Air Resources Board

Alan C. Lloyd, Ph.D.
Chairman
1001 I Street • P.O. Box 2815 • Sacramento, California 95812 • www.arb.ca.gov

Winston H. Hickox
Agency Secretary

Gray Davis
Governor

MEMORANDUM

TO: Mike Tollstrup, Chief
Project Assessment Branch
Stationary Source Division

FROM: George Lew, Chief
Engineering and Certification Branch
Monitoring and Laboratory Division

DATE: September 7, 2001

SUBJECT: RESULTS OF THE SMUD CAPSTONE 30 MICROTURBINE SOURCE TEST

Attached is a copy of the source test report, Select Gaseous Emissions Data for the SMUD Capstone 30 Microturbine. This report presents data from our emissions tests conducted at the Sacramento Municipal Utilities District headquarters located at 6301 S Street in Sacramento, California.

If you have questions or need further information, please contact Dean Bloudoff at (916) 323-1169.

Attachment

cc: Kitty Martin

California Environmental Protection Agency

Air Resources Board

SOURCE TEST REPORT

Select Gaseous Emissions Data from the SMUD Capstone 30 Microturbine

MONITORING AND LABORATORY DIVISION
ENGINEERING AND CERTIFICATION BRANCH

FILE NO: T-01-040

DATE: September 6, 2001

APPROVED:

_____, Project Engineer
Testing Section

_____, Manager
Testing Section

_____, Chief
Engineering and Certification Branch

ACKNOWLEDGEMENTS

The project leader was David Todd and the field engineer was Oscar Lopez with the ARB. Instrument technicians were Ken Lewis (lead), LaJuan Taylor, and Ron Barros with the ARB. Assistance was provided by H.I. “Bud” Beebe with Sacramento Municipal Utilities District. ARB Stationary Source Division assistance was provided by Grant Chin and Kitty Martin.

California Environmental Protection Agency
AIR RESOURCES BOARD
Monitoring and Laboratory Division

TABLE OF CONTENTS

TABLES

APPENDICES

California Environmental Protection Agency
AIR RESOURCES BOARD
Monitoring and Laboratory Division

Select Gaseous Emissions Data from the SMUD Capstone 30 Microturbine

I. INTRODUCTION

At the request of the Air Resources Board's (ARB) Stationary Source Division (SSD), staff of the Engineering and Certification Branch (ECB) collected gaseous emissions data from a Capstone Turbine Corporation's Model 30 MicroTurbine$^{TM?}$ (Model 30) generator. The Model 30, located behind the Sacramento Municipal Utilities District (SMUD) headquarters at 6301 S Street, is operated by SMUD as part of their distributed power generation network. Exhaust emissions data were collected from the Model 30 on June 10, 2001, at loads of 50%, 75%, and 100% of capacity while operating on natural gas.

II. PROCESS DESCRIPTION

In a gas turbine, a rotor compresses air that is then forced into a combustor where it mixes with natural gas and is ignited. This causes the gases to heat and expand. As the heated gases exit the combustor, they are directed towards a turbine forcing the turbine to rotate. The rotating turbine creates shaft horsepower to operate a generator thereby producing electricity. The Model 30 is a high efficiency gas turbine generator designed to produce 30kW of electrical net output.

As with any gas turbine, performance is dependent upon ambient temperature and pressure conditions. According to the manufacturer, as the inlet temperature of the Model 30 increases above 15? C (59? F) the maximum output decreases. For this reason, and based on the SMUD operator's experience, 28 kW was set as the 100 percent load. Additionally, SSD staff requested that emissions sampling be performed when the inlet air temperature was 15? C (59? F) or less.

III. SAMPLING METHODS AND LOCATIONS

Gaseous exhaust emissions were analyzed and their concentrations determined in accordance with ARB Stationary Source Test Method 100, "Procedures for Continuous Gaseous Emissions Stack Sampling." Emissions determined included oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), total hydrocarbons (THC), and oxides of nitrogen (NOx). Table III-1 lists the make, model and type of gas analyzers used during this source test. Data from all analyzers were collected on strip charts and read by ECB staff to determine the concentrations of gaseous emissions.

Table III-1
Method 100 Emissions Sampling Equipment

Emissions Parameter	Instrument Information		
	Manufacturer	**Model**	**Type**
O2	Rosemont Analytical	755 R	Paramagnetic
CO2	Horiba	VIA-510	NDIR
CO	TECO	48	NDIR
THC	Beckman	400	FID
NOx	TECO	42H	Chemiluminescence

Stack flows were determined with ARB Stationary Source Test Method 1 - Velocity Traverse, Method 2 - Stack Velocity and Flow Rate, Method 3 - Dry Molecular Weight, and Method 4 - Moisture Content.

To determine stack flows and collect samples for analysis, it was necessary to increase the length of the exhaust stack for the Model 30. ECB staff fabricated a stack extension that was 'slip-fitted' over the existing exhaust outlet. The stack extension was 6 inches in diameter and 84 inches in length. Pitot tube measurements were made at 48 inches downstream (8 diameters) and samples were collected at 72 inches downstream (12 diameters). The stack extensions were fabricated with two sets of sampling ports, each 90? apart, at both 48 inches and 72 inches downstream from the source.

A traverse performed with the gas analyzers sample probe prior to testing indicated that single point gaseous sampling was permissible per ARB Method 100. Full velocity traverses were performed at 100 percent, 75 percent, and 50 percent loadings.

Additionally, the Model 30 has a dedicated Roots positive displacement volume meter to measure the volume of natural gas fuel used by the Model 30. Staff periodically collected data from this meter during testing to monitor fuel flow. Fuel flow and EPA F-factors (see EPA Test Method 19) may be used to estimate stack flow.

IV. QUALITY ASSURANCE

All gas analyzers were calibrated immediately before and after source testing as required by ARB Method 100. Pre- and post-test sampling system bias checks were performed on all analyzers. Additionally, all instruments were within zero and calibration post-test drift requirements.

The Method 5 sampling console used for stack velocity and moisture determinations was calibrated per ARB Method 5 in March 2001. The Type S pitot tube used for stack velocity determinations met the required specifications for a baseline coefficient of 0.84 as specified in ARB Method 2. The pitot tube and console assembly passed leak

checks before and after the velocity determinations. The moisture train assembly also passed leak checks before and after sampling for water vapor.

V. TEST RESULTS

Test results are shown in Appendix A. Additionally, Appendix B contains copies of the Field Data Sheets, Appendix C copies of the continuous analyzer's strip charts, and Appendix D contains data collected by SMUD from the Model 30 during sampling at 100 percent, 75 percent, and 50 percent loadings.

In accordance with ARB Method 100, the range of each analyzer is selected such that the sampled gas concentrations are between 10 and 95 percent of the range of each specific instrument. Due to SSD's request to perform emissions sampling when the Model 30's inlet temperature was 59? F or less, analyzer ranges were not changed due to time constraints. Changing analyzer ranges requires time for additional calibrations of the instruments. Therefore, in some cases these limits were exceeded. Where this occurred the data are reported in parenthesis.

Table IV-1 presents a summary of the Model 30 power output, inlet air temperatures, and concentrations for NOx, CO, and THC as measured and as corrected to 15% oxygen. As indicated in Table IV-1, average inlet temperatures remained below 59? F for Test Runs 1 and 2. Average inlet temperatures for the 3 power loads for Run 3 ranged from 60? F to 63? F.

Table IV-2 presents a summary of average mass emissions in pounds per cubic foot (lb./cu.ft.) for the three power loadings.

Table IV-3 presents a summary of mass emissions in pounds per hour (lb/hr) and pounds per megawatt-hour (lb/MW-hr).

Table IV-4 presents measured concentrations in 5% power load intervals between 50% and 100% power loads and 25% power load. It should be noted that inlet air temperatures during this portion of the test were greater than 59? F.

Table IV-1
Test Results

Gaseous Concentrations at 100%, 75%, and 50% Loads

Power Load, (%)	Capstone, Output (kilowatts)	Inlet Air Temp. (deg. F)	Measured Concentrations					Concentrations Corrected to 15% O2		
			O2, (%)	CO2, (%)	NOx, (ppm)	THC (as C3), (ppm)	CO, (ppm)	NOx, (ppm)	THC (as C3), (ppm)	CO, (ppm)
100	28	58	18.3	1.4	(0.73)	(<1)	(3.7)			
100	28	58.5	18.3	1.5	(0.83)	(<1)	(3.4)			
100	28	60	18.3	1.5	(0.76)	(<1)	(3.2)			
Average	28		18.3	1.5	(0.77)	(<1)	(3.4)	(1.8)	(<2)	(7.7)
75	21	58	18.6	1.3	(0.26)	12	87			
75	21	58	18.6	1.3	(0.66)	11	89			
75	21	61	18.6	1.3	(0.33)	11	79			
Average	21		18.6	1.3	(0.42)	11	85	(1.1)	28	220
50	14	57	19.0	1.1	19	(3)	43			
50	14	56.5	19.0	1.1	19	(3)	35			
50	14	63	18.9	1.1	19	(3)	38			
Average	14		19	1.1	19	(3)	42	(59)	(9.3)	130

( ) - Numbers in parenthesis indicate data outside 10 to 95 percent of the analyzers full scale range.

Table IV-2
Test Results

Mass Emissions for Average Concentrations at 100%, 75%, and 50% Power Loads

Power Load, (%)	Capstone Output (kilowatts)	Measured Concentrations			Mass Emissions		
		NOx, (ppm)	THC (as C3), (ppm)	CO, (ppm)	NOx, (lb/cu.ft.)	THC (as C3), (lb/cu.ft.)	CO, (lb/cu.ft.)
100	28	(0.77)	(<1)	(3.4)	(8.8E-08)	(<1.1E-07)	(2.5E-07)
75	21	(0.42)	11	85	(4.8E-08)	1.3E-06	6.2E-08
50	14	(19)	(3)	42	(2.2 E-06)	(3.4E-07)	3.1 E-06

Standard conditions are 68 deg. F and 29.92 in. Hg.

( ) - Numbers in parenthesis indicate data outside 10 to 95 percent of the analyzers full scale range.

Table IV-3
Test Results

Mass Emissions in lb/hr and lb/MW-hr. at 100%, 75%, and 50% Loads

Power Load, (%)	Capstone, Output, (kilowatts)	Exhaust Flow, (dscfm)	Mass Emissions			Mass Emissions		
			NOx, (lb/hr)	THC (as C3), (lb/hr)	CO, (lb/hr)	NOx, (lb/MW-hr)	THC (as C3), (lb/MW-hr)	CO, (lb/MW-hr)
100	28	571	(0.003)	(<0.0039)	(0.0085)	(0.11)	(<0.14)	(0.30)
75	21	495	(0.0014)	0.037	0.18	(0.068)	1.8	8.7
50	14	417	(0.076)	(0.0086)	0.076	(3.9)	(0.61)	5.5

Standard conditions are 68 deg. F and 29.92 in. Hg.

( ) - Numbers in parenthesis indicate data outside 10 to 95 percent of the analyzers full scale range.

Table IV-4

Concentrations at 5% Intervals
from 50% to 100% and 25% Power Load

Power Load, (%)	Capstone Output (kilowatts)	Measured Concentrations				
		O2, (%)	CO2, (%)	NOx, (ppm)	THC (as C3), (ppm)	CO, (ppm)
50	14.0	18.9	1.4	19	(3)	(8.4)
55	15.4	18.8	1.2	19	(2)	23.8
60	16.8	18.8	1.2	(>20)	(<1)	15.6
65	18.2	18.8	1.3	(>20)	(<1)	10.8
70	19.6	18.8	1.3	(>20)	(<1)	(8.3)
75	21.0	18.7	1.3	(0.79)	(8)	66.7
80	22.4	18.5	1.4	(0.69)	(4)	40.6
85	23.8	18.5	1.4	(0.65)	(2)	21.4
90	25.2	18.7	1.4	(0.81)	(<1)	(8.9)
95	26.6	18.4	1.4	(0.84)	(<1)	(3.8)
100	27(max.)	18.5	1.4	(0.84)	(<1)	(3.1)
25	7	17.7	0.95	16.0	60	(>100)

( ) - Numbers in parenthesis indicate data outside 10 to 95 percent of the analyzers full scale range.

APPENDIX A

Calculated Results

Appendix A-1

Calculated Results (lb/cu.ft., lb/hr, and lb/MW-hr) at Different Concentrations for Different Concentrations at 100%, 75%, and 50% Power Loads

lb/cu.ft. = + ppm * mole. Wt. *0.000000002597
lb/hr = + lb/cu.ft. *scfm * 60 min/hr
lb/ mW*hr = + 1000kW/MW * lb/hr / (kW)

Mole. Wt.
NOx = NO2 = 44
CO = 28
THC as C3H8 = 44

Flows by Load, dscfm
100% = 571
75% = 495
50% = 417

Compound	Load, % %	Avg. Conc. ppm	Mole. Wt.	Emission, lb/cu.ft.	Flow, dscfm	Emission, lb/hr	Power Out, kW	Emissions lb./MW-hr
NOx	100	2	44	2.29E-07	571	7.83E-03	28	0.280
NOx	100	0.77	44	8.8E-08	571	3.01E-03	28	0.108
THC	100	10	44	1.14E-06	571	3.91E-02	28	1.400
THC	100	1	44	1.14E-07	571	3.92E-03	28	0.140
CO	100	10	28	7.27E-07	571	2.49E-02	28	0.890
CO	100	3.4	28	2.47E-07	571	8.47E-03	28	0.303
NOx	75	2	44	2.29E-07	495	6.79E-03	21	0.323
NOx	75	0.42	44	4.8E-08	495	1.43E-03	21	0.068
THC	75	11	44	1.26E-06	495	3.73E-02	21	1.778
CO	75	85	28	6.18E-06	495	0.184	21	8.742
NOx	50	18	44	2.06E-06	417	5.15E-02	14	3.676
NOx	50	19	44	2.17E-06	417	5.43E-02	14	3.880
THC	50	10	44	1.14E-06	417	0.02859	14	2.042
THC	50	3	44	3.43E-07	417	8.58E-03	14	0.612
CO	50	42	28	3.05E-06	417	7.64E-02	14	5.458

Table A-2
Capstone Turbine Emission Concentrations

Sample Time (min)	Load Capacity (%)	Concentration As Found				Actual C_{gas} Concentration		Concentration @ 15% O2	
		O2 (0-25%)	CO2 (1-10%)	NOx (0-20ppm)	CO (0-100ppm)	NOx (ppm)	CO (ppm)	NOx (ppm)	CO (ppm)
37	100	18.3	1.44	0.69	3.7	(0.73)	(3.7)	1.65	8.4
30	75	18.62	1.3	0.25	87	(0.26)	87.0	0.68	225.1
30	50	19	1.1	18.23	43.17	(19.22)	43.2	59.69	134.1
30	50	19	1.1	18.36	44.68	(19.36)	44.7	60.12	138.7
30	75	18.6	1.3	0.63	88.63	(0.66)	88.6	1.70	227.4
30	100	18.3	1.45	0.79	3.43	(0.83)	(3.4)	1.89	7.8
28	100	18.3	1.45	0.72	3.21	(0.76)	(3.2)	1.72	7.3
38	75	18.62	1.3	0.31	79.2	(0.33)	79.2	0.85	204.9
24	50	18.9	1.12	17.9	38	18.87	38.0	55.68	112.1

( ) - Numbers in parenthesis indicate data outside 10 to 95 percent of the analyzers full scale range.

FORMULAS

POLLUTANT CONCENTRATION

$C_{gas} = (C_{avg} - C_o) * C_{cal}/(C_{bal} - C_o)$ Equation

Where:

C_{gas} = Effluent gas concentration, ppm or % by volume

C_{avg} = Average gas concentration indicated by gas analyzer, ppm or % by volume

C_o = Average of initial (cib and final (cfb) system bias responses for zero gas, ppm or % by volume

C_{cal} = Actual concentration of the calibration gas used for the bias check, ppm or % by volume

C_{bal} = Average of initial (cib and final (cfb) sampling system bias responses for calibration gas, ppm or % by volume

NOx ppm	
C_o	0
C_{cal}	18.4
C_{bal}	17.45

CO ppm	
C_o	0
C_{cal}	60.7
C_{bal}	60

Corrrection to 15% O2 (using O2 in air as 20.9%)

$C_{15\%O2} = C_{dgas} * [(20.9-15)/(20.9-\%O_2 \text{ during test})]$ Equation

Table A-3
Capstone Turbine Emission Concentrations

Sample Time (min)	% Load Capacity	Concentration As Found				Actual C_{gas} Concentration		Concentration @ 15% O2	
		O2 0-25%	CO2 0-10%	NOx 0-20ppm	CO 0-100ppm	NOx 0-20ppm	CO 0-100ppm	NOx 0-20ppm	CO 0-100ppm
9	55	18.8	1.19	18.28	23.75	19.28	23.8	54.15	66.7
10	60	18.75	1.2	> 20	15.6	> 20	15.6	> 20	42.8
10	65	18.75	1.25	> 20	10.75	> 20	10.8	> 20	29.5
10	70	18.75	1.29	> 20	8.3	> 20	8.3	> 20	22.8
15	75	18.7	1.3	0.75	66.67	0.79	66.7	2.12	178.8
9	80	18.5	1.35	0.65	40.6	0.69	40.6	1.68	99.8
9	85	18.5	1.37	0.62	21.38	0.65	21.4	1.61	52.6
12	90	18.7	1.4	0.77	8.9	0.81	8.9	2.18	23.9
9	95	18.4	1.42	0.8	3.8	0.84	3.8	1.99	9.0
8	100	18.5	1.44	0.8	3.13	0.84	3.1	2.07	7.7
16	25	17.65	0.95	15.2	> 100	16.03	> 100	29.10	> 100

FORMULAS

POLLUTANT CONCENTRATION

$C_{gas} = (C_{avg} - C_o) * C_{cal}/(C_{bal} - C_o)$ Equation

Where:

C_{gas} = Effluent gas concentration, ppm or % by volume
C_{avg} = Average gas concentration indicated by gas analyzer, ppm or % by volume
C_o = Average of initial (cib and final (cfb) system bias responses for zero gas, ppm or % by volume
C_{cal} = Actual concentration of the calibration gas used for the bias check, ppm or % by volume
C_{bal} = Average of initial (cib and final (cfb) sampling system bias responses for calibration gas, ppm or % by volume

NOx ppm	
C_o	0
C_{cal}	18.4
C_{bal}	17.45

CO ppm	
C_o	0
C_{cal}	60.7
C_{bal}	60

Corrrection to 15% O2 (using O2 in air as 20.9%)

$C_{15\%O2} = C_{dgas} * [(20.9-15)/(20.9-\%O_2 \text{ during test})]$ Equation

MONITORING & LABORATORY DIVISION
ENGINEERING & CERTIFICATION BRANCH

FIELD DATA SHEET

FILE NO.:	T-01-040	PITOT TUBE FACTOR (Cp)	0.84
PROJECT NAME:	SMUD/Capstone 30	PROBE TIP DIA, in. (Dn)	N/A
RUN NO.:	100% load	STACK DIA, inches	6.0
LOCATION	Turbine Stack	STATIC PRESS, "H2O (Ps)	-0.69
BAR. PRESS, "Hg(Pb)	29.91	METER TEMP, F	60

SAMPLE POINT	t CLOCK TIME min.	Vm DRY GAS METER cu. ft.	dP PITOT PRESS. in. H2O	dH ORIFICE PRESS. (ACTUAL) in. H2O	Ts STACK TEMP. F
START	0	0	----	----	----
1E			1.1		528
2E			1.4		529
3E			1.6		529
4E			1.6		527
1W			1.3		527
2W			1.4		528
3W			1.7		530
4W			1.7		528
					528
	t= 0	Vm= 0.00	/dP avg.= 1.212	dH avg.= ERR	Ts avg.= 528.2

TEST SUMMARY AND RESULTS (FOR FIELD DATA RECORD)

FILE NO.:	T-01-040
PROJECT NAME:	SMUD/Capstone 30
RUN NO.:	100% load

SUMMARY OF TEST DATA

Barometric Pressure (Pb):	29.91	inches Hg
O2 in Stack (%O2):	18.3	percent
CO in Stack (%CO):	0.00	percent
CO2 in Stack (%CO2):	1.45	percent
N2 in Stack (%N2):	80.25	percent
Pitot Tube Factor (Cp)	0.84	
Avg. of Sqrt. of Pitot Press. (/dP avg):	1.21	/(inches H2O)
Stack Temperature (Ts)	988	deg. R
Static Pressure	-0.69	inches H2O
Absolute Stack Pressure (Ps)	29.86	inches Hg
Stack Dimensions	6.0	inches dia.
Stack Area (As)	0.196	square feet

CALCULATED RESULTS

Water Vapor in Stack (Bws):	2.75	percent by volume
Stack Gas Molecular Wt, Dry (Md):	28.96	lb/lbmole
Stack Gas Molecular Wt, Wet	28.66	lb/lbmole
Stack Gas Velocity (Vs):	93.50	feet/second
Stack Gas Flow Rate (Qs):	571	DSCFM(68 deg.F)

MONITORING & LABORATORY DIVISION
ENGINEERING & CERTIFICATION BRANCH

FIELD DATA SHEET

FILE NO.:	T-01-040	PITOT TUBE FACTOR (Cp)	0.84
PROJECT NAME:	SMUD/Capstone 30	PROBE TIP DIA, in. (Dn)	N/A
RUN NO.:	75% load	STACK DIA, inches	6.0
LOCATION	Turbine Stack	STATIC PRESS, "H2O (Ps)	-0.33
BAR. PRESS, "Hg(Pb)	29.91	METER TEMP, F	60

SAMPLE POINT	t CLOCK TIME min.	Vm DRY GAS METER cu. ft.	dP PITOT PRESS. in. H2O	dH ORIFICE PRESS. (ACTUAL) in. H2O	Ts STACK TEMP. F
START	0	0	----	----	----
1E			0.93		493
2E			1.1		486
3E			1.1		486
4E			1.1		484
1W			0.93		486
2W			1.1		486
3W			1.1		498
4W			1.1		489
					490
	t= 0	Vm= 0.00	/dP avg.= 1.028	dH avg.= ERR	Ts avg.= 488.7

TEST SUMMARY AND RESULTS (FOR FIELD DATA RECORD)

FILE NO.:	T-01-040
PROJECT NAME:	SMUD/Capstone 30
RUN NO.:	75% load

SUMMARY OF TEST DATA

Barometric Pressure (Pb):	29.91	inches Hg
O2 in Stack (%O2):	18.6	percent
CO in Stack (%CO):	0.00	percent
CO2 in Stack (%CO2):	1.3	percent
N2 in Stack (%N2):	80.10	percent
Pitot Tube Factor (Cp)	0.84	
Avg. of Sqrt. of Pitot Press. (/dP avg):	1.03	/(inches H2O)
Stack Temperature (Ts)	949	deg. R
Static Pressure	-0.33	inches H2O
Absolute Stack Pressure (Ps)	29.89	inches Hg
Stack Dimensions	6.0	inches dia.
Stack Area (As)	0.196	square feet

CALCULATED RESULTS

Water Vapor in Stack (Bws):	2.75	percent by volume
Stack Gas Molecular Wt, Dry (Md):	28.95	lb/lbmole
Stack Gas Molecular Wt, Wet	28.65	lb/lbmole
Stack Gas Velocity (Vs):	77.68	feet/second
Stack Gas Flow Rate (Qs):	495	DSCFM(68 deg.F)

MONITORING & LABORATORY DIVISION
ENGINEERING & CERTIFICATION BRANCH

FIELD DATA SHEET

FILE NO.:	T-01-040	PITOT TUBE FACTOR (Cp)	0.84
PROJECT NAME:	SMUD/Capstone 30	PROBE TIP DIA, in. (Dn)	N/A
RUN NO.:	50% Load	STACK DIA, inches	6.0
LOCATION	Turbine Stack	STATIC PRESS, "H2O (Ps)	-0.20
BAR. PRESS, "Hg(Pb)	29.91	METER TEMP, F	60

SAMPLE POINT	t CLOCK TIME min.	Vm DRY GAS METER cu. ft.	dP PITOT PRESS. in. H2O	dH ORIFICE PRESS. (ACTUAL) in. H2O	Ts STACK TEMP. F
START	0	0	----	----	----
1E			0.63		447
2E			0.70		444
3E			0.76		443
4E			0.76		443
1W			0.62		443
2W			0.74		443
3W			0.76		448
4W			0.76		447
	t= 0	Vm= 0.00	/dP avg.= 0.846	dH avg.= ERR	Ts avg.= 444.8

TEST SUMMARY AND RESULTS (FOR FIELD DATA RECORD)

FILE NO.: T-01-040
PROJECT NAME: SMUD/Capstone 30
RUN NO.: 50% Load

SUMMARY OF TEST DATA

Barometric Pressure (Pb):	29.91	inches Hg
O2 in Stack (%O2):	19.0	percent
CO in Stack (%CO):	0.00	percent
CO2 in Stack (%CO2):	1.1	percent
N2 in Stack (%N2):	79.90	percent
Pitot Tube Factor (Cp)	0.84	
Avg. of Sqrt. of Pitot Press. (/dP avg):	0.85	/(inches H2O)
Stack Temperature (Ts)	905	deg. R
Static Pressure	-0.20	inches H2O
Absolute Stack Pressure (Ps)	29.90	inches Hg
Stack Dimensions	6.0	inches dia.
Stack Area (As)	0.196	square feet

CALCULATED RESULTS

Water Vapor in Stack (Bws):	2.75	percent by volume
Stack Gas Molecular Wt, Dry (Md):	28.94	lb/lbmole
Stack Gas Molecular Wt, Wet	28.64	lb/lbmole
Stack Gas Velocity (Vs):	62.43	feet/second
Stack Gas Flow Rate (Qs):	417	DSCFM(68 deg.F)