "B" (7,622 lbs in Tank "B").
	0730	Shut down system to clean spray channel duct and drain pipes.
	0754	Turned off data recorder.
	0900	Started back up on natural gas.
	1105	Turned on data recorder. Initiated coal flow and decreased natural gas flow.
	1113	Started feedstock flow from Tank "B" (6,533 lbs feedstock in Tank "B").
	1210	CSC started Method 5 flue gas sampling.
	1310	Method 5 sampling complete.
	1553	CSC started Method 5 flue has sampling.
	1643	Method 5 sampling completed.
	1719	Shutt down to clean out spray channel duct.
	1754	Started back up on coal.
	1836	Restarted feedstock flow from Tank "B".
	2100	Switched from feedstock Tank "B" to Tank "A". Start feedstock flow from Tank "A" (7,445 lbs in Tank "A").
	2345	Shut down system to clean spray channel and exhaust duct.
9/15	0026	Started system back up, CM temperature at 1850°F . Increased coal flow; decreased natural gas flow.
	0103	CM temperature at $\approx 2550^{\circ}\text{F}$. Started feedstock flow from Tank "A".
	0118	Monitor indicated positive pressure in separator/reservoir. Reduced feedstock flow to 500 lb/hr until problem can be identified.
	0130	Opened exhaust damper to venturi scrubber to check duct to WESP. Monitor still indicating positive pressure with scrubber damper wide open.
	0142	Shut down system to inspect flue gas exhaust system. Pressure tape hole in separator/reservoir roof was plugged.
	0202	Determined that pressure tap hole in separator/reservoir roof was plugged. Cleaned tap hole. Started back up on coal. Pressure reading still high.
	0240	Terminated batch flow and reducing thermal input (coal flow) to check out separator/reservoir pressure transducer.

	0320	Switched impulse line from separator/reservoir to CM transducer. Pressure reading good. Restarted feedstock flow. Monitored separator/reservoir pressure at CM pressure location while recalibrating separator/reservoir transducer.
	0410	Recalibrated separator/reservoir pressure transducer and switched impulse line back.
	0530	Lost coal ignition in CRV combustor. Glass flow stopped and system cooled down. Went to gas firing to melt out and raise temperature.
	0645	Restarted feedstock flow and increased natural gas input.
	0735	Shut down system to clean out spray channel duct.
	0817	Restarted system on natural gas.
	0850	Initiated coal feed and decreased natural gas flow.
	0928	Restarted feedstock flow.
	1040	Water drain pipe from spray channel to scrubber recirculation tanks plugged. Shut down to clean pipe.
	1244	Starting up again and reheated on natural gas.
	1410	Water drain system from spray channel to recirculation tanks plugged again. Shut down to inspect system.
	1515	Removed and cleaned valves in water drain system. Started back up to reheat system on natural gas.
	1745 - 2040	Data recorder off.
	2000	Initiated coal flow.
	2030	Started feedstock flow at 700 lb/hr using Tank "B".
	2040	Flame out due to interruption of coal flow to CRV combustor. Feedstock flow terminated.
	2058	Coal feed hopper did not fill. Concluded no coal flow due to empty feed hopper. Manually filled coal feed hopper and started feeding coal. Stopped and started coal system to reset and got good feed rate.
	2222	Started feedstock flow.
9/16	0030	Started increasing feedstock flow to achieve maximum flow rate.
	0046	Feedstock flow rate at 1700 lb/hr.
	0047	Feedstock flow rate at 1800 lb/hr. Coal thermal input at ≈ 5 million Btu/hr; natural gas input at ≈ 1 million Btu/hr.
	0107	Feedstock flow rate at 1900 lb/hr.
	0120	Feedstock flow rate at 2000 lb/hr.
	0205	High pressure reading in separator reservoir. Carryover accumulation in flue gas exhaust duct. Shut down to clean duct. Turned off data recorder.
	0404	Started system heat up on coal.
	0700	Started feedstock flow and turned on data recorder.
	0800	Increased feedstock flow rate while maintaining $\approx 4\%$ (v) O ₂ in flue gas.
	0824	Coal flow appeared to have stopped. Terminated feedstock flow, and reduced air flow.
	0829	Coal flow resumed. Increased air flow.
	0849	Coal flow appeared stabilized. Restarted feedstock flow.
	0855	CSC started Method 5 flue gas sampling.
	0928	Finished Method 5 sampling.
	0949	Feedstock and coal flow terminated. Test complete.

Figure A-1

Figure A-2

**DEMONSTRATION TEST (TEST #93)
TOTAL FUEL THERMAL INPUT - 9/13/94**

Figure A-3

**DEMONSTRATION TEST (TEST #93)
TOTAL FUEL THERMAL INPUT - 9/14/94**

Figure A-4

**DEMONSTRATION TEST (TEST #93)
TOTAL FUEL THERMAL INPUT - 9/15/94**

Figure A-5

**DEMONSTRATION TEST (TEST #93)
TOTAL FUEL THERMAL INPUT - 9/16/94**

Figure A-7

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS THERMAL INPUT - 9/13/94**

Figure A-8

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS THERMAL INPUT - 9/14/94**

Figure A-9
DEMONSTRATION TEST (TEST #93)
NATURAL GAS THERMAL INPUT - 9/15/94

Figure A-10

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS THERMAL INPUT - 9/16/94**

Figure A-11

**DEMONSTRATION TEST (TEST #93)
NATURAL FLOW RATE - 9/12/94**

Figure A-12

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS FLOW RATE - 9/13/94**

Figure A-13

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS FLOW RATE - 9/14/94**

Figure A-14

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS FLOW RATE - 9/15/94**

Figure A-15

**DEMONSTRATION TEST (TEST #93)
NATURAL GAS FLOW RATE - 9/16/94**

Figure A-16

**DEMONSTRATION TEST (TEST #93)
COAL THERMAL INPUT - 9/12/94**

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**DEMONSTRATION TEST (TEST #93)
COAL THERMAL INPUT - 9/13/94**

Figure A-18

**DEMONSTRATION TEST (TEST #93)
COAL THERMAL INPUT - 9/14/94**

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COAL FLOW RATE - 9/13/94**

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COAL FLOW RATE - 9/14/94

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COAL FLOW RATE - 9/15/94**

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**DEMONSTRATION TEST (TEST #93)
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DEMONSTRATION TEST (TEST #93)
TOTAL AIR FLOW TO CMS - 9/13/94

Figure A-28

**DEMONSTRATION TEST (TEST #93)
TOTAL AIR FLOW TO CMS - 9/14/94**

Figure A-29

**DEMONSTRATION TEST (TEST #93)
TOTAL AIR FLOW TO CMS - 9/15/94**

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DEMONSTRATION TEST (TEST #93)
TOTAL AIR FLOW TO CMS - 9/16/94

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**DEMONSTRATION TEST (TEST #93)
PERCENT COAL THERMAL INPUT - 9/12/94**

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**DEMONSTRATION TEST (TEST #93)
PERCENT COAL THERMAL INPUT - 9/13/94**

Figure A-33

Figure A-34

**DEMONSTRATION TEST (TEST #93)
PERCENT COAL THERMAL INPUT - 9/15/94**

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**DEMONSTRATION TEST (TEST #93)
ACTUAL-TO-STOICHIOMETRIC AIR RATIO - 9/13/94
(INCLUDING CARBON IN FEEDSTOCK)**

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**DEMONSTRATION TEST (TEST #93)
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**DEMONSTRATION TEST (TEST #93)
FEEDSTOCK FLOW RATE - 9/13/94**

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FEEDSTOCK FLOW RATE - 9/14/94**

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**DEMONSTRATION TEST (TEST #93)
FEEDSTOCK FLOW RATE - 9/15/94**

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**DEMONSTRATION TEST (TEST #93)
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**DEMONSTRATION TEST (TEST #93)
FEEDSTOCK TANK WEIGHT - 9/13/94**

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FEEDSTOCK TANK WEIGHT - 9/14/94

Figure A-49
DEMONSTRATION TEST (TEST #93)
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**DEMONSTRATION TEST (TEST #93)
FEEDSTOCK TANK WEIGHT - 9/16/94**

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**DEMONSTRATION TEST (TEST #93)
CM EXHAUST GAS TEMPERATURE - 9/12/94**

Figure A-52

**DEMONSTRATION TEST (TEST #93)
CM EXHAUST GAS TEMPERATURE - 9/13/94**

Figure A-53

**DEMONSTRATION TEST (TEST #93)
CM EXHAUST GAS TEMPERATURE - 9/14/94**

Figure A-54

**DEMONSTRATION TEST (TEST #93)
CM EXHAUST GAS TEMPERATURE - 9/15/94**

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CM EXHAUST GAS TEMPERATURE - 9/16/94

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DEMONSTRATION TEST (TEST #93)
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Figure A-57

**DEMONSTRATION TEST (TEST #93)
CMS HEAT RATE - 9/13/94**

Figure A-58

**DEMONSTRATION TEST (TEST #93)
CMS HEAT RATE - 9/14/94**

Figure A-59
DEMONSTRATION TEST (TEST #93)
CMS HEAT RATE - 9/15/94

Figure A-60
DEMONSTRATION TEST (TEST #93)
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DEMONSTRATION TEST (TEST #93)
O2 CONCENTRATION IN FLUE GAS - 9/13/94

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DEMONSTRATION TEST (TEST #93)
O₂ CONCENTRATION IN FLUE GAS - 9/14/94

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**DEMONSTRATION TEST (TEST #93)
O2 CONCENTRATION IN FLUE GAS - 9/15/94**

Figure A-65
DEMONSTRATION TEST (TEST #93)
O2 CONCENTRATION IN FLUE GAS - 9/16/94

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DEMONSTRATION TEST (TEST #93)
MEASURED NO_x CONCENTRATION IN FLUE GAS - 9/12/94

Figure A-67

**DEMONSTRATION TEST (TEST #93)
NOx CONCENTRATION IN FLUE GAS - 9/12/94
(CORRECTED TO 3% O2)**

Figure A-68

**DEMONSTRATION TEST (TEST #93)
MEASURED NO_x CONCENTRATION IN FLUE GAS - 9/13/94**

Figure A-69

**DEMONSTRATION TEST (TEST #93)
NO_x CONCENTRATION IN FLUE GAS - 9/13/94
(CORRECTED TO 3% O₂)**

Figure A-70

**DEMONSTRATION TEST (TEST #93)
MEASURED NO_x CONCENTRATION IN FLUE GAS - 9/14/94**

Figure A-71
DEMONSTRATION TEST (TEST #93)
NO_x CONCENTRATION IN FLUE GAS - 9/14/94
(CORRECTED TO 3% O₂)

Figure A-72

**DEMONSTRATION TEST (TEST #93)
MEASURED NO_x CONCENTRATION IN FLUE GAS - 9/16/94**

Figure A-73

**DEMONSTRATION TEST (TEST #93)
NOx CONCENTRATION IN FLUE GAS - 9/16/94
(CORRECTED TO 3% O₂)**

Figure A-74

**DEMONSTRATION TEST (TEST #93)
MEASURED CO CONCENTRATION IN FLUE GAS - 9/12/94**

Figure A-75

**DEMONSTRATION TEST (TEST #93)
CO CONCENTRATION IN FLUE GAS - 9/12/94
(CORRECTED TO 3% O₂)**

Figure A-76

**DEMONSTRATION TEST (TEST #93)
MEASURED CO CONCENTRATION IN FLUE GAS - 9/13/94**

Figure A-77

**DEMONSTRATION TEST (TEST #93)
CO CONCENTRATION IN FLUE GAS - 9/13/94
(CORRECTED TO 3% O₂)**

Figure A-78

**DEMONSTRATION TEST (TEST #93)
MEASURED CO CONCENTRATION IN FLUE GAS - 9/14/94**

Figure A-79
DEMONSTRATION TEST (TEST #93)
CO CONCENTRATION IN FLUE GAS - 9/14/94
(CORRECTED TO 3% O₂)

Figure A-80
DEMONSTRATION TEST (TEST #93)
MEASURED CO CONCENTRATION IN FLUE GAS - 9/16/94

Figure A-81
DEMONSTRATION TEST (TEST #93)
CO CONCENTRATION IN FLUE GAS - 9/16/94
(CORRECTED TO 3% O₂)

Figure A-82
DEMONSTRATION TEST (TEST #93)
MEASURED SO₂ CONCENTRATION IN FLUE GAS - 9/12/94

Figure A-83
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SO₂ CONCENTRATION IN FLUE GAS - 9/12/94
(CORRECTED TO 3% O₂)

Figure A-84

**DEMONSTRATION TEST (TEST #93)
MEASURED SO₂ CONCENTRATION IN FLUE GAS - 9/13/94**

Figure A-85

**DEMONSTRATION TEST (TEST #93)
SO₂ CONCENTRATION IN FLUE GAS - 9/13/94
(CORRECTED TO 3% O₂)**

Figure A-86

**DEMONSTRATION TEST (TEST #93)
MEASURED SO₂ CONCENTRATION IN FLUE GAS - 9/14/94**

Figure A-87

**DEMONSTRATION TEST (TEST #93)
SO₂ CONCENTRATION IN FLUE GAS - 9/14/94
(CORRECTED TO 3% O₂)**

Figure A-88

**DEMONSTRATION TEST (TEST #93)
MEASURED SO₂ CONCENTRATION IN FLUE GAS - 9/16/94**

Figure A-89

**DEMONSTRATION TEST (TEST #93)
SO₂ CONCENTRATION IN FLUE GAS - 9/16/94
(CORRECTED TO 3% O₂)**