

**FINAL REPORT
1997 CRITERIA POLLUTANT TESTS
DURING THE TDF TRIAL BURN AT
STOCKTON COGEN, INC.**

Prepared For:

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Allentown, Pennsylvania

For Submittal To:

SAN JOAQUIN VALLEY UNIFIED AIR POLLUTION CONTROL DISTRICT
and
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SECTION 1.0

INTRODUCTION

Air Products and Chemicals, Inc. performed a trial burn of tire derived fuel (TDF) blended with coal and coke at the Stockton Cogen, Inc. plant located in Stockton, California. The project was partially funded by the Integrated Waste Management Board of the California EPA (IWMB) to determine the feasibility of using TDF as a supplementary fuel in fluidized-bed boilers. The trial burn program included sampling and analysis of the fuel and other commodities added to the boiler, of the ash produced by the boiler, and of the stack emissions.

Carnot was contracted to conduct emissions testing for criteria pollutants and for toxic air contaminants. The criteria pollutant tests were performed to determine the units' compliance with EPA Region IX PSD Permit number NSR 4-4-8/SJ 85-04 and San Joaquin Valley Unified Pollution Control District (SJVUAPCD) operating permit number N-802-1-3. The results of the criteria pollutant tests are presented in this report. The results of the toxics tests are provided in a separate report.

The plant operations were coordinated by Tom Hess of Air Products and Chemicals, Inc. Portions of the testing program were observed by John Cadrett of the San Joaquin Valley Unified APCD. The tests were performed by Kevin Crosby, Jeff Hogan, Marc Rodabaugh, Bob Conklin and Erick Mirabella of Carnot from February 27 to March 7, 1997.

Emission tests were performed on the boiler during the TDF trial burn as specified in the permits for the following parameters. The emission test results are summarized and compared with permit limits in Table 1-1.

- Particulate Matter
- SO_x as SO₂
- NO_x as NO₂, CO, and SO₂ (for comparison only)
- CO₂, O₂ (monitored as diluent gases)
- Non-methane organics as methane

**TABLE 1-1
COMPARISON OF TEST
RESULTS WITH PERMIT LIMITS
STOCKTON COGEN, INC.
TDF TRIAL BURN PROGRAM
FEBRUARY/MARCH 1997**

Parameter	Average Results	Lower Permit Limit
Particulate Matter, lb/hr	2.19	10.0
NO _x as NO ₂ ppm @ 13.6% CO ₂ (dry)	20.73	39
lb/hr	25.06	--
SO _x as SO ₂ lb/hr	38.4	59.2
Removal efficiency, %	95.1	70 (minimum)
CO, lb/hr	20.92	22.9
HC as Methane, lb/hr	<0.38	1.88

Note: HC denotes non-methane hydrocarbons expressed as Methane. See Section 4.0 for details.

The permit limits shown are the lower or more stringent of the EPA PSD Permit or the SJVUAPCD Permit. Complete results summary tables are presented in Section 4.

SECTION 2.0

UNIT DESCRIPTION

2.1 FACILITY DESCRIPTION

Air Products and Chemicals, Inc. operates a fluidized bed cogeneration facility near Stockton, California. This facility, operating as Stockton Cogen, Inc. produces both electricity and steam. A portion of the steam from the boiler is used to drive a steam turbine electrical generator, with the remaining steam provided to the CPC International facility across the fenceline from the Stockton Cogen plant.

The boiler is a circulating fluidized bed boiler, nominally rated at 620 MMBtu/hr heat input. The fuel fired during testing was a blend of up to 20% tire derived fuel (TDF), with the balance made up of delayed petroleum coke and/or fluid coke, with bituminous low sulfur coal (0.5 wt% sulfur). The boiler is equipped with the following pollution control systems:

1. An ammonia injection system for control of NO_x emissions. This system injects approximately 50 to 140 lb/hr of anhydrous ammonia (at nominal load) into the flue gas from the boiler as the gas passes through a bank of cyclones upstream of the boiler convective section.
2. A limestone injection system to limit emissions of SO_2 . This system adds approximately 2,000 to 7,000 lb/hr of limestone (at nominal load) to the bed material of the boiler.
3. A baghouse for control of particulate emissions.

Two sootblowing systems are installed to ensure the cleanliness of the convective section of the boiler. Acoustic sootblowers are installed in the upper part of the boiler's convective section. A low-frequency acoustic signal is used to prevent the buildup of fouling material on the boiler tubes. These acoustic sootblowers operate continuously during boiler operation. In addition to the acoustic sootblowers, conventional steam sootblowers are also installed on the boiler. These steam sootblowers are normally operated for 30 minutes during each operating day, with a maximum steam rate of approximately 15,000 lb steam/hr.

SECTION 3.0

TEST DESCRIPTION

The primary objective of the program was the measurement of emissions during a trial burn of TDF blended with the coal and coke fuel blend normally used in this boiler. The program was funded in part by the IWMB to determine the feasibility of using TDF as a supplementary fuel in fluidized bed units.

3.1 TEST CONDITIONS

The tests were conducted at nominal full load operating conditions with up to 20% of TDF with the coal/coke fuel. Test conditions were established and unit operating data were collected by Air Products personnel. A summary of unit load conditions during testing is included in Table 3-1. Additional process data printouts can be found in Appendix C.2.

3.2 SAMPLING LOCATIONS

Samples were collected at the stack serving the fluidized-bed boiler. Illustrations of the sampling port locations are shown in Appendix C.1. The sampling location meets EPA Method 1 criteria.

3.3 TEST PROCEDURES

The test procedures used for the criteria pollutant testing program are presented in Table 3-3. Descriptions of standard procedures are included in Appendix A. Information and procedural modifications specific to this test program are presented in the following sections.

3.3.1 Gaseous Emissions

Gaseous species (NO_x , CO , CO_2 , and O_2) were measured using Carnot's Continuous Emissions Monitor (CEM) described in Appendix A. This system meets EPA and CARB Methods for gaseous species. The heated Teflon line and ice bath described in Appendix A was used to prevent loss of NO_2 in the sampling system. Three gaseous emission test runs were performed to determine compliance with the permit conditions, with a combined run time of two hours. The CEM system was also operated during the wet-chemical tests to provide O_2 and CO_2 data for molecular weight and dilution calculations. These results are detailed in Section 4.0.

**TABLE 3-1
PROCESS CONDITIONS
CRITERIA POLLUTANT TESTS
STOCKTON COGEN, INC.
TDF TRIAL BURN PROGRAM**

Test No.	Date	Time	Total Fuel			NH ₃ lb/hr	Steam Flow, K lb/hr	Gen. Load MV
			Flow, K lb/hr	TDF K lb/hr	Coke K lb/hr			
1-VOC	2/27/97	1250-1320	56.3	6.46	19.80	4371	520	59
2-VOC	2/27/97	1515-1545	56.6	6.50	19.92	4366	528	60
3-VOC	2/27/96	1550-1620	56.1	6.45	19.75	3910	526	59
3-PM	2/28/97	0800-0936	54.5	6.25	19.16	4253	525	60
4-PM	2/28/97	1020-1146	54.8	6.29	19.27	4187	529	60
5-PM	2/28/97	1212-1340	54.4	6.24	19.13	3965	528	59
3H-CEM	3/5/97	1403-1443	56.6	6.40	7.14	3234	528	59
3I-CEM	3/5/97	1451-1531	57.2	6.48	7.22	3357	529	59
3L-CEM	3/5/97	1755-1855	57.2	6.48	7.22	3863	529	59

Note: Process data printouts can be found in Appendix C.2.

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TABLE 3-3
 TEST PROCEDURES FOR CRITERIA POLLUTANT EMISSIONS TESTS
 STOCKTON COGEN, INC.
 TDF TRIAL BURN PROGRAM, 1997

Parameter	Measurement Principle	Reference Method	Method Detection Limit
NO _x	Chemiluminescent	CARB 100	Below 2% of instrument full scale (2 ppm)
CO	NDIR/Gas filter correlation	CARB 100	Below 2% of instrument full scale (2 ppm)
O ₂	Electrochemical cell	CARB 100	Below 2% of instrument full scale (0.5% vol.)
CO ₂	Nondispersive infrared	CARB 100	Below 2% of instrument full scale (0.5% vol.)
Non-methane Organics	Tedlar Bags/GC	SCAQMD 25.2	1 ppm
Particulate	In-stack filtration	SCAQMD 5.3	0.0006 gr/dscf
Sulfur Oxides	Impinger absorption/ titrimetric	SCAQMD 6.1 (modified)	0.1 ppm

3.3.2 Particulate Matter

Particulate emissions were measured according to SCAQMD Method 5.3, which includes in-stack filtration and analysis of condensible particulate matter. The method was modified for application to a test site with hydrogen chloride (HCl) in the stack gas.

The method normally includes analysis of sulfuric acid mist from the filter, nozzle wash and impinger sample fractions. All sulfates including particulate acid mist and pseudo-particulate SO_2 - derived sulfate species are then subtracted from the total particulate residue, and the results from a separate sulfuric acid mist sampling train are added back in. The method was designed originally for accurate measurements at oil refinery fluidized catalytic cracking units (FCCU). The method was used at Air Products because it is the only published method that properly handles the formation of ammonium sulfate "pseudo-particulate" from absorption of ammonia and sulfur dioxide in the impinger water.

Method 5.3 does not include analysis for ammonium chloride, because FCCU sources generally have little or no HCl emission. The method was therefore modified for application to Air Products by adding the analysis of the chloride content of the impinger residue. The chloride was subtracted as ammonium chloride from the total impinger residue weight. No other modifications were made to Method 5.3. Table 3-5 presents a summary of the modified calculation procedure.

3.3.3 Sulfur Oxides

The concentration of total sulfur oxides (SO_x) was measured using SCAQMD Method 6.1, including the analysis for sulfuric acid mist, but modified to delete the sampling and analysis for free sulfur trioxide. The modification was made because the presence of ammonia in the stack gas would interfere with the analysis, and because the concentration of sulfur trioxide was expected to be a very small fraction of the total SO_x . The first impinger, which would normally include 80% isopropyl alcohol, was deleted from the sampling train, as the ammonia in the stack gas would interfere with the analysis of that SO_3 fraction of the sample, and with the analysis of SO_2 . Any small amount of sulfur trioxide was therefore included in the total SO_x result.

The samples were analyzed for sulfate by titration with barium chloride to a thorin xylene cyanole indicator end point. Prior to titration, the samples were passed through an ion exchange resin to remove interfering cations and to convert dissolved NH_3 , which interferes with the titration, to NH_4^+ , which does not interfere. Results are reported as total SO_x computed as SO_2 .

TABLE 3-5
MODIFIED ANALYTICAL PROCEDURE FOR PARTICULATE MATTER
PER SCAQMD METHOD 5-3, WITH FILTER TEMPERATURE
GREATER THAN 200°F

Fraction	Comments (Modifications in Parentheses)
A. Filter Catch	In-stack filter dried and weighed
B. Filter Acid or Total Sulfate	Analyzed from re-hydrated residue, as $H_2SO_4 \cdot 2H_2O$
C. Nozzle Wash	Acetone, dried and weighed
D. Probe Nozzle Acid or Total Sulfate	Analyzed from re-hydrated residue, as $H_2SO_4 \cdot 2H_2O$
E. Impinger Catch	Aliquot dried and weighed
F. (1) Impinger Acid (2) Impinger Total Sulfate	Analyzed from re-hydrated residue, as $H_2SO_4 \cdot 2H_2O$
G. Organic Extract	Dichloromethane, dried and weighed
H. $H_2SO_4 \cdot 2H_2O$ from SO_x train filter	Analyzed from re-hydrated residue, as $H_2SO_4 \cdot 2H_2O$
K. Mass from H pro-rated for sample volume	$K = H \cdot \text{Part. Vol.} / SO_x \text{ Vol.}$
L. Impinger Total Chloride as $NH_4 Cl$	(Analyzed from re-hydrated residue)
N. Total Particulate (Corrected for Ammonium Sulfate and Ammonium Chloride)	Subtract ammonium sulfate and ammonium chloride from impinger catch

$$\text{Modified N} = A - B + C - D + E - F(1) + G + K - [F(2) - (1)] \cdot 132/134 - L$$

Note: Method 5.3 was modified by analyzing the re-hydrated impinger residue for total Chloride. The Chloride was then subtracted from the total particulate as Ammonium Chloride.

3.3.4 Total Gaseous Non-Methane Organics

Concentrations of non-methane hydrocarbons were determined by SCAQMD Method 25.2, which includes total carbon analysis using special GC techniques. Triplicate samples were collected into Tedlar bags using a lung sampler. The bags were analyzed by AtmAA laboratory in Chatsworth, California, within 72 hours of sampling.

3.3.5 Volumetric Flow Rate and Moisture Content

Stack gas flow rate and moisture content were determined by CARB Methods 2 and 4 in conjunction with every particulate test, and additionally as needed for the Relative Accuracy tests. The additional tests included separate pitot tube traverses, and moisture determinations from the Sulfur Oxides sampling trains.

3.3.6 Fuel Analysis

During each test day, composite fuel samples were taken and analyzed for higher heating value and for C, H, O, N, S, and moisture content. The fuel analysis results are presented in Appendix C.7. The results were used to calculate fuel "F" Factors according to EPA Method 19.

3.3.7 SO₂ Removal Efficiency

The coal-fired cogeneration boiler includes systems for removal of SO₂ emissions. The efficiency of those removal systems has been calculated for comparison with permit conditions. The removal efficiency was calculated using the following equation.

$$\% \text{ Efficiency} = \frac{(C_{in} - C_{out})}{C_{in}} * 100$$

Where C = SO₂ lb/hr, at the Inlet or Outlet

The mass flow of uncontrolled SO₂ emissions was calculated from the fuel flow data for each test run and from the sulfur content of the fuel (fuel analysis data). The mass flow of controlled SO₂ emissions was provided by the measured stack gas concentration and volumetric flow rates for each test run. See Appendix D for detailed calculations.

3.3.8 Process Data

The plant's distributed control system (DCS) was used to document process conditions during the test runs. Trends of fuel flow rates, steam and power production rates, and other data have been provided on printouts from the DCS. Process data has been summarized in Section 4.0 and is presented in Appendix C.2. Data for the fluidized-bed boiler includes fuel, limestone and ammonia feed rates and steam production rates.

SECTION 4.0

RESULTS

The test results are summarized in Tables 4-1 through 4-4. The average results are compared to the permit limits in Table 1-1. Particulate test runs 1 and 2, conducted on February 27, were thrown out due to sample contamination. However, their flow rate measurements were valid, and so were used in calculation of the hydrocarbon emission rates in Table 4-3. The results from runs 3-PM, 4-PM and 5-PM, conducted on February 28, are presented in this report. The tests for NO_x and CO emissions were run concurrently with the ammonia emissions tests on March 5, 1997. The ammonia test results are presented in the report for toxic emissions.

The raw field data sheets are provided in Appendix C. Sample calculations are shown in Appendix D, and laboratory reports in Appendix E. CEM strip charts are in Appendix F, and chain of custody sheets for the samples are in Appendix G.

The test results show that the emissions were within permit limits for the Stockton facility. Emissions have been reported in units consistent with permit limits, and removal efficiencies have been calculated based on the permit requirements. NO_x and SO₂ removal efficiencies were better than permit requirements in all cases.

The particulate emissions results have been corrected for the formation of ammonium sulfate salt in the impingers. A similar correction for ammonium chloride was not included. The total particulate was so low that the chloride analysis would be near the detection limit. Therefore, the particulate results were reported corrected for ammonium sulfate only, as prescribed by SCAQMD Method 5.3.

**TABLE 4-1
RESULTS SUMMARY
PARTICULATE EMISSIONS
STOCKTON COGEN, INC.
TDF TRIAL BURN PROGRAM
FEBRUARY/MARCH 1997**

Test No.:	3-PM	4-PM	5-PM	Average
Date:	2/28/97	2/28/97	2/28/97	
Time:	0800-0936	1020-1146	1212-1340	
Flue Gas:				
Flow rate, dscfm	148,955	151,369	148,909	149,744
Temperature, °F	297	298	298	298
O ₂ , % vol. dry	3.83	3.83	3.85	3.84
CO ₂ , % vol. dry	15.24	15.22	15.24	15.23
H ₂ O, % vol.	6.8	6.5	6.6	6.6
Total Particulate*, gr/dscf	0.0015	0.0023	0.0013	0.0017
gr/dscf @ 12% CO ₂	0.0012	0.0018	0.0010	0.0013
lb/hr	1.96	3.00	1.62	2.19
SO_x as SO₂				
ppm vol. dry	20.8	31.4	22.4	24.9
ppm @ 3% O ₂	21.8	33.0	23.5	26.1
lb/hr	32.1	48.5	34.6	38.4

* Particulate values have been corrected for ammonium salt formation in the sampling impingers. See Appendix C.4 for details.

**TABLE 4-2
RESULTS SUMMARY
GASEOUS EMISSIONS
STOCKTON COGEN, INC.
TDF TRIAL BURN PROGRAM
FEBRUARY/MARCH 1997**

Test No.:	3H-CEM	3I-CEM	3L-CEM	Average
Date:	3/5/97	3/5/97	3/5/97	
Time:	1403-1443	1451-1531	1755-1855	
Flue Gas:				
Flow rate, dscfm	150,220	150,220	150,220	150,220
Temperature, °F	299	299	299	299
O ₂ , % vol. dry	4.03	3.88	4.11	4.01
CO ₂ , % vol. dry	14.99	15.14	15.01	15.05
H ₂ O, % vol.	8.3	8.3	8.3	8.3
NO _x , ppm vol. dry	22.84	23.89	22.08	22.94
ppm @ 3% O ₂	24.23	25.13	23.54	24.30
lb/hr as NO ₂	24.95	26.10	24.12	25.06
CO, ppm vol. dry	31.12	32.20	31.07	31.46
ppm @ 3% O ₂	33.02	33.86	33.12	33.33
lb/hr	20.69	21.41	20.66	20.92

Note: These test runs were conducted during the ammonia emission tests, which are reported in the toxic emissions report. The flue gas flow rate was taken from Chromium sampling run 3-Cr, which ran from 0857 to 1730 hours.

**TABLE 4-3
RESULTS SUMMARY
HYDROCARBON EMISSIONS
STOCKTON COGEN, INC.
TDF TRIAL BURN PROGRAM
FEBRUARY/MARCH 1997**

Test No.:	1-VOC	2A-VOC	2B-VOC	Average
Date:	2/27/97	2/27/97	2/27/97	
Time:	1250-1320	1515-1545	1550-1620	
Flue gas flow rate, dscf	155,727	149,376	149,376	151,493
Concentration ppm, vol. dry as CH ₄ ,				
Methane	ND < 1.0	ND < 1.0	ND < 1.0	ND < 1.0
TGNMO	ND < 1.0	ND < 1.0	ND < 1.0	ND < 1.0
Emission Rate, lb/hr, as CH ₄ ,				
TGNMO Non-Methane Hydrocarbons	ND < 0.39	ND < 0.38	ND < 0.38	ND < 0.38

Note: TGNMO denotes total gaseous non-methane organics, expressed as the methane equivalent. The symbol "ND <" denotes "not detected, less than the detection limit". The symbol "<" denotes detection on some test runs and non-detection on other runs.

TABLE 4-4
BOILER SO₂ REMOVAL EFFICIENCY
STOCKTON COGEN, INC.
TDF TRIAL BURN PROGRAM FEBRUARY/MARCH 1997

Test No.	3-SO ₂	4-SO ₂	5-SO ₂	Average
Date	2/28/97	2/28/97	2/28/97	
Time:	0906-0946	1020-1100	1212-1252	
Sulfur in Coal/Coke, % by weight (dry):	0.68	0.68	0.68	
Coal/Coke feed rate, 1000 lb/hr:	48.23	48.28	48.30	
Sulfur in TDF, % by weight (dry)	1.02	1.02	1.02	
TDF feed rate, 1000 lb/hr.	6.26	6.26	6.26	
SO ₂ emissions, lb/hr:				
Calculated (uncontrolled)	782.9	783.6	783.8	
Measured	32.1	48.5	34.6	
Efficiency, %	95.9	93.8	95.6	95.1
Minimum Efficiency Required by Permit %				70