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AFOEHL REPORT 90-064EQ00094DEF

FOR HEALTH & ENVIRONMENT

Source Emission Test of Gas Turbine Engine Test Facility Kelly AFB TX

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April 1990

Final Report

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AF Occupational and Environmental Health Laboratory (AFSC)
Human Systems Division
Brooks Air Force Base, Texas 78235-5501

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13. ABSTRACT *(Maximum 200 words)*
Source emission testing was conducted on the F-15 JFS and GT CP 85-180 gas turbine engines for particulates, carbon monoxide, total hydrocarbons, sulfur dioxide and nitrogen oxide. The present Gas Turbine Engine Test Facility is grandfathered per Texas Air Control Board and Federal (40CFR60) Regulations. The data in this report will be used to initiate a permit application for a new Gas Turbine Engine Test Facility.

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Illustrations

I. INTRODUCTION

On 15 Nov 89, source emission testing for particulates, carbon monoxide (CO), total hydrocarbons (HC), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) was conducted on the Gas Turbine Engine Test Facility, Bldg 340, by personnel from the Air Quality Function of the AF Occupational and Environmental Health Laboratory Environmental Quality Division (AFOEHL/EQ). This survey was requested by SA-ALC/EM to determine emission data on various gas turbine engines. The emission data will be used to initiate a permit application for a new Gas Turbine Engine Test Facility. Personnel involved with on-site testing are listed in Appendix A.

II. DISCUSSION

A. Background

SA-ALC/EM requested emission data on various gas turbine engines. This information is required to initiate a permit application for a new Gas Turbine Engine Test Facility. No emission data could be located for two of the engines. SA-ALC/EM then requested source emission testing at the existing facility to determine emission data for these gas turbine engines.

B. Site Description

The Gas Turbine Engine Test Facility, Bldg 340, is a one story building located on Kelly AFB. The building is divided into several test cells (Fig 1). Cells 8 and 15A were selected for emission testing. The exhaust stacks for cells 8 and 15A are shown in Figures 2 and 3, respectively. Cell 8 was used to test gas turbine engine GTCP 85-180. Cell 15A was used to test jet fuel starter F-15 JFS.

C. Sampling Methods and Procedures

Federal Regulations require that stack emission testing be conducted in accordance with Appendix A and B to Title 40, Code of Federal Regulations, Part 60 (40 CFR 60). Determination of gas turbine engines emissions is to be done in accordance with Title 40, Code of Federal Regulations, Part 87. Therefore, sample train preparation, sampling and recovery, calculations and quality assurance were done in accordance with the methods and procedures outlined in 40 CFR 60 and 87.

Five sampling ports were installed on one side of the rectangular stacks resulting in five traverses of the stack cross-section. The ports on Cells 8 and 15A were installed approximately 1 and 1.5 duct diameters upstream and 2.8 and 4 duct diameters downstream from any flow disturbance, respectively. Based on the inside stack diameter, port location and type of sample (particulate), 25 traverse points (5 per traverse) were used to collect a representative sample.

Prior to the emission test on each stack, cyclonic flow was determined by using the Type S pitot tube and measuring the stack gas rotational angle at each traverse point. Flow conditions were considered acceptable when the arithmetic mean of the rotational angles was 20 degrees or less. A preliminary velocity pressure traverse was also accomplished concurrently.

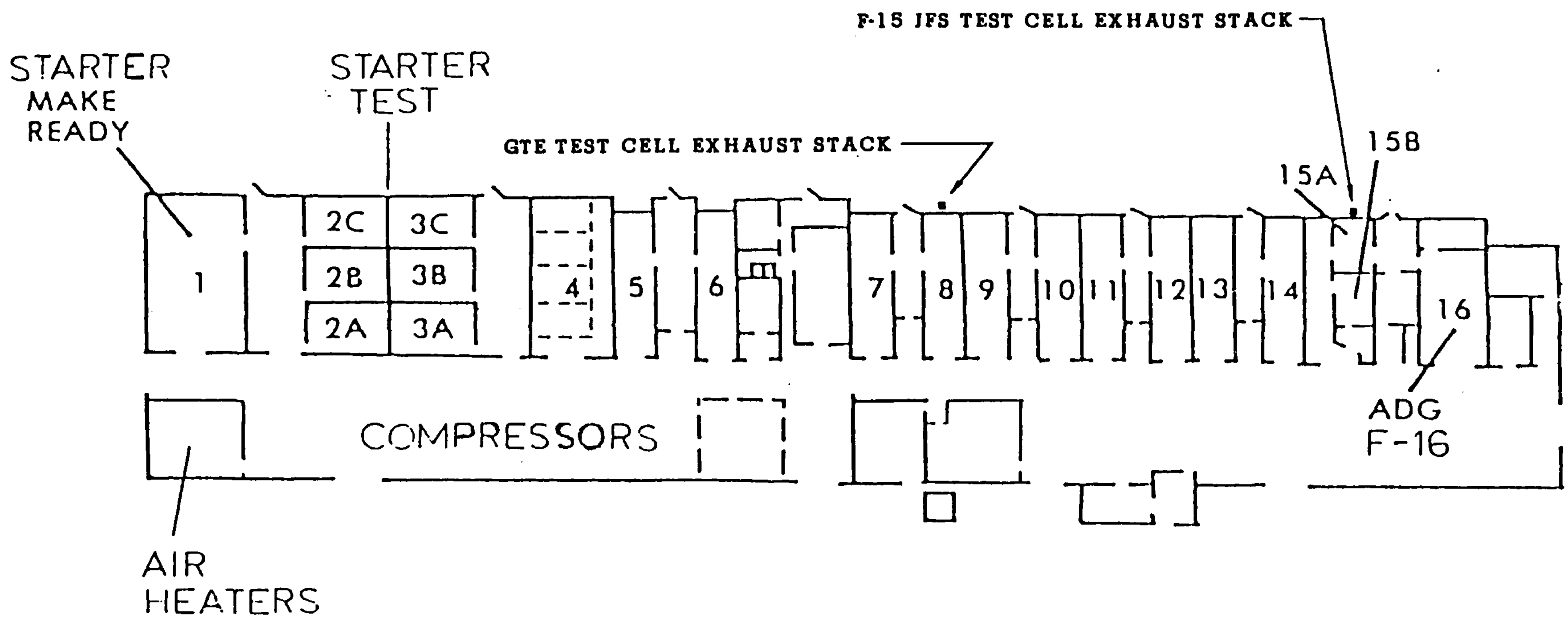

Figure 1. Schematic of Gas Turbine Engine Test Cell Facility

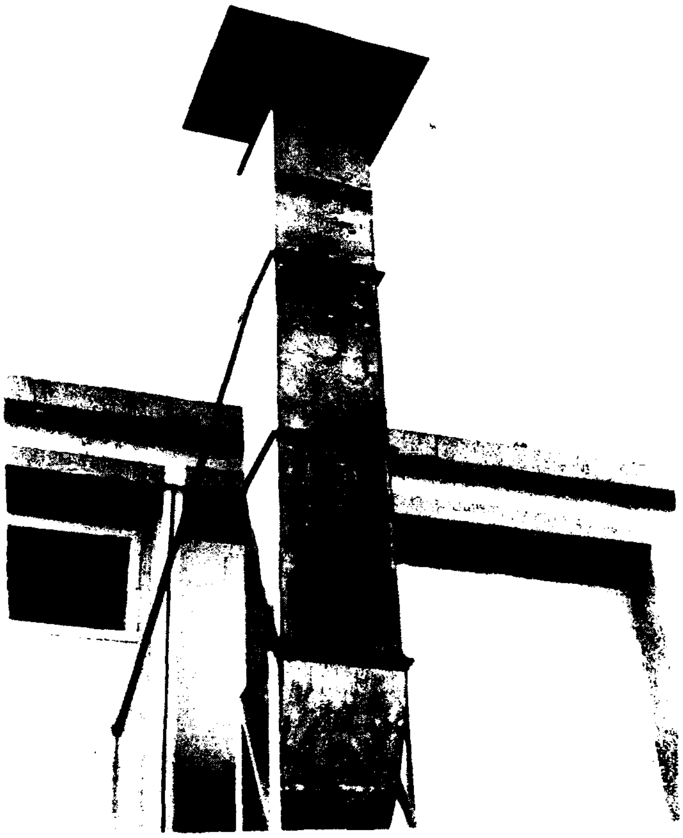

Figure 2. View of Cell 15A Exhaust Stack

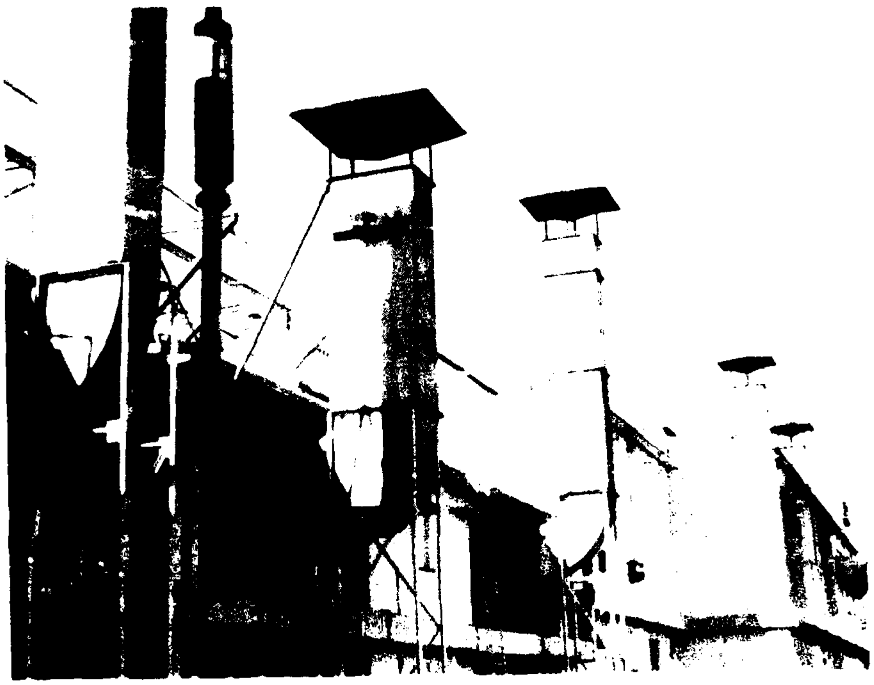

Figure 3. View of Cell 8 Exhaust Stack

Particulates and sulfur oxides (SO_2) were collected and analyzed according to EPA method 8. Normally, three minimum one hour runs constitute a test; however, because jet fuel starters, as opposed to aircraft engines, can only operate for abbreviated periods, only one 62.5 minute run constituted a test.

The EPA method 8 sampling train (Figure 4) consisted of a button-hook probe nozzle, heated inconel probe, heated glass filter, impingers and a pumping and metering device. The nozzle was sized prior to each stack test so that the gas stream could be sampled isokinetically. In other words, the velocity at the nozzle tip was the same as the stack gas velocity at each point sampled. Flue gas velocity pressure was measured at the nozzle tip using a Type S pitot tube connected to a 10-inch inclined-vertical manometer. Type K thermocouples were used to measure flue gas and sampling train temperatures. The stainless steel probe liner was heated to minimize moisture condensation and the heated filter was used to collect particulates. The impinger train consisted of four impingers. The first and third impingers were standard Greenburg-Smith designs and the second and fourth impingers were modified Greenburg-Smiths. The first impinger contained an 80% solution of isopropanol and the second and third impinger each contained a 3% hydrogen peroxide solution. The fourth impinger contained silica gel. This system collected the water and SO_2 from the gas stream. Moisture was subsequently determined according to EPA method 4. The pumping and metering system was used to control and monitor the sample gas flow rate.

Hydrocarbons were collected using a sampling train which consisted of a metal probe, two charcoal tubes connected *in series*, and a pump. The pump was calibrated before and after sampling.

Carbon monoxide (CO) was continuously monitored according to EPA method 10 using Neotronics (model CO101) direct reading equipment. However, ascarite and silica gel tubes were not used in the sampling train to remove CO_2 and water, since CO_2 and water were considered to be too low in concentration to be a significant interference in the CO infrared absorptance band used. Carbon monoxide monitor was calibrated using known concentrations of CO (0, 24, 55, and 100 parts per million). Calibration was accomplished according to EPA method 10. (Appendix F)

Nitrogen oxides were monitored using an Anarad Continuous Emission Monitor (CEM) according to EPA method 7E. The CEM consisted of a metal probe, heated umbilical, sample conditioner and NO_x analyzer. Nitrogen oxide analyzer was calibrated using known concentrations of NO (0, 50, 155, 250, and 348 parts per million). Calibration was accomplished according to EPA method 20. (Appendix F)

Oxygen (O_2) and carbon dioxide (CO_2) were collected and analyzed according to EPA method 3. The sampling train and ORSAT analyzer are shown in Figures 5 and 6.

EPA methods calculations were made using the Environmental Protection Agency publication entitled, "Source Test Calculation and check programs for Hewlett-Packard 41 Calculators," (EPA-340/1-85-013) and associated software programs. Equipment calibration data is shown in Appendix F.

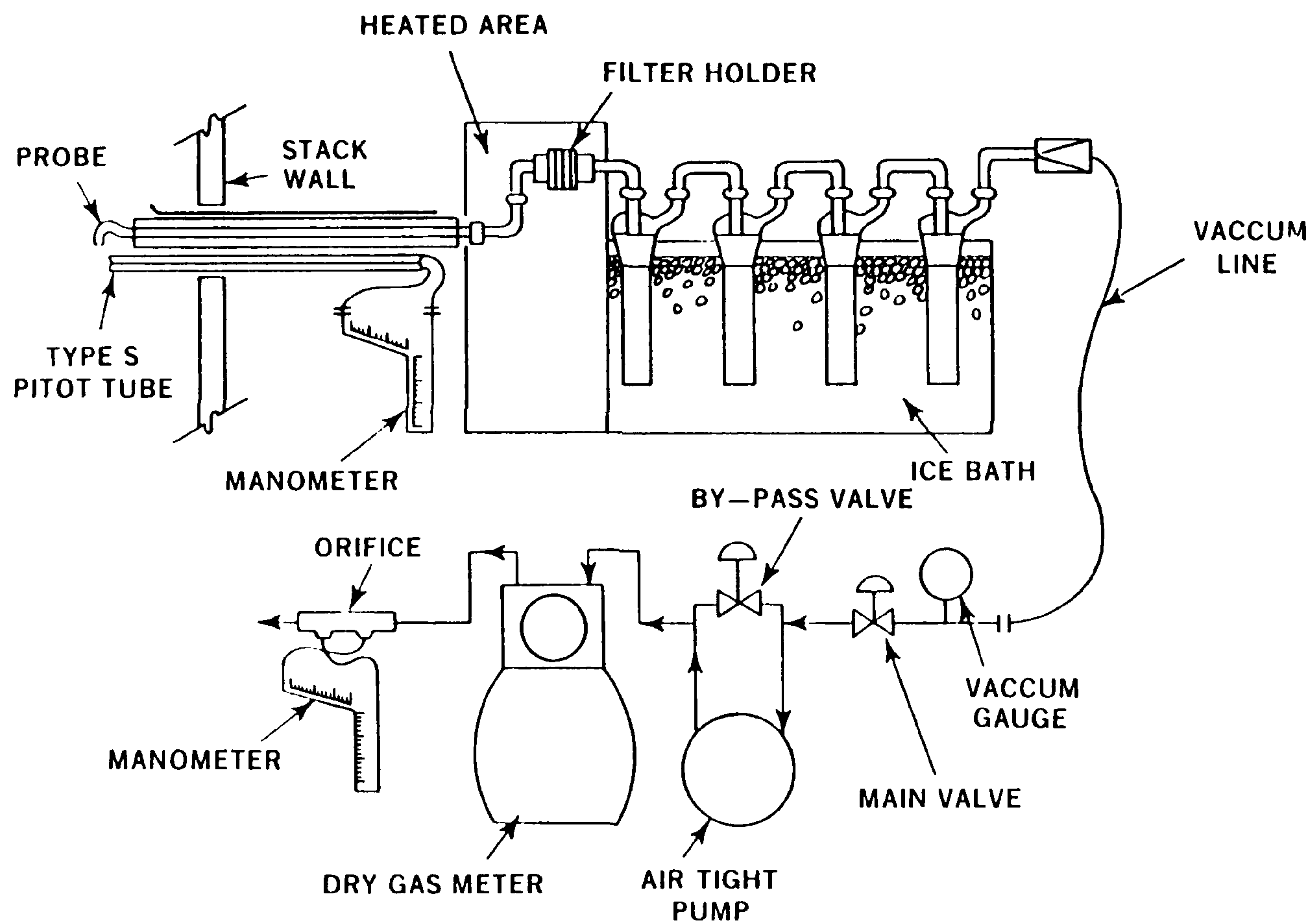

Figure 4. EPA Method 8/5 Sampling Train

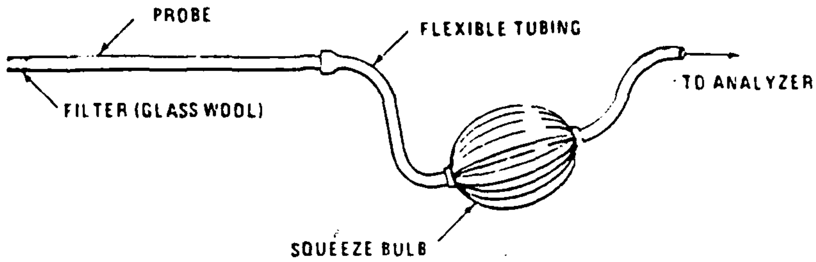

Figure 5. EPA Method 3 Sampling Train

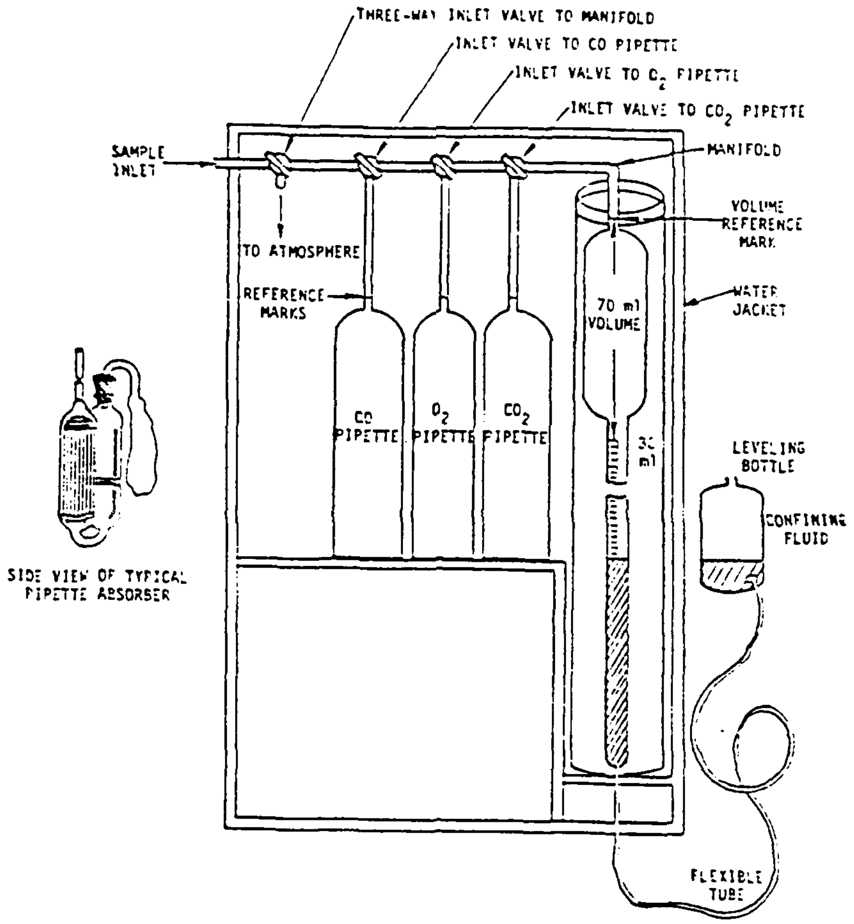

Figure 6. ORSAT GAS ANALYZER

D. Results

Table 1 provides a summary of the test results. Field data sheets are found in Appendix B and C and the resulting emissions data are presented in Appendix D. Tables 2 and 3 give engine operating parameters and emission rates. Emission rates were calculated according to 40 CFR 87 Subpart G, and these equations are shown in Appendix E.

TABLE 1. Summary of Test Results

Engine Tested	Vol, Part. Sample Part Vol (dscf)*	Part. (gdscf)+	CO_2 (%)	O_2 (%)	CO (ppm)	SO_2 (mg/m^3)	NO_x (ppm)	HC (mg/m^3)
F-15 JFS	72.26	1.49E-7	2.8	14.1	290.4	<.005	14.8	<.0067
GTCP85-180	49.06	6.45E-6	3.2	14.4	118.0	<.005	18.2	<.0067

*dry standard cubic feet
+grains per dry standard cubic feet

TABLE 2. Emission Rates

Engine Tested	Power Setting (%)	Fuel Consumed (lbs/hr)	Parts. (lbs/hr)	CO (lbs/hr)	NO_x (lbs/hr)	HC (lbs/hr)
F-15 JFS	100	150	3.83E-6	3.08	0.258	<.0001
GTCP 85-180	100	360	2.48E-4	2.64	0.670	<.0001

Note: SO_2 was below detection limits

TABLE 3. Emissions Per Fuel Consumed

Engine Tested	Power Setting (%)	Parts. (lbs / 1000 lbs fuel burned)	CO	NO_x	HC
F-15 JFS	100	2.55E-5	20.53	1.72	<.001
GTCP 85-180	100	6.89E-4	7.35	1.86	<.001

III. CONCLUSIONS

Both engines ran very clean; however, it is important to note that typically particulates and hydrocarbons concentrations are inversely proportional to the engine thrust or power setting; while nitrogen oxides and carbon monoxide emissions are proportional to thrust. Therefore, this test does not give an accurate indication of the maximum particulate and hydrocarbon emissions. However, maximum hydrocarbon emissions could be estimated by comparing the data of this report with emissions of other gas turbine engines.

IV. RECOMMENDATIONS

The Kelly AFB Gas Turbine Engine Test Facility, Bldg 340, is meeting Texas Air Control Board standards. No further action is necessary at this time.

The data contained in this report should be used as an estimate of emissions from the F-15 JFS and GTCP 85-180 and used to initiate a permit application for a new Gas Turbine Engine Test Facility.

REFERENCES

1. Standards of Performance for New Stationary Sources, Title 40, Part 60, Code of Federal Regulations, July 1, 1988.

2. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume III, Stationary Source Specific Methods, U.S. Environmental Protection Agency, EPA-600/4-77-027-b, Research Triangle Park, North Carolina, April 1977.

3. Source Test Calculations and Check Programs for Hewlett-Packard 41 Calculators, U.S. Environmental Protection Agency, EPA-340/1-85-018, Research Triangle Park, North Carolina, Sept 1985.

4. Control of Air Pollution From Aircraft and Aircraft Engines, Title 40, Part 87, Code of Federal Regulations, July 1, 1988.

5. Aircraft Engine Emissions, International Civil Aviation Organization, Annex 16, Vol II, June 1981.

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APPENDIX A

Personnel

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1. AFOEHL TEST TEAM

Capt Paul Scott, Chief, Air Quality Function
Capt Ronald Vaughn, Consultant, Air Quality Engineer
Sgt Harold Casey, Environmental Quality Technician
Amn Chris Feagin, Environmental Quality Technician

AFOEHL/EQE
Brooks AFB TX 78235-5501

Phone: AUTOVON 240-2891
Commercial (512) 536-2891

2. Kelly AFB on-site representatives

Mr C.B. Laughlin	SA-ALC/EM AV 945-6874 COM (512) 925-6874
Mr Dave Bartels	SA-ALC/MATEF AV 945-8711 COM (512) 925-8711

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APPENDIX B

Field Data F-15 JFS

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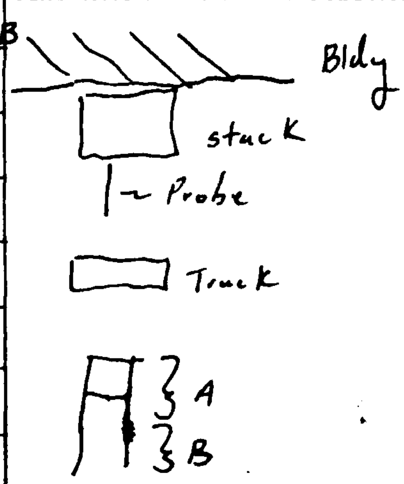
V2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER	F-15 ONE JFS CGB
DATE	15 ~~14~~ NOV 89
PLANT	Bldg 340
BASE	Kelly AFB
SAMPLE BOX NUMBER	
METER BOX NUMBER	Nutech #2
Qw/Qm	
Co	

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$°R = °F + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pitot check Pre – oK

Leak check Pre – oK

~~Pitot check Post~~ –

Leak check Post @ 15 – oK

AMBIENT TEMP	°F
STATION PRESS	28.85 in Hg
HEATER BOX TEMP	°F
PROBE HEATER SETTING	
PROBE LENGTH	in
NOZZLE AREA (A)	.500 sq ft
Cp	.84
DRY GAS FRACTION (Fd)	

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	2.5		565		.11	3.88	981.325	77		76	240	77
2	2.5		437		.10	4.04		79		76	240	81
3	2.5		448		.12	4.80		81		76	246	96
4	2.5		458		.12	4.77		85		77	255	118
5	2.5		456		.10	3.99		88		78	259	119
6	2.5		469		.13	5.13		90		78	264	116
7	2.5		475		.13	5.11		91		79	265	116
8	2.5		478		.12	4.70		91		79	249	113
9	2.5		478		.12	4.71		92		80	240	111
10	2.5		380		.15	6.53		86		80	236	77
11	2.5		412		.15	6.31		89		80	242	90
12	2.5		438		.14	5.74		92		81	245	96
13	2.5		456		.13	5.24		94		82	239	96
14	2.5		478		.12	4.73		95		82	238	91
15	2.5		479		.12	4.73		95		83	242	89
16	2.5	10	476		.14	5.53		94		83	238	88
17	2.5		476		.14	5.53		95		83	226	87
18	2.5		480		.12	4.73		96		83	242	87
19	2.5	9	441		.12	4.91		91		83	236	83
20	2.6		467		.13	5.18		93		83	244	84
21	2.5		457		.15	6.06		95		84	256	85
22	2.5		472		.14	5.57		96		84	225	83
23	2.6		476		.14	5.54		97		84	226	81

OEHL FORM MAY 78 18

2/2

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER	one
DATE	16 Nov 83
PLANT	
BASE	
SAMPLE BOX NUMBER	
METER BOX NUMBER	
Qw/Qm	
Co	

SCHEMATIC OF STACK CROSS SECTION

EQUATIONS

$$^{o}R = {}^{o}F + 460$$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

AMBIENT TEMP	°F
STATION PRESS	in Hg
HEATER BOX TEMP	°F
PROBE HEATER SETTING	
PROBE LENGTH	in
NOZZLE AREA (A)	sq ft
Cp	
DRY GAS FRACTION (Fd)	

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
24	2.5	12	479		.14	5.53		96		84	249	79
25	2.5		480		.13	5.13		96		84	252	78
							1055.292					
			$\overline{T_s}$ =	464								
									86			

Jet Fuel Starter
with Central Gear Box connected

$\Delta H = 5.12$

$\sqrt{P_s T_s} = 10.873$

OEHL FORM MAY 78 18

PRELIMINARY SURVEY DATA SHEET NO. 2
(Velocity and Temperature Traverse)

BASE: Kelly AFB	DATE: ~~14~~ 15 NOV 89
BOILER NUMBER: F15 Jet Fuel Starter	
INSIDE STACK DIAMETER: 25 in equivalent diameter	Inches 6% CO_2
STATION PRESSURE: 29.85	In Hg 8% O_2
STACK STATIC PRESSURE: -.04	In H20 1% CO
SAMPLING TEAM: AFOEHL	5% H_2O

TRAVERSE POINT NUMBER	VELOCITY HEAD, V_p IN H20	$\sqrt{V_p}$ α	STACK TEMPERATURE (°F)
~~25~~ 1	.04	2	560
~~75~~ 2	.05		563
~~125~~ 3	.05		563
~~175~~ 4	.05		575
~~225~~ 5	.05		565
	$\overline{FPS} = 17$		
	$\overline{T_s} = 565$		
	$\Theta = .525$		
	AVERAGE		

PRELIMINARY SURVEY DATA SHEET NO. 1
(Stack Geometry)

BASE Kelly AFB	PLANT Test Cell
DATE 14 NOV 89	SAMPLING TEAM AFOEHL
SOURCE TYPE AND MAKE	
SOURCE NUMBER 1	INSIDE STACK DIAMETER equivalent diameter 25" Inches
RELATED CAPACITY 0	TYPE FUEL JP-4
DISTANCE FROM OUTSIDE OF NIPPLE TO INSIDE DIAMETER 0 Inches	
NUMBER OF TRAVERSES	NUMBER OF POINTS/TRAVERSE

LOCATION OF SAMPLING POINTS ALONG TRAVERSE

POINT	PERCENT OF DIAMETER	DISTANCE FROM INSIDE WALL *(Inches)*	TOTAL DISTANCE FROM OUTSIDE OF NIPPLE TO SAMPLING POINT *(Inches)*
2.5 1		2.5	
7.5 2		7.5	
12.5 3		12.5	
17.5 4		17.5	
22.5 5		22.5	

OEHL FORM APR 78 15

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE	DATE	RUN NUMBER
Kelly AFB	15 Nov 89	one

BUILDING NUMBER	SOURCE NUMBER
340	F15 JFS

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER	.2889	.2886	.0003
ACETONE WASHINGS *(Probe, Front Half Filter)*	104.9783	104.9579	.0004
BACK HALF *(If needed)*			
	Total Weight of Particulates Collected		.0007 gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)*	32.0	200	-68.0
IMPINGER 2 *(H20)*	244.Ø	200	44.0
IMPINGER 3 *(Dry)*	240.0	200	40.Ø
IMPINGER 4 *(Silica Gel)*	243.5	200	43.5
	Total Weight of Water Collected		gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2	2.8	2.8	2.8		2.8
VOL % O_2	14.2	14.1	14.1		14.1
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

OEHL FORM MAY 78 20

AFOEHL/EQE
Date of report: Nov 15, 1989 11:46.04
Coverage of report:
Nov 15,1989 10:10.00 to Nov 15, 1989 11:34.00

Stream	Gas		Avg	Max	Min	n
Stack	NOX	PPM	14.8	15.9	13.0	64
Stack	CO	PPM	345.8	408.0	333.0	64

Corrected to Calibration Plots

Stack	NOX	PPM	14.8	15.9	13.0	64
Stack	CO	PPM	290.4	349.0	292.0	64

APPENDIX C

Field Data GTCP 85-180

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½

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: 2

DATE: 15 NOV 89

PLANT: Kelly AFB

BASE: Bldg 340

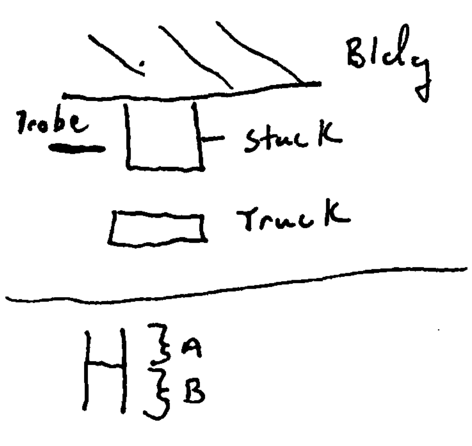
SAMPLE BOX NUMBER: Nutech #2

METER BOX NUMBER:

Qw/Qm:

Co:

SCHEMATIC OF STACK CROSS SECTION



EQUATIONS

$^{o}R = {^{o}F} + 460$

$$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$$

Pitot Check Pre - OK

Leak Check Pre - OK

Pos leak Check @ 15 - OK

AMBIENT TEMP: °F

STATION PRESS: 29.85 in Hg

HEATER BOX TEMP: °F

PROBE HEATER SETTING:

PROBE LENGTH: in

NOZZLE AREA (A): .377 sq ft

Cp: .84

DRY GAS FRACTION (Fd):

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
1	2.5		445		.15	1.94	55.776	77	X	76	192	89
2	2.5		464		.17	2.14		80		76	223	83
3	2.5		466		.15	1.90		80		76	246	87
4	2.5		462		.11	1.40		84		77	264	92
5	2.5		454		.10	1.29		86		77	272	92
6	2.5		441		.13	1.70		86		77	280	89
7	2.5		465		.14	1.79		88		78	275	86
8	2.5		472		.19	2.42		89		79	262	87
9	2.5	4	470		.19	2.42		89		79	255	86
10	2.5		462		.20	2.57		91		79	275	85
11	2.5		470		.24	3.07		92		79	272	87
12	2.5		478		.20	2.54		93		80	273	89
13	2.5	4	473		.15	1.92		94		81	270	91
14	2.5		469		.14	1.80		93		81	275	91
15	2.5		460		.14	1.81		93		81	274	91
16	2.5		466		.20	2.58		93		82	269	91
17	2.5		472		.19	2.44		94		83	273	92
18	2.5		474		.20	2.56		95		83	267	94
19	2.5		477		.23	2.93		95		83	273	94
20	2.5		457		.21	2.74		96		84	262	94
21	2.5		463		.21	2.73		96		84	274	90
22	2.5		478		.19	2.43		96		84	277	84
23	2.5		478		.19	2.43		96		85	276	81

OEHL FORM MAY 78 18

PARTICULATE SAMPLING DATA SHEET

RUN NUMBER: 2	SCHEMATIC OF STACK CROSS SECTION	EQUATIONS	AMBIENT TEMP: °F
DATE: 15 Nov 89		$°R = °F + 460$	STATION PRESS: in Hg
PLANT: Kelly AFB		$H = \left[\frac{5130 \cdot Fd \cdot Cp \cdot A}{Co}\right]^2 \cdot \frac{Tm}{Ts} \cdot Vp$	HEATER BOX TEMP: °F
BASE: Bldg 340			PROBE HEATER SETTING
SAMPLE BOX NUMBER: Nutech #2			PROBE LENGTH: in
METER BOX NUMBER			NOZZLE AREA (A): sq ft
Qw/Qm			Cp
Co			DRY GAS FRACTION (Fd)

TRAVERSE POINT NUMBER	SAMPLING TIME (min)	STATIC PRESSURE (in H20)	STACK TEMP (°F)	STACK TEMP (Ts) (°R)	VELOCITY HEAD (Vp)	ORIFICE DIFF. PRESS. (H)	GAS SAMPLE VOLUME (cu ft)	GAS METER TEMP IN (°F)	GAS METER TEMP AVG (Tm) (°R)	GAS METER TEMP OUT (°F)	SAMPLE BOX TEMP (°F)	IMPINGER OUTLET TEMP (°F)
24	2.5		475		.19	2.44		96		85	273	79
25	2.5		475		.19	2.44		96		85	273	79
							106.401					
		$\overline{T_s}$ =	467		ΔH =	2.26			86			

$\sqrt{P_s T_s} = 12.7063$

OEHL FORM MAY 78 18

PRELIMINARY SURVEY DATA SHEET NO. 2
(Velocity and Temperature Traverse)

BASE Kelly	DATE 15 Nov 89
BOILER NUMBER 0	
INSIDE STACK DIAMETER 28.7	Inches
STATION PRESSURE 29.85	In Hg 5% H_2O
STACK STATIC PRESSURE -.05	In H20
SAMPLING TEAM	

TRAVERSE POINT NUMBER	VELOCITY HEAD, V_p IN H20	$\sqrt{V_p}$	STACK TEMPERATURE (°F)
1	.13	0	394
2	.13	1	397
3	.14	3	415
4	.16	2	420
5	.20	4	426
	$\overline{\Delta P_s} = 28$		
	$\overline{T_s} = 410$		
	$\Theta = .377$		
AVERAGE			

OEHL FORM APR 78 16

PRELIMINARY SURVEY DATA SHEET NO. 1

(Stack Geometry)

BASE Kelly	PLANT
DATE 15 Nov 89	SAMPLING TEAM
SOURCE TYPE AND MAKE	
SOURCE NUMBER	INSIDE STACK DIAMETER equal 28.7 Inches
RELATED CAPACITY	TYPE FUEL
DISTANCE FROM OUTSIDE OF NIPPLE TO INSIDE DIAMETER Inches	
NUMBER OF TRAVERSES 5	NUMBER OF POINTS/TRAVERSE 5 (25 total Points

LOCATION OF SAMPLING POINTS ALONG TRAVERSE

POINT	PERCENT OF DIAMETER	DISTANCE FROM INSIDE WALL *(Inches)*	TOTAL DISTANCE FROM OUTSIDE OF NIPPLE TO SAMPLING POINT *(Inches)*
1		3.6	
2		10.8	
3		18.0	
4		25.2	
5		32.4	

OEHL FORM APR 78 15

AIR POLLUTION PARTICULATE ANALYTICAL DATA

BASE	DATE	RUN NUMBER
Kelly AFB	15 Nov 89	N/A

BUILDING NUMBER	SOURCE NUMBER
GTE	GTE

I. PARTICULATES

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT PARTICLES (gm)
FILTER NUMBER	.2957	.2943	.0014
ACETONE WASHINGS *(Probe, Front Half Filter)*	98.7549	98.7358	.0191
BACK HALF *(If needed)*			.
	Total Weight of Particulates Collected		.0205 gm

II. WATER

ITEM	FINAL WEIGHT (gm)	INITIAL WEIGHT (gm)	WEIGHT WATER (gm)
IMPINGER 1 *(H20)*	72	200	-128
IMPINGER 2 *(H20)*	230	200	30
IMPINGER 3 *(Dry)*	241	200	41
IMPINGER 4 *(Silica Gel)*	233	200	33
	Total Weight of Water Collected		gm

III. GASES *(Dry)*

ITEM	ANALYSIS 1	ANALYSIS 2	ANALYSIS 3	ANALYSIS 4	AVERAGE
VOL % CO_2	3.1	3.2	3.2		3.2
VOL % O_2	14.3	14.4	14.4		14.4
VOL % CO					
VOL % N_2					

Vol % N_2 = (100% - % CO_2 - % O_2 - % CO)

OEHL FORM 20 MAY 78

AFOEHL/EQE

Date of report: Nov 15, 1989 15:52.45

Coverage of report:

Nov 15,1989 13:50.00 to Nov 15, 1989 14:54.00

Stream	Gas		Avg	Max	Min	n
Stack	NOX	PPM	18.2	21.1	13.5	64
Stack	CO	PPM	134.4	139.0	115.0	64

Corrected to Calibration Plots

Stack	NOX	PPM	18.2	21.1	13.5	64
Stack	CO	PPM	118.0	123.0	96.0	64

APPENDIX D

Emission Data

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EPA Method 5

	RUN #1	RUN #2
Meter Box Y	.9990	.9990
Delta H (in H_2O	5.12	2.26
Bar Press (in Hg)	29.85	29.85
Meter Vol (FT^3)	73.9670	50.6250
MTR TEMP F	86	86
Static HOH IN	-.04	-.05
ml Wate	59.5	76
% HOH	3.7	6.8
% CO_2	2.8	3.2
% Oxygen	11	14.4
MWd	29.20	29.09
MW Wet	28.78	28.33
SQRT PSTS	10.8739	12.7063
Time Min	62.5	62.5
Nozzle Dia	.500	.377
STK Dia IN	25.0	28.7
VOL MTR STD	72.261	49.064
Stack DSCFM	2,990	4,479
% Isokinetics	96.72	101.64

EPA Mass Flow

	RUN 1 F-15JFS	RUN 2 GTCP 85-180
VOL MTR STD	72.261	49.064
Stack DSCFM	2,990	4,479
Front 1/2 mg	.0007	.0205
GR/DSCF	1.49E -7	6.45E -6
mg/MMM	3.42E -4	0.01
lb/HR	3.83E -6	2.48E -4
KG/HR	1.74E -6	1.12E -4

LABORATORY ANALYSIS REPORT AND RECORD *(General)*

DATE: 05 DEC 1989

TO:

FROM:

SAMPLE IDENTITY

DATE RECEIVED: 20 NOV 89

SAMPLE FROM: BLDG 340

LAB CONTROL NR: 65384 - 388

TEST FOR: PD-680

RESULTS

OEHL #	BASE #	Volume Sampled	mg FRONT SECTION	mg BACK SECTION	TOTAL mg/m^3
65384	SX890083	7.38L	ND	ND	ND
65385	SX890084	7.38L	ND	ND	ND
65386	SX890085	7.50L	ND	ND	ND
65387	SX890086	7.50L	ND	ND	ND
65388	BK890087		ND	ND	—

ND=NONE DETECTED

LIMIT OF DETECTION - 0.005 mg

Andrew Richardson, III

ANDREW RICHARDSON, III, GS-12
Chief, IH Analysis Section

REQUESTING AGENCY *(Mailing Address)*

OEHL/ECE

ATT CAPT VAUGHN

AFSC Form 3511, DEC 85 REPLACES AMD FORM 641, SEP 82, WHICH IS OBSOLETE

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APPENDIX E

Emission Equations

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CALCULATION OF MASS EMISSION RATES

1. Mass emission rates for gas turbine and piston engines were calculated using the formulas specified by EPA.

For gas turbine engines, these formulas are:

$$\text{HC emission rate} = \frac{M_{HC}\,\frac{(HC)}{10^4}\,F^{*}}{(M_C + \alpha M_H)\left[\frac{(CO)}{10^4} + (CO_2) + \frac{(HC)}{10^4}\right]}$$

$$\text{CO emission rate} = \frac{M_{CO}\,\frac{(CO)}{10^4}\,F}{(M_C + \alpha M_H)\left[\frac{(CO)}{10^4} + (CO_2) + \frac{(HC)}{10^4}\right]}$$

$$NO_x \text{ emission rate} = \frac{M_{NO_2}\,\frac{(NO_x)}{10^4}\,F}{(M_C + \alpha M_H)\left[\frac{(CO)}{10^4} + (CO_2) + \frac{(HC)}{10^4}\right]}$$

* Defined - next page

2. Emission rates for hydrocarbons, carbon monoxide, oxides of nitrogen, and particulates also are expressed as pounds per 1000 pounds of fuel. These values are obtained by dividing the emission rate, expressed as pounds per hour, by the fuel flow (pounds per hour) and multiplying by 1000.

where:

HC emission rate = Pounds per hour of exhaust hydrocarbons emitted in an operational mode

CO emission rate = Pounds per hour of exhaust carbon monoxide emitted in an operational mode

NO_x emission rate = Pounds per hour of exhaust oxides of nitrogen emitted in an operational mode

M_{HC} = Molecular weight of methane, $M_{HC} = 16.04$

M_{CO} = Molecular weight of carbon monoxide

M_{NO_2} = Molecular weight of nitrogen dioxide

M_C = Atomic weight of carbon

M_H = Atomic weight of hydrogen, $M_H = 1.008$

α = Atomic hydrogen - carbon ratio of fuel (equal to 2 in approximation equations)

(HC) = Concentration of hydrocarbons in the exhaust sample in parts per million carbon equivalent, i.e., equivalent propane × 3.

(CO) = Concentration of carbon monoxide in the exhaust sample in parts per million by volume.

(CO_2) = Concentration of carbon dioxide in the exhaust sample in volume percent

(NO_x) = Concentration of oxides of nitrogen in the exhaust sample in parts per million by volume, NO + NO_x.

F = Mass rate of fuel flow in pounds per hour.

APPENDIX F

Calibration Data

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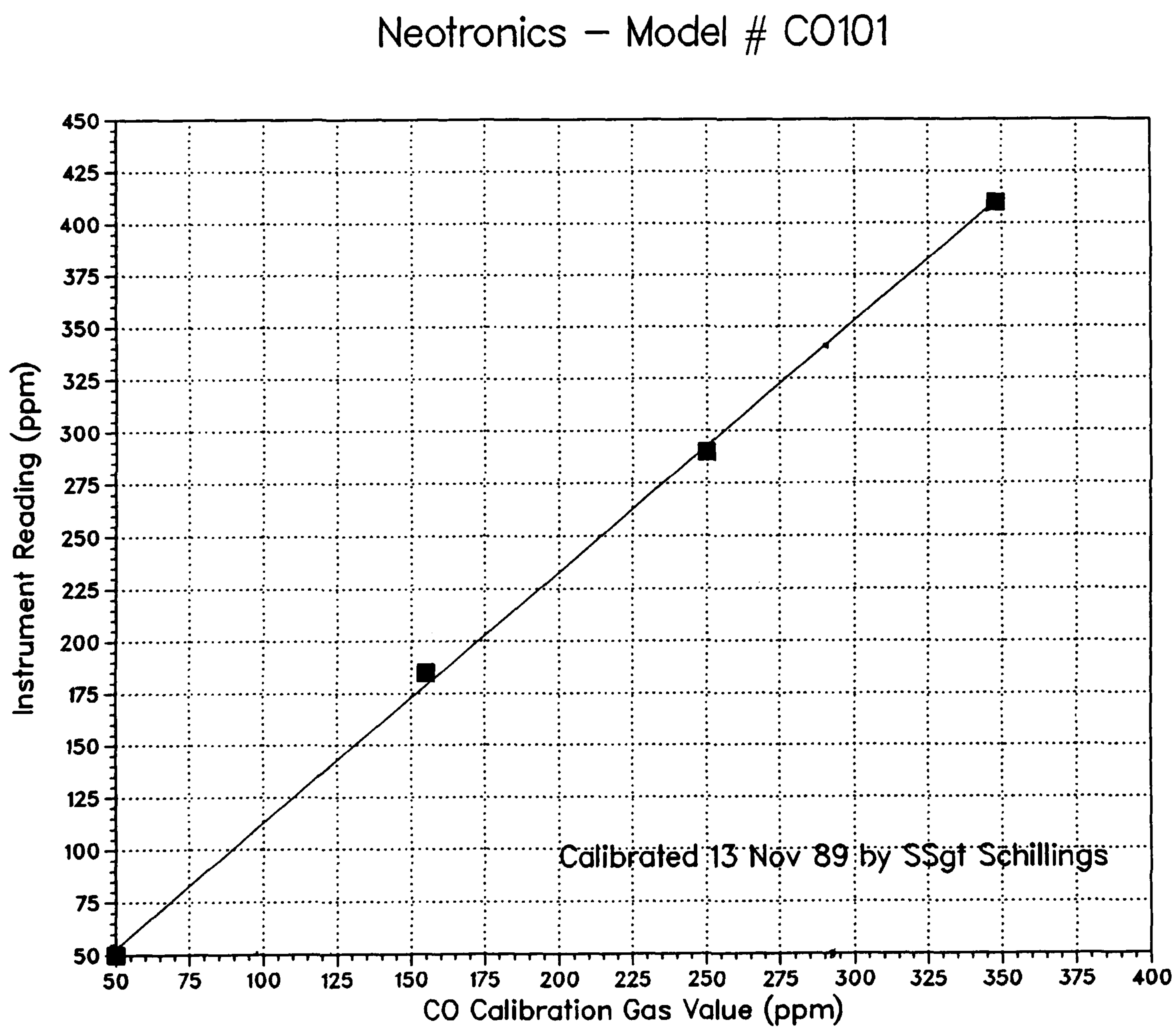
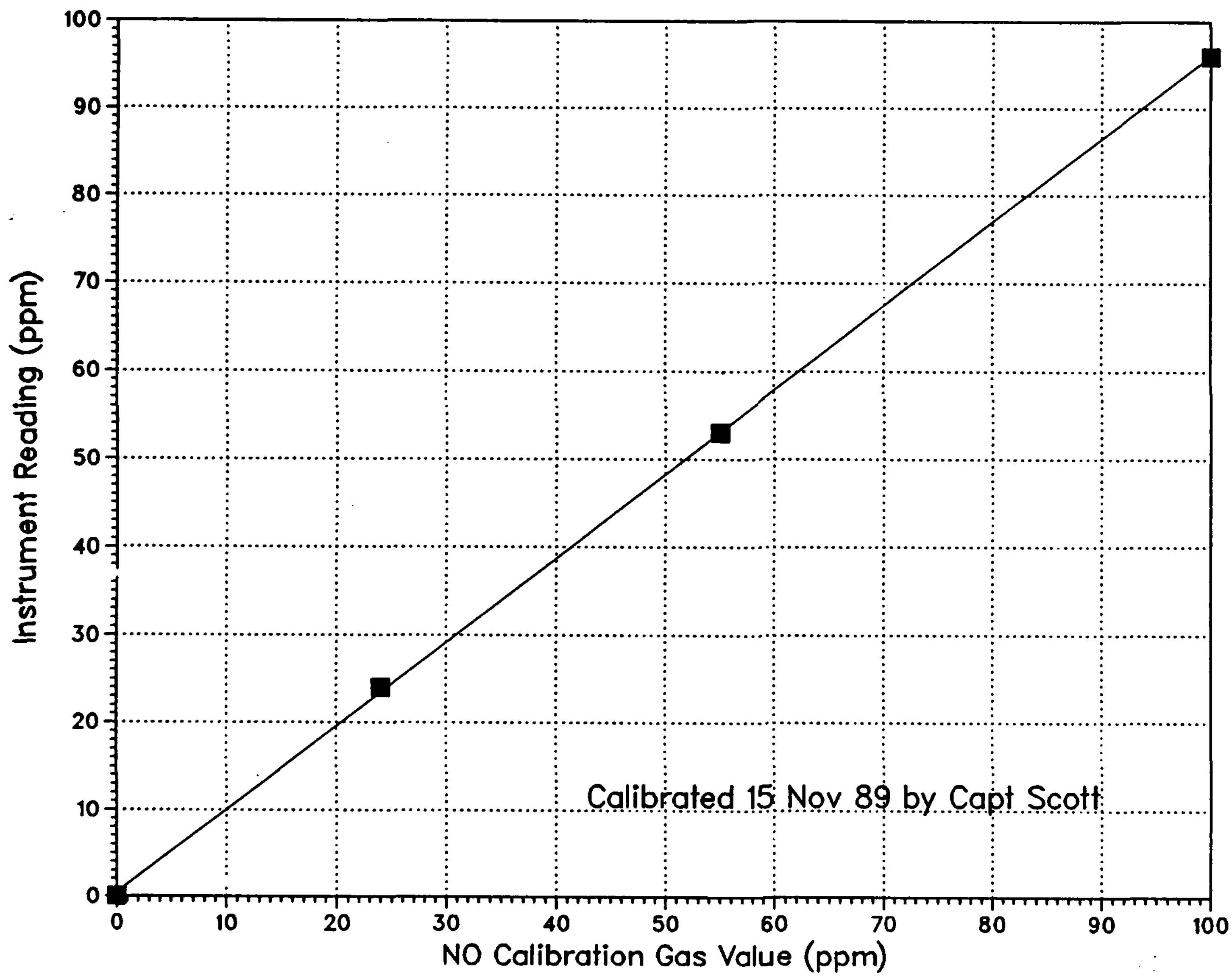


Neotronics – Model # CO101
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
Instrument Reading (ppm)
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
CO Calibration Gas Value (ppm)
Calibrated 13 Nov 89 by SSgt Schillings

Anarad – CEM


Instrument Reading (ppm)
NO Calibration Gas Value (ppm)
Calibrated 15 Nov 89 by Capt Scott
0
10
20
30
40
50
60
70
80
90
100

POSTTEST DRY GAS METER CALIBRATION DATA FORM (English units)

Scott/Vaughn

Test number one   Date 12 Dec 89   Meter box number Nutech 2   Plant Pre Kelly Fl, Post Kelly GTE

Barometric pressure, P_b = 29.350 in. Hg   Dry gas meter number N/A   Pretest Y Ø.999   ΔH@ = 1.969

Orifice manometer setting, (ΔH), in. H_2O	Gas volume: Wet test meter (V_w), ft^3	Gas volume: Dry gas meter (V_d), ft^3	Temperature: Wet test meter (t_w), °F	Temperature: Dry gas meter: Inlet (t_{d_i}), °F	Temperature: Dry gas meter: Outlet (t_{d_o}), °F	Temperature: Dry gas meter: Average[a] (t_d), °F	Time (θ), min	Vacuum setting, in. Hg	Y_i	$Y_i = \frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$
.5	10	10.174	66 64 65	70 75 72.5	70 70 70.0	71.25	25.51	4.0	Ø.993	$\frac{(10)(29.35)(531.25)}{(10.174)(29.35+.0368)(525)}$
.5	10	10.225	64 65 64.5	75 78 76.5	70 73 71.5	74.0	25.52	4.0	Ø.992	$\frac{(10)(29.35)(534)}{(29.35+.0368)(10.225)(524.5)}$
.5	10	10.277	67 67 67	80 81 80.5	75 76 75.5	78.0	25.51	4.0	Ø.992	$\frac{(10)(29.35)(538)}{(29.35+.0368)(10.277)(527)}$
									Y = Ø.992	

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d

where

V_w = Gas volume passing through the wet test meter, ft^3.

V_d = Gas volume passing through the dry gas meter, ft^3.

t_w = Temperature of the gas in the wet test meter, °F.

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F.

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F.

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F.

ΔH = Pressure differential across orifice, in. H_2O.

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run.

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ±0.05Y. .999 ± .04995 → Ø.941 < y_{post} → 1.049

P_b = Barometric pressure, in. Hg.

θ = Time of calibration run, min.

Quality Assurance Handbook M4-2.4A

METER BOX CALIBRATION DATA AND CALCULATION FORM

(English units)

Date 28 Sept 89 Meter box number Nutech 2

Barometric pressure, P_b = 29.82 in. Hg Calibrated by Scott & Vaughn

IAC	Orifice manometer setting (ΔH), in. H_2O	Gas volume: Wet test meter (V_w), ft^3	Gas volume: Dry gas meter (V_d), ft^3	Temperature: Wet test meter (t_w), ~~°F~~ R	Temperature: Dry gas meter Inlet (t_{d_i}), ~~°F~~ R	Temperature: Dry gas meter Outlet (t_{d_o}), ~~°F~~ R	Temperature: Dry gas meter Avg[a] (t_d), ~~°F~~ R	Time (Θ), min	Y_i	$\Delta H@_i$ in. H_2O
	0.5	5	5.060	78 78 538	79 84 541.5	77 79 538	539.8	12.9	0.990	1.897
	1.0	5	5.060	79 79 539	87 91 549	80 81 540.5	544.8	9.0	0.996	1.837 ~~1.840~~
	1.5	10	10.150	80 79 539.5	96 98 557	86 87 546.5	551.8	15.2	1.004	1.943
	2.0	10	10.195	79 ~~79~~ 539	98 100 559	87 89 548	553.5	13.2	1.002	1.944
	3.0	10	10.155	79 80 539.5	101 104 562.5	90 91 550.5	556.5	10.7	1.008	1.910
	4.0	10	10.025 ~~10.139~~	80 77 538.5	80 89 544.5	74 77 535.5	540	10.0	0.991	2.283
								Avg	0.999	1.969

ΔH, in. H_2O	$\frac{\Delta H}{13.6}$	$Y_i = \frac{V_w P_b (t_d + 460)}{V_d (P_b + \frac{\Delta H}{13.6}) (t_w + 460)}$	$\Delta H@_i = \frac{0.0317 \Delta H}{P_b (t_d + 460)} \left[\frac{(t_w + 460) \Theta}{V_w}\right]^2$
0.5	0.0368	$y_1 = \frac{(5)(29.82)(539.8)}{(5.06)(29.82 + 0.5/13.6)(538)}$	$H@_1 = \frac{(0.0317)(.5)}{(29.82)(539.8)} \left[\frac{(538)(12.9)}{5}\right]^2$
1.0	0.0737	$y_2 = \frac{(5)(29.82)(544.8)}{(5.06)(29.82 + 1/13.6)(539)}$	$H@_2 = \frac{(.0317)(1)}{(29.82)(544.8)} \left[\frac{(539.0)(9.0)}{5}\right]^2$
1.5	0.110	$y_3 = \frac{(10)(29.82)(551.8)}{(10.15)(29.82 + 1.5/13.6)(539.5)}$	$H@_3 = \frac{(.0317)(1.5)}{(29.82)(551.8)} \left[\frac{(539.5)(15.2)}{10}\right]^2$
2.0	0.147	$y_4 = \frac{(10)(29.82)(553.5)}{(10.195)(29.82 + 2.0/13.6)(539)}$	$H@_4 = \frac{(.0317)(2.0)}{(29.82)(553.5)} \left[\frac{(539)(13.2)}{10}\right]^2$
3.0	0.221	$y_5 = \frac{(10)(29.82)(556.5)}{(10.155)(29.82 + 3/13.6)(539.5)}$	$H@_5 = \frac{(.0317)(3.0)}{(29.82)(556.5)} \left[\frac{(539.5)(10.7)}{10}\right]^2$
4.0	0.294	$y_6 = \frac{(10)(29.82)(540)}{(10.025)(29.82 + 4/13.6)(538.5)}$	$H@_6 = \frac{(.0317)(4.0)}{(29.82)(540)} \left[\frac{(538.5)(10.0)}{10}\right]^2$

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d.

CALIBRATION DATA FOR PUMPS A and B

	BEFORE	AFTER
PUMP A	123 cc/min	124 cc/min
PUMP B	123 cc/min	127 cc/min

Pump A used in determining total hydrocarbons on F-15 JFS.

Pump B used in determining total hydrocarbons on GTE.

cc/min = cubic centimeter per minute

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Distribution List

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OL AD, AFOEHL APO San Francisco 96274-5000	1
USAFSAM/TSK/ED/EDH/EDZ Brooks AFB TX 78235-5301	1 ea
Defense Technical Information Center Cameron Station Alexandria VA 22304-6145	2
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