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AEROSPACE INFORMATION REPORT

SAE AIR4068

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Submitted for recognition as an American National Standard

GAS TURBINE EMISSION PROBE FACTORS

FOREWORD

The requirements of the ICAO recommendations on the control of aircraft engine emissions (ICAO ANNEX 16, VOL II), the measurement technology sections of which are incorporated by reference in the USA national regulations (SFAR 27), state that the design of a representative engine exhaust sampling probe must be validated by means of a detailed traverse. In practice, it is becoming clear that the execution of detailed traverse tests by single point sampling is both very costly and often technically difficult to achieve because of engineering problems at the higher engine power settings.

Consequently, recent discussions within SAE Committee E-31 have highlighted this problem area, and several possibilities for alternative strategies are being evaluated. These include a probe factor (pf) approach, the use of a rotating sampling rake, for all engine applications, and the development of core and/or turbine exit plane sampling to meet the specific problems raised by mixed flow engine types.

The pf scheme is designed to be applicable to all engine types with axis-symmetric exhaust systems. This might, therefore, preclude certain aircraft and helicopter engines. The essential ingredient in its development is the analysis of as representative as possible a body of engine exhaust traverse data. To this end, the E-31 Standards Subcommittee sought the assistance of manufacturers, government agencies, and military users in the provision of relevant data. The suppliers of these data were asked to quote predictions of the ratios of simulated averaging probe concentrations to actual mass-weighted detailed traverse averages, for an agreed range of probe geometries and engine powers. These individual probe factors (pfi) were then collectively analyzed to determine the effect of probe geometry, engine type, etc., and thence to show what "global" values of probe factors, one for each constituent, could be chosen such that a given (high) percentage of engines would be predicted to have higher actual probe factors - and, thus, guarantee a high confidence of compliance judgement.

FOREWORD (Continued)

The rotating rake concept would be designed to obtain an isokinetic radial sample which could be temporally averaged over a circumferential traverse of the engine exhaust plane. This technique would enable a true emissions average to be obtained more simply, at a lower cost and with a much reduced engine test time.

Sampling upstream of the final discharge nozzle, for example within the hot core exhaust stream, also raises the possibility of obtaining a representative sample in a less technically complex manner - particularly when the final discharge nozzle encloses both core and bypass stream.

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1. SCOPE:

This report describes the concept and data analysis of the probe factor (pf) scheme. Conclusions are drawn and recommendations made for action to further the requirements for improved methods and procedures in emissions sampling technology.

2. REFERENCES:

There are no referenced publications specified herein.

2.1 Nomenclature:

2.1.1 Ea - Adjusted emission concentration

2.1.2 Em - Measured emission concentration

2.1.3 N - Number of engines in SAGPOOL data set

2.1.4 pf or individual probe factor (pfi) - For one rake orientation and one probe configuration (# of tips)

2.1.5 $\overline{pf}$ - Engine pf - the average of the 24 pf's for one engine and one constituent

2.1.6 $\overline{\overline{pf}}$ - Constituent average pf - the average pf across engines for one constituent

2.1.7 PF - GLOBAL PROBE FACTOR (PF3) - $\overline{\overline{pf}}$ minus the scatter in $\overline{pf}$ and SAGPOOL

2.1.8 pfr - Real engine pf - actual probe results divided by traverse area weighted average

2.1.9 PF3 - PF for average of 3 rake or probe positions

2.1.10 R - Emission regulation limit

2.1.11 Ra - Adjusted emission regulation limit

2.1.12 Rs - Rake sample emission concentration

2.1.13 Sa - pfi standard deviation across angles at each tip option

2.1.14 SAGPOOL - Grand pooled SAPOOL across engines

2.1.15 SAPOOL - Pooled Sa across tip options for one engine

2.1.16 Si - Arbitrary individual standard deviation

2.1.17 $S\overline{pf}$ - Standard deviation of $\overline{pf}$ across engines for one constituent

2.1.18 Ta - Area weighted traverse average concentration

2.1.19 t - Student t at α confidence and υ degrees of freedom 95% two sided confidence

2.1.20 υ or (d.f.) - Degrees of freedom, one less than the number of points used to calculate a standard deviation

2.1.21 υ_1 or υ_2 - Example υ in Welch-Satterthwaite formula for combining degrees of freedom

3. EXTENT OF INPUT DATA:

The engines for which detailed traverses existed and which are included in the analysis are shown in Table 4; the data sets that were utilized are summarized in Table 5.

4. METHOD OF ANALYSIS:

4.1 Definition of Probe Factors (pf):

The emission pf for a particular engine and emission specie is defined as follows:

$$PF = Rs/Ta \qquad \text{(Eq.1)}$$

where:

PF = PF3
Rs = Rake sample emission concentration
Ta = Area weighted traverse average concentration

Were a PF3 approached to be adopted, engine emission regulation could then be based on the rake measurements and a derived PF3 for each constituent. The PF3 could be utilized in either of two ways:

Firstly, the pf could be used to adjust the measured emission concentrations. The adjusted emission concentration, Ea, would be determined as follows:

$$Ea = Em/PF \qquad \text{(Eq.2)}$$

where:

Ea = Adjusted emission concentration
Em = Emmission concentration as measured but with ICAO required corrections applied

Regulation decisions would then be based on Ea, not Em.

Secondly, the PF3 could be used to alter the regulation limits as follows:

$$Ra = R * PF \qquad \text{(Eq.3)}$$

where:

R = Present emission regulation limited adjusted according to the Table in Appendix 6 of ICAO regulations
Ra = Adjusted emission regulation limit

4.1 (Continued):

The adjusted limit would be as hard to pass with Em (as-measured emissions) as would be the unadjusted limit with Ea (adjusted emissions). Use of the adjusted limit has the advantage of leaving intact the measurement results and, hence, long-term emission totals.

In either of the applications, traverse sampling would not be required but remain as a sampling option.

4.2 Assumption of Analysis:

In this derivation of PF, the following assumptions were made:

a. Forty point (min) traverse data adequately represents the true emissions for each engine constituent, and power level.

b. PF3 will be acceptable even though derived across only the following data:

(1) All available engines
(2) CO at idle
(3) THC at idle
(4) NOx at high power ($\geq$85%)
(5) SN at high power ($\geq$85%)
(6) CO_2 at idle and high power ($\geq$85%)

c. Separate PF3 may be needed for mixed flow engines.

d. The several manufacturers' emission contour plotting and interpolation programs are equivalent.

e. Overlaying the contour plots with cruciform sampling probe geometries and extracting emission levels by interpolation yields averages equivalent to what would be obtained by using that probe geometry on that engine.

The analyses which verified these assumptions are in Appendix A, attached to this document (pp. 48-61).

4.3 Variables Considered in Analysis:

The effects of the following variables (choices) in determining the magnitude of the PF3 were included in this analysis:

a. Accepting either a 2.5% or 10% risk that when using this alternate procedure in an emission certification test, an engine will have the advantage of having a real pf less than the PF3 herein derived.

4.3 (Continued):

b. Utilizing measurements from the averaging rake in one angular position or measurements obtained by averaging three rake angular positions. The probe angles analyzed were 0, 15, 30, 45, 60, and 75° from TDC clockwise looking upstream.

c. Basing calculations on emission levels or emission index (EI).

d. Including probe center sampling ports or not.

e. Including or excluding small engine data.

f. Including or excluding mixed flow type data.

g. Using probe (rake) designed for equal area sampling or equal interval (sometimes called equal radii).

h. Specifying a particular number of probe tips on each arm of the cruciform rake, or not (choices analyzed were 3, 4, 5, or 10 tips per arm).

4.4 Outline of Analysis:

An outline of the analysis method used is as follows:

a. Manufacturers generate traverse emission data at idle and high power.

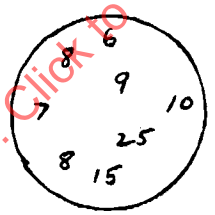


FIGURE 1

b. Each manufacturer's computer generates contours (isopleths).

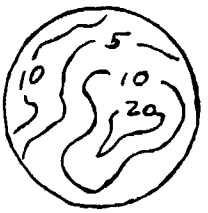


FIGURE 2

c. Each manufacturer's computer plots probe points and interpolates concentrations.

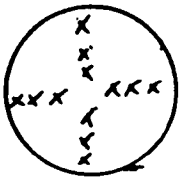


FIGURE 3

4.4 (Continued):

d. Each manufacturer's computer rotates probe and again interpolates concentrations.

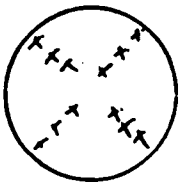


FIGURE 4

e. Each manufacturer's computer produces an array (4 probe tip options by 6 angle options) for all calculated concentration.

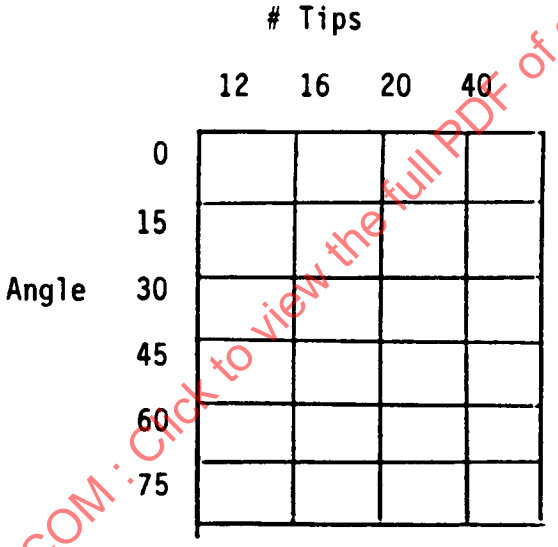


FIGURE 5

f. The 24 value arrays are divided by the area weighted traverse averages producing 24 individual pf.

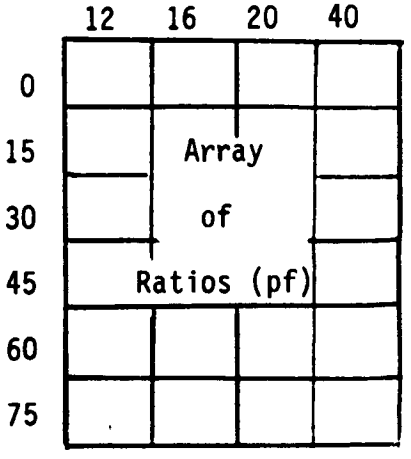


FIGURE 6

4.4 (Continued):

The variation in pf due to probe angle was then calculated:

g. For each constituent and each engine, Sa, the individual pf standard deviation across angles at each probe tip option, is calculated.

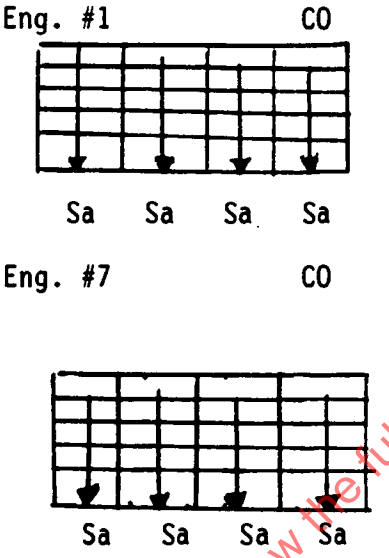


FIGURE 7

h. For each constituent and each engine, the SA's are pooled across probe tip options.

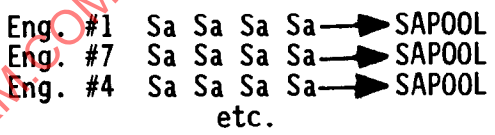


FIGURE 8

i. For each constituent, the SAPOOL's are pooled across engines yielding SAGPOOL.

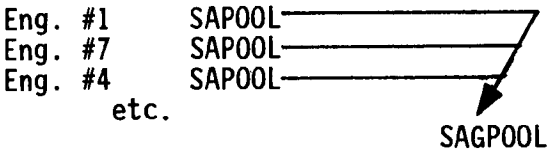


FIGURE 9

4.4 (Continued):

The SAGPOOL for each constituent (CO, NOx, SN and THC) represents the variability in constituent average pf, (defined below), due to angle. Its formula is:

$$SAGPOOL = \frac{\left[\frac{\sum_{1}^{N} (SAPOOL)^2}{N}\right]^{1/2}}{\sqrt{6}} \qquad \text{(Eq.4)}$$

where:

SAPOOL = Pooled Sa's for each constituent across angles
N = Number of engines included in pooling

SAGPOOL is used later in 4.4(l) and 4.4(m).

The final PF3, PF, was then calculated:

j. For each constituent, each engine's $\overline{pf}$ is calculated. Its formula was as follows:

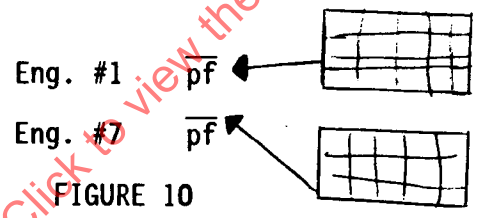


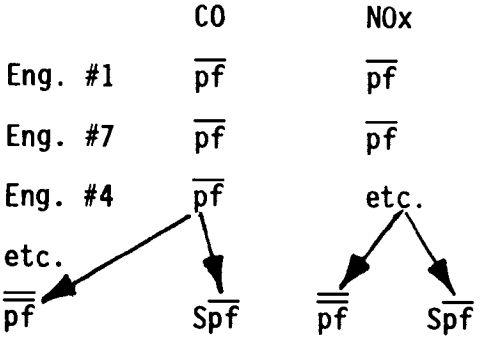
FIGURE 10

$$\overline{pf} = \frac{\sum_{1}^{N} pfi}{N} \qquad \text{(Eq.5)}$$

where:

pfi = each of 24 individual pf's from 4.4(h)
N = 24 (6 angle x 4 tip options)

k. For each constituent, the average $\overline{pf}$, $\overline{\overline{pf}}$, across engines, and its standard deviation, $S\overline{pf}$, are calculated.



4.4 (Continued):

l. For each constituent the PF3, PF, is then computed as:

$$PF = \overline{\overline{pf}} - (t_{\alpha,\upsilon} \times (SAGPOOL^2 + S\overline{pf}^2)^{1/2}) \quad \text{(Eq.6)}$$

where:

$\overline{\overline{pf}}$, $S\overline{pf}$ and SAGPOOL = defined above

$t_{\alpha,\upsilon}$ = Student t at either 95 or 80% confidence (α) and for degrees of freedom (υ)

m. The degrees of freedom, υ, are obtained by the Welch-Satterthwaite formula:

$$\upsilon = (\Sigma\ Si^2)^2/(\Sigma\ (si^4/\upsilon i)) \quad \text{(Eq.7)}$$

Here this is:

$$\upsilon = \frac{((SAGPOOL)^2 + (Spf)^2)^2}{\frac{(SAGPOOL)^4}{\upsilon 1} + \frac{(Spf)^4}{\upsilon 2}} \quad \text{(Eq.8)}$$

n. The PF3 obtained from average data for three probe angles or circumferential locations are calculated as follows:

$$PF3 = \overline{\overline{pf}} - (t_{\alpha,\upsilon} * (\frac{SAGPOOL^2}{3} + S\overline{pf}^2)^{1/2}) \quad \text{(Eq.9)}$$

Note the angle variance is divided by the number of angles over which the data is averaged.

o. The degrees of freedom for PF3 are calculated as shown in 4.4(m) by substituting $SAGPOOL/\sqrt{3}$ for SAGPOOL.

p. PF, PF3, and υ are calculated for all combinations of variables included in the analysis as listed in 4.3.

The results calculated for all variable combinations in 4.3, permit the comparison of PF's for various options. Values which are appropriate for use in a given application may then be selected.

NOTE: A numerical example of the above calculations is provided for a NOx data set in Appendix B attached to this document.

5. RESULTS OF ANALYSIS:

5.1 Detailed Results:

Results of this analysis are shown in detail in Tables 7 through 18 as follows:

TABLE 1 - Results Tables' Descriptions

Table Number	Included Results	Risk	Emission Units	Number of Probe Angles	Page Number
7	$S\overline{pf}$, PF	2.5%	Index	1	30
8	$S\overline{pf}$, PF	2.5%	Level	1	31
9	$S\overline{pf}$, PF	10%	Index	1	32
10	$S\overline{pf}$, PF	10%	Level	1	33
11	SAGPOOL	--	Index	-	34
12	SAGPOOL	--	Level	-	35
13	$S\overline{pf}$, $\overline{\overline{pf}}$	--	Index		36
14	$S\overline{pf}$, $\overline{\overline{pf}}$	--	Level	-	37
15	$S\overline{pf}$, PF3	2.5%	Index	3	38
16	$S\overline{pf}$, PF3	2.5%	Level	3	39
17	$S\overline{pf}$, PF3	10%	Index	3	40
18	$S\overline{pf}$, PF3	10%	Level	3	41

5.1 (Continued):

Data sets with 3° or less of freedom were deemed to contain insufficient data to draw significant conclusions about PF. Those results are, however, left in the data tables for reference. The symbol, PF3, is used for pf determined from data obtained by averaging emissions from three probe positions.

Verification of several examples of computer results was done by hand. The comparisons of hand calculations and computer results are shown in Table 19. The agreement is excellent, thus, verifying the computer program.

5.2 Summary Results:

The summary results are shown in Table 20 with specific selections from the analysis options available. Table 20 shows the effect of the reversal of each option choice, one at a time, and the recommended PF3 for all chosen options. Table 21 is a summary of the percent change associated with each option reversal.

5.3 Recommended PF3:

The final PF3 recommended are as follows:

TABLE 2

Constituent	Probe Factor
CO	0.959
NOx	0.963
SN	0.854
THC	0.898

The above PF3 result when the following options are chosen:

a. 2.5% risk
b. Three probe angles averaged
c. EI used
d. Without a probe center port
e. Including small engines
f. Including mixed flow models
g. Using equal area probe ports
h. (see below)

The choices available in the analysis for the number of sampling tips (3, 4, 5, or 10 per arm on the cruciform rake) were also evaluated and little, if any, effect noted. Figure 11 is typical of the kind of data scatter observed when individual pfs, are plotted as a function of probe angle and number of tips. Note some angle dependency for this engine (not all engines had clear angle dependency) but note also no clear differences can be discerned by changing the number of probe tips.

6. DISCUSSION:

Note in Table 21 that the effect of option choice reversal often is not significant. The rationale for the option choices cited in the results is as follows:

TABLE 3

Option Choices	Rationale
1. 2.5% or 10% Risk	The committee with FAA participation felt that a 10% risk of passing an engine that should fail would result in too big an impact on the environment. Thus, 2.5% risk is recommended.

TABLE 3 (Continued)

Option Choices	Rationale
2. Use rake at one angle or average 3 angles' results	The angle dependency in some engines was thought to be significant. To preclude choosing a "low emissions" angle for a certification test, the requirement to average three angles was advanced. Averaging three angles also results in pfs closer to 1, thus, requiring less correction to data or limits.
3. Use emissions index or concentration level data	The use of emissions index data will have the effect of slight corrections for some sampling problems such as small leaks. The index is also recommended as it is the basis of the DP/F00 calculation.
4. Including probe center sampling ports or not	By not recommending center ports, the construction of the sampling probe is simplified. In addition, in some engines tested, there is a center body and a center sampling port is not possible.
5. Including small engines	These small engines were left in to broaden the impact of the pfs. It was felt that the wider the diversity of engines over which the pfs were obtained, the more applicable they would be and the easier they would be accepted by the technical community.
6. Including mixed flow type engines	These were included for the reasons cited in "5" above. In addition, the inclusion of mixed flow engines almost doubles the data base used and broadens the impact of the pfs to include the most numerous commercial engines. Including it also permits the application of pfs to new mixed flow engines.

TABLE 3 (Continued)

Option Choices	Rationale
7. Equal area or equal interval probe tip locations	Probe tip locations at centroids of equal area were chosen as that is a common sampling practice for providing automatic area weighting. Equal interval sampling, sometimes incorrectly called equal radii sampling, is not a standard practice.
8. Choice of number of probe tips per cruciform arm (3, 4, 5, or 10 tips)	No significant differences were observed due to the number of sampling tips (or ports) on each arm as illustrated in Figure 11.

7. CONCLUSIONS:

This document has made an analysis of pfs over a range of engine types, which includes seven large engines and two small engines. The pf is the ratio of sampling probe measurement to detailed traverse mass-weighted average, and this investigation has focused on the dominant constituent/power mode conditions only. It has included a comprehensive evaluation of the effect of variables or assumptions such as number and position of probe tips, inclusion or not of center points, species concentrations versus emissions index, etc. Of the total of engine types in the study only one was of the "mixed flow" variety.

Using all the engine type data available, making the choice of statistical risk at 2.5%, and optimizing the various remaining option choices, the PF3 for CO, NOx, Smoke, HC are 0.959, 0.963, 0.854, and 0.898, respectively. (This implies that, if these pf's were used to factor sampling probe measurements from a population of engines within the range of generic types here studied, there would be virtual certainty that the true emissions average would be at or less than these factored values for 97.5% of engines tested.) If the data from the mixed flow engine is not included, these pf's are increased by up to 4% or more. The strong influence of number of probe angles averaged is also indicated, and can be almost 10%. The choice of using EI rather than concentration level gives a PF advantage of up to 10%. (A further practical advantage for EI is the reduced sensitivity to small sampling system leaks.) Another fairly strong influence is the choice between using probe tips spaced at "centers of equal area" and "equal interval". Here, for example, the choice of equal area gives an advantage of up to 5% or greater.

The study here reported is reasonably comprehensive with respect to most current nonmixed-flow and mixed-flow civil engines. However, additional analysis of the mixed flow type and other varieties may be needed in the future. Furthermore, it is realized that a definition of PF in terms of the full landing/takeoff emissions cycle is to be preferred to the use of the single dominant engine power mode for each constituent. The simpler approach was chosen at the outset on the grounds of the significant reduction of data analysis and complexity, and the consequent increase in expectation that both data and analysis would be forthcoming.

8. RECOMMENDATION:

As noted in Section 7, the pf scheme is a viable and technologically-sound procedure. It is applicable to the range of current engine types included. The existence of other alternative strategies, such as rotating rake and core sampling approaches raises the desirability of a cohesive program of work in this area. It is recommended that SAE should give its support to such a program, and also that SAE should initiate and/or support any relevant recommendation to ICAO for the inclusion of research on the problems of representative sampling in any future work program of the Committee on Aircraft Environmental Protection (CAEP).

TABLE 4 - Engine Data Analyzed

Large Engines	
Nonmixed	Mixed Flow
JT9D	JT8D-9
RB211	JT8D-217
CFM56-3	JT8D-11
M45H	JT8D-9A
CF6-50	JT8D-17R
JT3D	JT8D-209

Small Engines	
Nonmixed	Mixed Flow
ALF502	--
TFE731-3	

TABLE 5 - Title Definitions

Title	Definition
"In Computer"	X = This data set is in P&W computer file. Blank = This data set is on record at P&W in paper format only.
"Used"	X = These data sets are used in the analysis.
"With Cp"	X = These data sets have probe center port values. Blank = These data sets have no probe center ports.
"Data Set"	Arbitrary P&W data set number.
"Engine Number"	Arbitrary number assigned to manufacturer's engine.
"Date"	Engine test date.
"PLA"	Estimate of engine power; examples are "Idle", "12640" (thrust pounds), and "85" (high power).
"# of Points"	Number of traverse points.
"Const"	Emission constituent.
"Avg Wt Trav."	Traverse area-weighted average.
"Comments"	Self-explanatory.

TABLE 6

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG WT TRAV.	COMMENTS
X	X		1	1	92272	IDLE	81	CO	451.3367	
X	X		2	1	92272	IDLE	81	CO	451.3367	
X	X		3	1	92272	IDLE	81	CO2	1.7740	
X	X		4	1	92272	IDLE	81	CO2	1.7740	
X	X		5	1	92272	IDLE	81	THC	196.9803	
X	X		6	1	92272	IDLE	81	THC	196.9803	
X	X		9	1	92572	36793	81	CO2	3.8719	
X	X		10	1	92572	36793	81	CO2	3.8719	
X	X		11	1	92572	36793	81	NOX	358.7161	
X	X		12	1	92572	36793	81	NOX	358.7161	
X			13	2	61380	IDLE	44	CO	136.2077	
X			14	2	61380	IDLE	44	CO	136.2077	
X			15	2	61380	IDLE	44	CO2	.8909	
X			16	2	61380	IDLE	44	CO2	.8909	
X			17	2	61380	IDLE	44	THC	91.2435	
X			18	2	61380	IDLE	44	THC	91.2435	
X			21	2	61880	12640	44	CO2	7.5725	
X			22	2	61880	12640	44	CO2	7.5725	
X			23	2	61880	12640	44	NOX	3.6335	
X			24	2	61880	12640	44	NOX	3.6335	
X	X		25	3	112383	IDLE	40	CO	25.0098	
X	X		26	3	112383	IDLE	40	CO	25.0098	
X	X		27	3	112383	IDLE	40	CO2	.4305	
X	X		28	3	112383	IDLE	40	CO2	.4305	
X	X		29	3	112383	IDLE	40	THC	11.5496	
X	X		30	3	112383	IDLE	40	THC	11.5496	
X	X		31	3	112983	85	40	SN	9.7095	
X	X		32	3	112983	85	40	SN	9.7095	
X	X		33	3	112983	85	40	CO2	1.1548	
X	X		34	3	112983	85	40	CO2	1.1548	
X	X		35	3	112983	85	40	NOX	71.5812	
X	X		36	3	112983	85	40	NOX	71.5812	
			37	4		IDLE	28	CO		
			38	4		IDLE	28	CO		
			39	4		IDLE	28	CO2		
			40	4		IDLE	28	CO2		
			41	4		IDLE	28	THC		
			42	4		IDLE	28	THC		
			43	4		IDLE	28	SN		REANALYZED
			44	4		IDLE	28	SN		LATER
			45	4		85	28	SN		
			46	4		85	28	SN		
			47	4		85	28	CO2		
			48	4		85	28	CO2		

TABLE 6 (Continued)

IN COMPUTER	USED	HIGH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG HT TRAV.	COMMENTS
			49	5		85	28	NOX		
			50	5		85	28	NOX		
			51	5		7	28	CO2		
			52	5		7	28	CO2		
			53	5		7	28	CO		
			54	5		7	28	CO		REANALYZED
			55	5		7	28	THC		LATER
			56	5		7	28	THC		
			57	5		7	28	NOX		
			58	5		7	28	NOX		
			59	5		7	28	CO2		
			60	5		7	28	CO2		
			61	4	80284	7	28	CO		START RR ERROR
			62	4	80284	7	28	CO		
			63	4	80284	7	28	THC		
			64	4	80284	7	28	THC		
X			75	4	80284	79	44	NOX		
X			76	4	80284	79	44	NOX		
X			77	4	80284	IDLE	44	CO2	1.89	
X			78	4	80284	IDLE	44	CO2	1.89	
X			79	4	80284	IDLE	44	CO	671.1	REANALYSIS OF
X			80	4	80284	IDLE	44	CO	671.1	DATASET 37-48
X			81	4	80284	IDLE	44	THC	762.3	
X			82	4	80284	IDLE	44	THC	762.3	
X			83	4	80284	IDLE	44	NOX	16.5	
X			84	4	80284	IDLE	44	NOX	16.5	
X			85	4	80284	IDLE	48	CO2		
X			86	4	80284	IDLE	48	CO2		
X			87	4	80284	79	48	CO		WAS RUN WITH ERROR
X			88	4	80284	79	48	CO		
X			89	4	80284	79	48	THC		
X			90	4	80284	79	48	THC		
X			91	4	80284	79	48	NOX		
X			92	4	80284	79	48	NOX		
			93	4	80284	7	33	CO2		
			94	4	80284	7	33	CO2		
			95	4	80284	7	33	CO		
			96	4	80284	7	33	CO		
			97	4	80284	7	33	THC		
			98	4	80284	7	33	THC		
			99	4	80284	7	33	NOX		
			100	4	80284	7	33	NOX		
			101	4	80284	7	33	CO2		
			102	4	80284	7	33	CO2		
			103	4	80284	7	33	CO		
			104	4	80284	7	33	CO		
			105	4	80284	7	33	THC		
			106	4	80284	7	33	THC		
			107	4	80284	7	33	NOX		
			108	4	80284	7	33	NOX		

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG MT TRAV.	COMMENTS
			109	4	80284	7	33	CO2		
			110	4	80284	7	33	CO2		
			111	4	80284	7	33	CO		
			112	4	80284	7	33	CO		
			113	4	80284	7	33	THC		
			114	4	80284	7	33	THC		
			115	4	80284	7	33	NOX		
			116	4	80284	7	33	NOX		
			117	4	80284	7	33	CO2		
			118	4	80284	7	33	CO2		
			119	4	80284	7	33	CO		
			120	4	80284	7	33	CO		
			121	4	80284	7	33	THC		
			122	4	80284	7	33	THC		
			123	4	80284	7	33	NOX		
			124	4	80284	7	33	NOX		
X			125	4	80284	85	44	CO2	3.69	
X			126	4	80284	85	44	CO2	3.69	
X			127	4	80284	85	44	NOX	375.3	
X			128	4	80284	85	44	NOX	375.3	
X			129	4	80284	85	44	SN	11.9	
X			130	4	80284	85	44	SN	11.9	
X			131	4	80284	85	44	CO2		
X			132	4	80284	85	44	CO2		
X			133	4	80284	85	44	NOX		
X			134	4	80284	85	44	NOX		
X			135	4	80284	85	44	SN		
X			136	4	80284	85	44	SN		
X			137	4	80284	IDLE	44	CO2	3.69	
X			138	4	80284	IDLE	44	CO2	3.69	
X			139	4	80284	85	44	NOX	375.3	
X			140	4	80284	85	44	NOX	375.3	
X			141	4	80284	IDLE	44	SN	11.9	
X			142	4	80284	IDLE	44	SN	11.9	
X			143	4	80284	85	44	CO2		
X			144	4	80284	85	44	CO2		
X			145	4	80284	85	44	NOX		
X			146	4	80284	85	44	NOX		
X			147	4	80284	85	44	SN		
X			148	4	80284	85	44	SN		
			150	4	80284	85	32	CO2		
			151	4	80284	85	32	CO2		
			152	4	80284	85	32	NOX		
			153	4	80284	85	32	NOX		
			154	4	80284	85	32	SN		
			155	4	80284	85	32	SN		
			156	4	80284	85	32	CO2		
			157	4	80284	85	32	CO2		
			158	4	80284	85	32	NOX		
			159	4	80284	85	32	NOX		
			160	4	80284	85	32	SN		
			161	4	80284	85	32	SN		

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG MT TRAV.	COMMENTS
			162	4	80284	85	32	CO2		
			163	4	80284	85	32	CO2		
			164	4	80284	85	32	NOX		
			165	4	80284	85	32	NOX		
			166	4	80284	85	32	SN		
			167	4	80284	85	32	SN		
			168	4	80284	85	32	CO2		
			169	4	80284	85	32	CO2		
			170	4	80284	85	32	NOX		
			171	4	80284	85	32	NOX		
			172	4	80284	85	32	SN		
			173	4	80284	85	32	SN		END RR ERROR
X			174	6		IDLE	57	SN	30	
X			175	6		IDLE	57	SN	30	
X	X	X	176	6		85	57	SN	30	
X	X	X	177	6		85	57	SN	30	
			178	6		IDLE	57	SN		
			179	6		IDLE	57	SN		
			180	6		85	57	SN		
			181	6		85	57	SN		
			182	6		IDLE	57	SN		
			183	6		IDLE	57	SN		
			184	6		85	57	SN		
			185	6		85	57	SN		
X	X		186	7	81580	IDLE	40	CO	298.2	
X	X		187	7	81580	IDLE	40	CO	298.2	
X	X		188	7	81580	IDLE	40	THC	18.3	
X	X		189	7	81580	IDLE	40	THC	18.3	
X	X		190	7	81580	IDLE	40	CO2	1.96	
X	X		191	7	81580	IDLE	40	CO2	1.96	
X	X		192	7	81880	85	40	NOX	166.6	
X	X		193	7	81880	85	40	NOX	166.6	
X	X		194	7	81880	85	40	SN	22.3	
X	X		195	7	81880	85	40	SN	22.3	
X	X		196	7	81880	85	40	CO2	3.82	
X	X		197	7	81880	85	40	CO2	3.82	
X	X		200	5		IDLE	40	CO	220.0	
X	X		201	5		IDLE	40	CO	220.0	
X	X		202	5		100	40	CO2	4.60	
X	X		203	5		100	40	CO2	4.60	
X	X		204	5		IDLE	40	CO2	2.7	RE-ANAYLSIS
X	X		205	5		IDLE	40	CO2	2.7	OF DATASETS
X	X		206	5		IDLE	40	THC	20	49-60
X	X		207	5		IDLE	40	THC	20	
X	X		208	5		100	40	NOX	98	
X	X		209	5		100	40	NOX	98	

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG WT TRAV.	COMMENTS
X	X	X	210	5		IDLE	40	CO2	2.7	
X	X	X	211	5		IDLE	40	CO2	2.7	
X	X	X	212	5		100	40	CO2	4.6	
X	X	X	213	5		100	40	CO2	4.6	
X	X	X	214	5		IDLE	40	CO	220	
X	X	X	215	5		IDLE	40	CO	220	
X	X	X	216	5		IDLE	40	THC	20	
X	X	X	217	5		IDLE	40	THC	20	
X	X	X	218	5		100	40	NOX	98	
X	X	X	219	5		100	40	NOX	98	
X	X	X	220	8		7	24	CO2	1.650	
X	X	X	221	8		7	24	CO2	1.650	
X	X	X	222	8		7	24	CO	399	
X	X	X	223	8		7	24	CO	399	
X	X	X	224	8		7	24	THC	214	
X	X	X	225	8		7	24	THC	214	
X		X	226	8		7	24	NOX		CORRECTION OF RR ERROR
X		X	227	8		7	24	NOX		
X	X	X	228	8		85	24	CO2	3.632	
X	X	X	229	8		85	24	CO2	3.632	
X	X	X	230	8		85	24	NOX	128	
X	X	X	231	8		85	24	NOX	128	
X	X	X	232	8		85	24	SN	9.1	
X	X	X	233	8		85	24	SN	9.1	
X	X	X	234	4		7	24	CO2	1.858	
X	X	X	235	4		7	24	CO2	1.858	
X	X	X	236	4		7	24	CO	614	
X	X	X	237	4		7	24	CO	614	
X	X	X	238	4		7	24	THC	757	CORRECTION OF RR ERROR
X	X	X	239	4		7	24	THC	757	
X		X	240	4		7	24	NOX		
X		X	241	4		7	24	NOX		
X	X	X	242	4		85	24	CO2	3.581	
X	X	X	243	4		85	24	CO2	3.581	
X	X	X	244	4		85	24	NOX	372.3	
X	X	X	245	4		85	24	NOX	372.3	
X	X	X	246	4		85	24	SN	11.7	
X	X	X	247	4		85	24	SN	11.7	
X	X	X	249	9	111176	600	50	CO	77.1767	
X	X	X	250	9	111176	600	50	CO	77.1767	
X	X	X	251	9	111176	600	50	CO2	.3533	
X	X	X	252	9	111176	600	50	CO2	.3533	
X	X	X	253	9	111176	600	50	THC	62.1590	
X	X	X	254	9	111176	600	50	THC	62.1590	
X		X	255	9	111176	600	50	NOX	2.5045	
X		X	256	9	111176	600	50	NOX	2.5045	

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG WT TRAV.	COMMENTS
X		X	257	2	111576	12850	50	CO	12.5369	
X		X	258	2	111576	12850	50	CO	12.5369	
X	X	X	259	2	111576	12850	50	CO2	1.7448	
X	X	X	260	2	111576	12850	50	CO2	1.7448	
X		X	261	2	111576	12850	50	THC	5.8489	
X		X	262	2	111576	12850	50	THC	5.8489	
X	X	X	263	2	111576	12850	50	NOX	65.2860	
X	X	X	264	2	111576	12850	50	NOX	65.2860	
X	X	X	265	10	111576	IOLE	177	THC	128.5199	
X	X	X	266	10	111576	IOLE	177	THC	128.5199	
X	X	X	267	10	111576	IOLE	177	CO	248.1871	
X	X	X	268	10	111576	IOLE	177	CO	248.1871	
X	X	X	269	10	111576	IOLE	177	CO2	.7249	
X	X	X	270	10	111576	IOLE	177	CO2	.7249	
X		X	271	10	111576	IOLE	177	NOX	5.8660	
X		X	272	10	111576	IOLE	177	NOX	5.8660	
X		X	273	10	111576	MAX	177	THC	1.2073	
X		X	274	10	111576	MAX	177	THC	1.2073	
X		X	275	10	111576	MAX	177	CO	18.0100	
X		X	276	10	111576	MAX	177	CO	18.0100	
X	X	X	277	10	111576	MAX	177	CO2	1.3357	
X	X	X	278	10	111576	MAX	177	CO2	1.3357	
X	X	X	279	10	111576	MAX	177	NOX	45.4215	
X	X	X	280	10	111576	MAX	177	NOX	45.4215	
X		X	281	10	111576	IOLE	177	NOX	119.0570	
X		X	282	10	111576	IOLE	177	NOX	119.0570	
X		X	283	10	111576	IOLE	177	CO	242.3800	
X		X	284	10	111576	IOLE	177	CO	242.3800	
X		X	285	10	111576	IOLE	177	CO2	.7212	
X		X	286	10	111576	IOLE	177	CO2	.7212	
X		X	287	10	111576	IOLE	177	NOX	5.7016	
X		X	288	10	111576	IOLE	177	NOX	5.7016	
X	X	X	289	11	81580	IOLE	120	CO	776.8752	
X	X	X	290	11	81580	IOLE	120	CO	776.8752	
X	X	X	291	11	81580	IOLE	120	CO2	2.2827	
X	X	X	292	11	81580	IOLE	120	CO2	2.2827	
X		X	295	11	81580	IOLE	120	NOX	15.2589	
X		X	296	11	81580	IOLE	120	NOX	15.2589	
X	X	X	297	11	81580	IOLE	120	THC	910.8357	
X	X	X	298	11	81580	IOLE	120	THC	910.8357	
X		X	299	11	81880	40000	120	CO	23.5340	
X		X	300	11	81880	40000	120	CO	23.5340	P&W PLOT ANALYSIS
X	X	X	301	11	81880	40000	120	CO2	4.3451	
X	X	X	302	11	81880	40000	120	CO2	4.3451	
X		X	303	11	81880	40000	120	THC	.7435	
X		X	304	11	81880	40000	120	THC	.7435	
X	X	X	305	11	81880	40000	120	NOX	277.6284	
X	X	X	306	11	81880	40000	120	NOX	277.6284	

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG WT TRAV.	COMMENTS
X	X	X	307	24		IOLE	153	CO	711.0361	
X	X	X	308	24		IOLE	153	CO	711.0361	
X	X	X	309	24		IOLE	153	CO2	1.1732	
X	X	X	310	24		IOLE	153	CO2	1.1732	
X	X	X	311	24		IOLE	153	THC	9.9340	
X	X	X	312	24		IOLE	153	THC	9.9340	
X		X	313	12	110376	13400	49	SN	14.9873	
X		X	314	12	110376	13400	49	SN	14.9873	
X	X	X	315	12	111576	12750	50	SN	23.0068	
X	X	X	316	12	111576	12750	50	SN	23.0068	
X		X	317	13	111375	12800	48	CO2	1.6075	
X		X	318	13	111375	12800	48	CO2	1.6075	
X	X	X	319	13	111375	12800	48	SN	27.8946	
X	X	X	320	13	111375	12800	48	SN	27.8946	
X	X	X	321	14	31577	14600	50	SN	28.0267	
X	X	X	322	14	31577	14600	50	SN	28.0267	
X	X	X	323	14	31577	14600	50	CO2	1.7715	
X	X	X	324	14	31577	14600	50	CO2	1.7715	
X	X	X	325	15	71580	18000	80	SN	9.1253	
X	X	X	326	15	71580	18000	80	SN	9.1253	
X		X	327	15	71580	18000	80	CO2	1.2171	
X		X	328	15	71580	18000	80	CO2	1.2171	
			330	3	121683		80	NOX	6.1853	
			331	3	121683		80	NOX	6.1853	
			332	3	112983	18000	40	O2	19.0855	
			333	3	112983	18000	40	O2	19.0855	
			334	3	112983		40	CO	5.7536	
			335	3	112983		40	CO	5.7536	
			336	3	112983		40	THC	2.5277	
			337	3	112983		40	THC	2.5277	
			338	3	112383		40	O2	20.2005	
			339	3	112383		40	O2	20.2005	
			340	3	112383		40	NOX	5.2551	
			341	3	112383		40	NOX	5.2551	
			342	3	112983	18028	40	SN	9.5756	
			343	3	112983	18028	40	SN	9.5756	
			344	8	80284	7	24	CO2		
			345	8	80284	7	24	CO2		
			346	8	80284	7	24	CO		
			347	8	80284	7	24	CO		
			348	8	80284	7	24	THC		
			349	8	80284	7	24	THC		
			350	8	80284	7	24	NOX		
			351	8	80284	7	24	NOX		
			352	8		85	24	CO2		
			353	8		85	24	CO2		

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG MT TRAV.	COMMENTS
			354	8		85	24	NOX		
			355	8		85	24	NOX		
			356	8		85	24	SN		
			357	8		85	24	SN		
			358	4		7	24	CO2		
			359	4		7	24	CO2		
			360	4		7	24	CO		
			361	4		7	24	CO		
			362	4		7	24	THC		
			363	4		7	24	THC		
			364	4		7	24	NOX		
			365	4		7	24	NOX		
			366	4		85	24	CO2		
			367	4		85	24	CO2		
			368	4		85	24	NOX		
			369	4		85	24	NOX		
			370A	4		85	24	SN		
			370B	4		85	24	SN		
			371	1	92272	85	81	NOX	26.0428	
			372	1	92272	85	81	NOX	26.0428	
			373	1	92572	36793	81	CO	10.7590	
			374	1	92572	36793	81	CO	10.7590	
			375	1	92572	36793	81	THC	1.3598	
			376	1	92572	36793	81	THC	1.3598	
			377	2	61380		44	NOX	6.8574	
			378	2	61380		44	NOX	6.8574	
			379	2	61880	12640	44	CO	18.2296	
			380	2	61880	12640	44	CO	18.2296	
			381	2	61880	12640	44	THC	1.5389	
			382	2	61880	12640	44	THC	1.5389	
			383	3	110983		80	O2	20.2602	
			384	3	110983		80	O2	20.2602	
			385	3	110983		80	CO	43.1808	
			386	3	110983		80	CO	43.1808	
			387	3	110983		80	CO2	.4675	
			388	3	110983		80	CO2	.4675	
			389	3	110983		80	THC	30.0852	
			390	3	110983		80	THC	30.0852	
			391	3	110983		80	NOX	5.9815	
			392	3	110983		80	NOX	5.9815	
			393	3	110983		80	O2	20.0427	
			394	3	110983		80	O2	20.0427	
			395	3	121683		80	CO	42.0671	
			396	3	121683		80	CO	42.0671	
			397	3	121683		80	CO2	.5829	
			398	3	121683		80	CO2	.5829	
			399	3	121683		80	THC	15.9004	

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG HT TRAV.	COMMENTS
			400	3	121683		80	THC	15.9004	
			401	16	31780	960	52	CO	33.2964	
			402	16	31780	960	52	CO	33.2964	
			403	16	31780	960	52	CO2	.9823	
			404	16	31780	960	52	CO2	.9823	
			405	16	31780	960	52	THC	7.0428	
			406	16	31780	960	52	THC	7.0428	
			407	16	31780	960	52	NOX	8.9710	
			408	16	31780	960	52	NOX	8.9710	
			409	17	61380	580	45	NOX	6.9628	
			410	17	61380	580	45	NOX	6.9628	
			411	17	61380	580	45	CO2	.9414	
			412	17	61380	580	45	CO2	.9414	
			413	17	61380	580	45	CO	152.0537	
			414	17	61380	580	45	CO	152.0537	
			415	17	61380	580	45	THC	99.2331	
			416	17	61380	580	45	THC	99.2331	
			417	18	61880	12640	45	NOX	90.4704	
			418	18	61880	12640	45	NOX	90.4704	
			419	18	61880	12640	45	CO	7.8504	
			420	18	61880	12640	45	CO	7.8504	
			421	18	61880	12640	45	THC	3.6284	
			422	18	61880	12640	45	THC	3.6284	
			423	18	61880	12640	45	CO2	1.7526	
			424	18	61880	12640	45	CO2	1.7526	
			425	18	110176	800	52	CO	97.6327	
			426	18	110176	800	52	CO	97.6327	
			427	18	110176	800	52	CO2	.8356	
			428	18	110176	800	52	CO2	.8356	
			429	18	110176	800	52	THC	30.5829	
			430	18	110176	800	52	THC	30.5829	
			431	18	110176	800	52	NOX	5.7630	
			432	18	110176	800	52	NOX	5.7630	
			433	18	110376	13400	52	CO	8.0281	
			434	18	110376	13400	52	CO	8.0281	
			435	18	110376	13400	52	CO2	1.8175	
			436	18	110376	13400	52	CO2	1.8175	
			437	18	110376	13400	52	THC	3.1992	
			438	18	110376	13400	52	THC	3.1992	
			439	18	110376	13400	52	NOX	75.4026	
			440	18	110376	13400	52	NOX	75.4026	
			441	2	61980		52	CO2	1.3397	
			442	2	61980		52	CO2	1.3397	
			443	2	62080	12100	52	SN	6.3323	
			444	2	62080	12100	52	SN	6.3323	
			445	2	62080	12100	52	CO2	1.5309	
			446	2	62080	12100	52	CO2	1.5309	

TABLE 6 (Continued)

IN COMPUTER	USED	WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG WT TRAV.	COMMENTS
			447	19	30375	12800	45	CO2	1.4506	
			448	19	30375	12800	45	CO2	1.4506	
			449	19	30375	12800	45	SN	26.0239	
			450	19	30375	12800	45	SN	26.0239	
			451	20	31075	12800	45	CO2	1.4886	
			452	20	31075	12800	45	CO2	1.4886	
			453	20	31075	12800	45	SN	21.4514	
			454	20	31075	12800	45	SN	21.4514	
			455	20	40875	12800	45	CO2	1.5596	
			456	20	40875	12800	45	CO2	1.5596	
			457	20	40875	12800	45	SN	32.0060	
			458	20	40875	12800	45	SN	32.0060	
			459	20	61375	12800	45	CO2	1.6441	
			460	20	61375	12800	45	CO2	1.6441	
			461	20	61375	12800	45	SN	27.6732	
			462	20	61375	12800	45	SN	27.6732	
			463	20	61675	12800	45	CO2	1.6578	
			464	20	61675	12800	45	CO2	1.6578	
			465	20	61675	12800	45	SN	21.4589	
			466	20	61675	12800	45	SN	21.4589	
			467	21	62475	12800	45	CO2	1.7306	
			468	21	62475	12800	45	CO2	1.7306	
			469	21	62475	12800	45	SN	20.4071	
			470	21	62475	12800	45	SN	20.4071	
			471	21	62675	12800	45	CO2	1.4970	
			472	21	62675	12800	45	CO2	1.4970	
			473	21	62675	12800	45	SN	19.8134	
			474	21	62675	12800	45	SN	19.8134	
			475	21	63075	12800	45	CO2	1.4381	
			476	21	63075	12800	45	CO2	1.4381	
			477	21	63075	12800	45	SN 2	1.8018	
			478	21	63075	12800	45	SN 2	1.8018	
			479	21	70275	12800	45	CO 1	.6166	
			480	21	70275	12800	45	CO 1	.6166	
			481	21	70275	12800	45	SN 1	8.6404	
			482	21	70275	12800	45	SN 1	8.6404	
			483	21	111375	12800	45	CO2	1.6053	
			484	21	111375	12800	45	CO2	1.6053	
			485	21	111375	12800	45	SN	27.9920	
			486	21	111375	12800	45	SN	27.9920	
			487	25	22076	12800	45	CO2	1.6877	
			488	25	22076	12800	45	CO2	1.6877	
			489	25	22076	12800	45	SN	26.184	
			490	25	22076	12800	45	SN	26.184	
			491	22	32876	12800	45	SN	26.2390	
			492	22	32876	12800	45	SN	26.2390	

TABLE 6 (Continued)

IN COMPUTER	USED WITH CP	DATA SET	ENGINE NUMBER	DATE	PLA	PTS	# OF CONST	AVG WT TRAV.	COMMENTS
		493	14	22177	14600	43	SN	31.7982	
		494	14	22177	14600	43	SN	31.7982	
		495	14	22177	14600	43	CO2	1.7673	
		496	14	22177	14600	43	CO2	1.7673	
		497	14	22377	13750	44	SN	30.5123	
		498	14	22377	13750	44	SN	30.5123	
		499	14	22377	13750	44	CO2	1.9406	
		500	14	22377	13750	44	CO2	1.9406	
		501	14	41977	13575	43	SN	25.0594	
		502	14	41977	13575	43	SN	25.0594	
		503	14	41977	13575	43	CO2	1.9369	
		504	14	41977	13575	43	CO2	1.9369	
		505	14	42677	14750	45	SN	28.8175	
		506	14	42677	14750	45	SN	28.8175	
		507	14	42677	14750	45	CO2	2.0784	
		508	14	42677	14750	45	CO2	2.0784	
		509	14	42777	13600	45	SN	26.2896	
		510	14	42777	13600	45	SN	26.2896	
		511	14	42777	13600	45	CO2	2.0924	
		512	14	42777	13600	45	CO2	2.0924	
		513	23	31380	15000	43	SN	14.9238	
		514	23	31380	15000	43	SN	14.9238	
		515	23	31380	15000	43	CO2	1.8188	
		516	23	31380	15000	43	CO2	1.8188	
		517	15	40380	14000	43	SN	5.4562	
		518	15	40380	14000	43	SN	5.4562	
		519	15	40380	14000	43	CO2	.7878	
		520	15	40380	14000	43	CO2	.7878	
		521	15	40380	14000	43	SN	3.5054	
		522	15	40380	14000	43	SN	3.5054	
		523	15	40380	12000	43	CO2	.7395	
		524	15	40380	12000	43	CO2	.7395	
		525	15	40980	12000	43	SN 4	.7689	
		526	15	40980	12000	43	SN 4	.7689	
		527	15	40980	12000	43	CO2	.7448	
		528	15	40980	12000	43	CO2	.7448	

TABLE 7

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR INDEX 195 (2.5% RISK) TABLE III

SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$												PF							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.016	.026	6	.005	.012	5	.056	.072	5	.026	.042	6	.930/86	.916/14	.929/123	.95/80	.769/56	.795/20	*.865/111	.835/26
ALL	W/O SMALL ENGS	.017	.027	5	.005	.013	4	.026	.074	4	.028	.039	5	.925/71	.908/12	.922/102	.94/64	.763/102	.76/17	.856/91	.830/27
MIXED FLOW		.010	.029	1	.007	.000	1	.015	.063	2	.010	.020	1	.917/40	.809/2	.897/41	.929/40	.705/61	.789/20	.902/41	.819/21
W/O	WITH SMALL ENGS	.018	.022	4	.004	.013	3	.057	.084	2	.026	.036	4	.936/28	.930/11	.952/83	.962/26	.839/8	.601 /3	.854/79	.858/24
MIXED FLOW	W/O SMALL ENGS	.020	.024	3	.005	.014	2	.002	.065	1	.027	.035	3	.927/20	.917/8	.945/62	.958/19	.898/40	.062/1	.840/64	.847/21
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.008	.030	9	.004	.009	8	.040	.068	7	.019	.055	9	.931/209	.917/25	.935/184	.95/159	.769/146	.81/35	.824/209	.823/40
ALL	W/O SMALL ENGS	.008	.031	8	.004	.009	7	.015	.071	6	.020	.056	8	.928/188	.911/22	.931/164	*.95/141	.759/144	.80/31	.816/188	.813/37
MIXED FLOW		.009	.027	2	.007	.002	2	.006	.065	3	.025	.045	2	.904/62	.877/12	.909/62	.940/60	.686/80	.805/33	.762/62	.761/20
W/O	WITH SMALL ENGS	.007	.027	6	.001	.010	5	.047	.065	3	.009	.048	6	.948/142	.935/13	.954/120	.96/66	.877/15	.794/5	.867/144	.857/28
MIXED FLOW	W/O SMALL ENGS	.008	.029	5	.001	.011	4	.007	.052	2	.009	.052	5	.945/121	.926/11	.949/100	.96/56	.915/62	.783/3	.859/123	.843/22

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

* CALCULATIONS VERIFIED BY HAND

TABLE 8

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR LEVEL 195 (2.5% RISK) TABLE IV SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$										PF							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.042	.120	6	.043	.086	5	.056	.072	5	.034	.106	6	.816/61	.746/10	.792/72	.800/16	.769/56	.795/20	.823/90	.754/10
ALL	W/O SMALL ENGS	.045	.129	5	.046	.092	4	.026	.074	4	.034	.116	5	.800/52	.716/7	.770/59	.785/13	.763/102	.76/16	.811/81	.721/7
MIXED FLOW		.033	.073	1	.014	.085	1	.015	.063	2	.017	.078	1	.686/37	.911/9 *	.649/40	.793/9	.705/61	.789/19	.784/39	.706/2
H / O	WITH SMALL ENGS	.027	.055	4	.006	.008	3	.057	.084	2	.027	.065	4	.907/25	.834/6	.943/83	.939/78	.839/8	.601 /3	.849/82	.789/10
MIXED FLOW	W/O SMALL ENGS	.031	.063	3	.004	.010	2	.002	.065	1	.029	.072	3	.892/16	.797/4	.936/61	.931/54	.898/40	.062/1	.835/62	.750/6
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.023	.119	9	.024	.093	8	.040	.068	7	.020	.099	9	.766/208	.754/20	.821/182	.79/20	.769/146	.81/35	.829/207	.789/18
ALL	W/O SMALL ENGS	.024	.124	8	.025	.096	7	.015	.071	6	.021	.105	8	.753/187	.745/18	.809/162	.78/18	.759/144	.80/30	.821/186	.779/16
MIXED FLOW		.019	.144	2	.021	.124	2	.006	.065	3	.007	.122	2	.574/60	.711/8	.690/61	.721/7	.686/80	.805/32	.767/60	.717/4
H / O	WITH SMALL ENGS	.018	.046	6	.006	.022	5	.047	.065	3	.018	.057	6	.926/87	.886/10	.942/124	.92/30	.877/14	.794/4	* .862/144	.835/21
MIXED FLOW	W/O SMALL ENGS	.020	.050	5	.006	.023	4	.007	.052	2	.019	.063	5	.921/70	.873/8	* .937/103	.91/28	.915/61	.783/3	.855/122	.819/16

EQ = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

* CALCULATIONS VERIFIED BY HAND

TABLE 9

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR INDEX t_{80} (10% RISK) TABLE V — SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$									PF							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.016	.026	6	.005	.012	5	.056	.072	5	.026	.042	6	.954/86	.941/14	.955/123	.96/80	.847/56	.873/20	*.912/111	.881/26
ALL	W/O SMALL ENGS	.017	.027	5	.005	.013	4	.026	.074	4	.028	.039	5	.950/71	.936/12	.951/102	.96/64	.835/102	.85/17	.906/91	.874/27
MIXED FLOW		.010	.029	1	.007	.000	1	.015	.063	2	.010	.020	1	.948/40	.896/2	.935/41	.953/40	.792/61	.879/20	.944/41	.856/21
H/O	WITH SMALL ENGS	.018	.022	4	.004	.013	3	.057	.084	2	.026	.036	4	.957/28	.954/11	.970/83	.979/26	.915/8	.816 /3	.902/79	.902/24
MIXED FLOW	W/O SMALL ENGS	.020	.024	3	.005	.014	2	.002	.065	1	.027	.035	3	.951/20	.947/8	.966/62	.978/19	.932/40	.730/1	.891/64	.892/21
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.008	.030	9	.004	.009	8	.040	.068	7	.019	.055	9	.956/208	.945/24	.958/184	.97/158	.852/146	.88/35	.889/208	.880/40
ALL	W/O SMALL ENGS	.008	.031	8	.004	.009	7	.015	.071	6	.020	.056	8	.954/187	.941/21	*.956/163	.97/140	.841/143	.87/30	.884/187	.872/36
MIXED FLOW		.009	.027	2	.007	.002	2	.006	.065	3	.025	.045	2	.940/61	.914/11	.942/61	.961/60	.790/80	.893/32	.855/61	.826/20
H/O	WITH SMALL ENGS	.007	.027	6	.001	.010	5	.047	.065	3	.009	.048	6	.967/141	.962/13	.970/120	.97/65	.934/14	.884/4	.914/144	.910/27
MIXED FLOW	W/O SMALL ENGS	.008	.029	5	.001	.011	4	.007	.052	2	.009	.052	5	.964/120	.957/10	.967/100	.97/55	.947/61	.874/3	.908/123	.900/22

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

* CALCULATIONS VERIFIED BY HAND.

TABLE 10

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR LEVEL t80 (10% RISK) TABLE VI — SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$									PF							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	OF	EA	EI	DF	EA	EI	DF	EA	EI	OF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.042	.120	6	.043	.086	5	.056	.072	5	.034	.106	6	.873/61	.864/10	.857/72	.891/16	.847/56	.873/20	.877/90	.859/10
ALL	W/O SMALL ENGS	.045	.129	5	.046	.092	4	.026	.074	6	.034	.116	5	.861/52	.854/7	.842/59	.886/13	.835/102	.85/16	.868/81	.844/7
MIXED FLOW		.033	.073	1	.014	.085	1	.015	.063	2	.017	.078	1	.771/37	1.03/9	.746/40	.929/9	.792/61	.879/19	.839/39	.955/2
W/O	WITH SMALL ENGS	.027	.055	4	.006	.008	3	.057	.084	2	.027	.065	4	.939/25	.900/6	.965/83	.959/78	.915/8	.816 /3	.900/82	.861/10
MIXED FLOW	W/O SMALL ENGS	.031	.063	3	.004	.010	2	.002	.065	1	.029	.072	3	.931/16	.881/4	.961/61	.954/54	.932/40	.730/1	.889/62	.838/6
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.023	.119	9	.024	.093	8	.040	.068	7	.020	.099	9	.847/208	.865/20	.881/182	.88/20	.852/146	.88/35	.888/207	.882/18
ALL	W/O SMALL ENGS	.024	.124	8	.025	.096	7	.015	.071	6	.021	.105	8	.838/188	.863/18	.874/162	.88/18	.841/144	.87/31	.883/187	.877/17
MIXED FLOW		.019	.144	2	.021	.124	2	.006	.065	3	.007	.122	2	.715/60	.900/8	.787/61	.884/7	.790/80	.893/32	.842/60	.905/4
W/O	WITH SMALL ENGS	.018	.046	6	.006	.022	5	.047	.065	3	.018	.057	6	.954/87	.931/10	.965/124	.94/30	.934/14	.884/4	* .913/144	.895/21
MIXED FLOW	W/O SMALL ENGS	.020	.050	5	.006	.023	4	.007	.052	2	.019	.063	5	.951/70	.925/8	* .962/103	.94/28	.947/61	.874/3	.908/122	.886/16

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

* CALCULATIONS VERIFIED BY HAND.

TABLE 11

SAGPOOL TABLE VII

INDEX

SMD 3/17/86

			CO			NOX			SN			THC		
			EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF
WITH CENTERPOINT	ALL	WITH SMALL ENGINES	.031	.019	140	.037	.025	120	.096	.073	120	.062	.045	140
		WITHOUT SMALL ENGINES	.033	.020	120	.041	.027	100	.100	.078	100	.065	.046	120
	MIXED FLOW		.043	.022	40	.054	.034	40	.123	.099	60	.059	.044	40
	H/O	WITH SMALL ENGINES	.024	.018	100	.025	.019	80	.057	.030	60	.063	.045	100
	MIXED FLOW	WITHOUT SMALL ENGINES	.026	.019	80	.029	.022	60	.049	.025	40	.068	.047	80
H/O CENTERPOINT	ALL	WITH SMALL ENGINES	.034	.024	200	.033	.022	180	.111	.079	160	.091	.059	200
		WITHOUT SMALL ENGINES	.036	.026	180	.035	.024	160	.115	.083	140	.095	.062	180
	MIXED FLOW		.050	.034	60	.046	.029	60	.147	.107	80	.131	.072	60
	H/O	WITH SMALL ENGINES	.025	.019	140	.024	.018	120	.053	.031	80	.067	.053	140
	MIXED FLOW	WITHOUT SMALL ENGINES	.027	.020	120	.026	.020	100	.045	.027	60	.070	.056	120

TABLE 12

SAGPDOL TABLE VIII — SMD 3/17/86

LEVEL

			CO			NOX			SN			THC		
			EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF
WITH CENTERPOINT	ALL	WITH SMALL ENGINES	.069	.062	140	.083	.078	120	.096	.073	120	.069	.054	140
		WITHOUT SMALL ENGINES	.074	.066	120	.091	.086	100	.100	.078	100	.072	.056	120
	MIXED FLOW		.117	.109	40	.137	.130	40	.123	.099	60	.076	.067	40
	H/O	WITH SMALL ENGINES	.035	.024	100	.031	.027	80	.057	.030	60	.066	.048	100
	MIXED FLOW	WITHOUT SMALL ENGINES	.038	.026	80	.035	.031	60	.049	.025	40	.071	.050	80
H/O CENTERPOINT	ALL	WITH SMALL ENGINES	.113	.085	200	.083	.072	180	.111	.079	160	.082	.067	200
		WITHOUT H/O A&G	.119	.089	180	.088	.076	160	.115	.083	140	.085	.070	180
	MIXED FLOW		.200	.150	60	.136	.118	60	.147	.107	80	.105	.090	60
	H/O	WITH SMALL ENGINES	.036	.025	140	.032	.028	120	.053	.031	80	.070	.055	140
	MIXED FLOW	WITHOUT SMALL	.038	.027	120	.035	.031	100	.045	.027	60	.073	.058	120

TABLE 13

CONSTITUENT AVERAGE PROBE FACTORS ($\bar{\bar{pf}}$) FOR INDEX TABLE IX

SM0 05/27/86

WITH CENTERPOINT

		$S_{\bar{pf}}$									$\bar{\bar{pf}}$								
		CO			NOX			SN			THC			CO			NOX			SN			THC		
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF
ALL	WITH SMALL ENGS	.016	.026	6	.005	.012	5	.056	.072	5	.026	.042	6	.999	.985	6	1.00	1.01	5	.990	1.01	5	1.00	.961	6
ALL	W/O SMALL ENGS	.017	.027	5	.005	.013	4	.026	.074	4	.028	.039	5	.998	.981	5	1.00	1.01	4	.969	.998	4	.998	.953	5
MIXED FLOW		.010	.029	1	.007	.000	1	.015	.063	2	.010	.020	1	1.01	.963	1	1.01	.997	1	.952	1.03	2	1.02	.920	1
H/O	WITH SMALL ENGS	.018	.022	4	.004	.013	3	.057	.084	2	.026	.036	4	.996	.993	4	1.00	1.01	3	1.03	.984	2	.991	.978	4
MIXED FLOW	W/O SMALL ENGS	.020	.024	3	.005	.014	2	.002	.065	1	.027	.035	3	.994	.990	3	1.00	1.01	2	.996	.944	1	.986	.969	3
WITHOUT CENTERPOINT																									
ALL	WITH SMALL ENGS	.008	.030	9	.004	.009	8	.040	.068	7	.019	.055	9	1.00	.996	9	1.00	1.00	8	1.01	1.02	7	1.01	.984	9
ALL	W/O SMALL ENGS	.008	.031	8	.004	.009	7	.015	.071	6	.020	.056	8	1.00	.994	8	1.00	1.00	7	.992	1.02	6	1.01	.980	8
MIXED FLOW		.009	.027	2	.007	.002	2	.006	.065	3	.025	.045	2	1.01	.973	2	1.00	.998	2	.981	1.06	3	1.03	.938	2
H/O	WITH SMALL ENGS	.007	.027	6	.001	.010	5	.047	.065	3	.009	.048	6	1.00	1.01	6	1.00	1.00	5	1.03	.994	3	1.00	1.00	6
MIXED FLOW	W/O SMALL ENGS	.008	.029	5	.001	.011	4	.007	.052	2	.009	.052	5	1.00	1.01	5	1.00	1.01	4	1.01	.970	2	1.00	1.00	5

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

TABLE 14

CONSTITUENT AVERAGE PROBE FACTORS ($\bar{s}_{pf}$) FOR LEVEL TABLE X — SMD 05/27/86

WITH CENTERPOINT

		$\bar{s}_{pf}$ CO EA	CO EI	CO DF	NOX EA	NOX EI	NOX DF	SN EA	SN EI	SN DF	THC EA	THC EI	THC DF	$\bar{m}_{pf}$ CO EA	CO EI	CO DF	NOX EA	NOX EI	NOX DF	SN EA	SN EI	SN DF	THC EA	THC EI	THC DF
ALL	WITH SMALL ENGS	.042	.120	6	.043	.086	5	.056	.072	5	.034	.106	6	.978	1.05	6	.978	1.05	5	.990	1.01	5	.977	1.02	6
ALL	W/O SMALL ENGS	.045	.129	5	.046	.092	4	.026	.074	4	.034	.116	5	.974	1.06	5	.974	1.06	4	.969	.998	4	.972	1.03	5
MIXED FLOW		.033	.073	1	.014	.085	1	.015	.063	2	.017	.078	1	.929	1.21	1	.924	1.14	1	.952	1.03	2	.939	1.15	1
W/O 8D	WITH SMALL ENGS	.027	.055	4	.006	.008	3	.057	.084	2	.027	.065	4	.997	.988	4	1.01	.996	3	1.03	.984	2	.992	.973	4
W/O 8D	W/O SMALL ENGS	.031	.063	3	.004	.010	2	.002	.065	1	.029	.072	3	.997	.985	3	1.01	.997	2	.996	.944	1	.988	.964	3

WITHOUT CENTERPOINT

ALL	WITH SMALL ENGS	.023	.119	9	.024	.093	8	.040	.068	7	.020	.099	9	.997	1.06	9	.993	1.04	8	1.01	1.02	7	.998	1.04	9
ALL	W/O SMALL ENGS	.024	.124	8	.025	.096	7	.015	.071	6	.021	.105	8	.996	1.07	8	.992	1.05	7	.992	1.02	6	.997	1.05	8
MIXED FLOW		.019	.144	2	.021	.124	2	.006	.065	3	.007	.122	2	.975	1.19	2	.965	1.13	2	.981	1.06	3	.978	1.14	2
W/O 8D	WITH SMALL ENGS	.018	.046	6	.006	.022	5	.047	.065	3	.018	.057	6	1.01	1.00	6	1.01	.993	5	1.03	.994	3	1.01	1.00	6
W/O 8D	W/O SMALL ENGS	.020	.050	5	.006	.023	4	.007	.052	2	.019	.063	5	1.01	1.00	5	1.01	.997	4	1.01	.970	2	1.01	.999	5

EQ = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

TABLE 15

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR INDEX 195 (2.5% RISK) AVERAGE OF THREE PROBE ANGLES TABLE XI — SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$									PF3							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.016	.026	6	.005	.012	5	.056	.072	5	.026	.042	6	.951/29	.920/8	.960/125	.96/28	.825/19	.821/9	.911/42	.853/11
ALL	H/O SMALL ENGS	.017	.027	5	.005	.013	4	.026	.074	4	.028	.039	5	.946/24	.913/7	.956/104	.96/22	.843/71	.792/7	.904/34	.849/11
MIXED FLOW		.010	.029	1	.007	.000	1	.015	.063	2	.010	.020	1	.950/27	.567/1	.942/40	.958/40	.807/62	.826/6	.950/36	.840/6
H/O	WITH SMALL ENGS	.018	.022	4	.004	.013	3	.057	.084	2	.026	.036	4	.946/10	.931/6	.973/79	.971/9	.820/4	.616 /2	.901/30	.877/9
MIXED FLOW	H/O SMALL ENGS	.020	.024	3	.005	.014	2	.002	.065	1	.027	.035	3	.936/7	.916/4	.969/58	.966/6	.939/40	.100/1	.888/25	.864/7
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.008	.030	9	.004	.009	8	.040	.068	7	.019	.055	9	.959/176	.925/13	.963/188	.97/69	.854/68	.849/14	.898/186	.848/17
ALL	H/O SMALL ENGS	.008	.031	8	.004	.009	7	.015	.071	6	.020	.056	8	.957/156	.919/12	.960/167	.97/61	.855/146	.83/13	.893/165	.838/16
MIXED FLOW		.009	.027	2	.007	.002	2	.006	.065	3	.025	.045	2	.945/55	.880/5	.947/59	.965/61	.810/81	.856/11	.869/54	.788/7
H/O	WITH SMALL ENGS	.007	.027	6	.001	.010	5	.047	.065	3	.009	.048	6	.968/91	.940/8	.974/121	.97/22	.892/6	.780 /3	.922/145	.879/12
MIXED FLOW	H/O SMALL ENGS	.008	.029	5	.001	.011	4	.007	.052	2	.009	.052	5	.966/75	.928/7	.971/101	.97/18	.952/60	.736/2	.917/125	.863/10

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

CALCULATIONS VERIFIED BY HAND.

TABLE 16

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR LEVEL t_{95} (2.5% RISK) AVERAGE OF THREE PROBE ANGLES TABLE XI SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$									PF3							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.042	.120	6	.043	.086	5	.056	.072	5	.034	.106	6	.856/21	.755/7	.846/24	.822/8	.825/19	.821/9	.872/31	.762/7
ALL	W/O SMALL ENGS	.045	.129	5	.046	.092	4	.026	.074	4	.034	.116	5	.843/17	.713/6	.828/20	.801/7	.843/71	.792/7	.861/28	.716/6
MIXED FLOW		.033	.073	1	.014	.085	1	.015	.063	2	.017	.078	1	.771/19	.793/3	.764/41	.783/3	.807/62	.826/6	.843/27	.039/2
W/O	WITH SMALL ENGS	.027	.055	4	.006	.008	3	.057	.084	2	.027	.065	4	.921/9	.831/5	.968/76	.961/42	.820/4	.616 /2	.899/32	.791/6
MIXED FLOW	W/O SMALL ENGS	.031	.063	3	.004	.010	2	.002	.065	1	.029	.072	3	.903/7	.780/3	.965/62	.954/26	.939/40	.100/1	.885/24	.749/4
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.023	.119	9	.024	.093	8	.040	.068	7	.020	.099	9	.858/190	.778/12	.886/117	.81/11	.854/68	.849/14	.895/161	.806/12
ALL	W/O SMALL ENGS	.024	.124	8	.025	.096	7	.015	.071	6	.021	.105	8	.850/170	.771/11	.879/104	.81/10	.855/146	.83/13	.890/143	.796/11
MIXED FLOW		.019	.144	2	.021	.124	2	.006	.065	3	.007	.122	2	.742/62	.656/4	.803/60	.675/3	.810/81	.856/11	.856/61	.567/3
W/O	WITH SMALL ENGS	.018	.046	6	.006	.022	5	.047	.065	3	.018	.057	6	.950/30	.889/7	.968/118	.93/12	.892/6	.780 /3	.918/107	.855/10
MIXED FLOW	WITH SMALL ENGS	.020	.050	5	.006	.023	4	.007	.052	2	.019	.063	5	.946/24	.876/6	.966/100	.93/10	.952/60	.736/2	.913/86	.836/8

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

* CALCULATIONS VERIFIED BY HAND.

TABLE 17

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR INDEX t80 (10% RISK) AVERAGE OF THREE PROBE ANGLES TABLE XIII SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$									PF3							
		CO			NOX			SN			THC			CO		NOX		SN		THC	
		EA	EI	DF	EA	EI	DF	EA	EI	DF	EA	EI	DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF	EA/DF	EI/DF
ALL	WITH SMALL ENGS	.016	.026	6	.005	.012	5	.056	.072	5	.026	.042	6	.968/29	.945/8	.975/125	.98/28	.886/19	.894/9	.942/42	.894/11
ALL	H/O SMALL ENGS	.017	.027	5	.005	.013	4	.026	.074	4	.028	.039	5	.965/24	.940/7	.973/104	.97/22	.887/71	.875/7	.937/34	.889/11
MIXED FLOW		.010	.029	1	.007	.000	1	.015	.063	2	.010	.020	1	.970/27	.867/1	.964/40	.971/40	.858/62	.912/6	.976/36	.873/6
H/O	WITH SMALL ENGS	.018	.022	4	.004	.013	3	.057	.084	2	.026	.036	4	.966/10	.957/6	.984/79	.986/9	.921/4	.823 /2	.933/30	.916/9
MIXED FLOW	H/O SMALL ENGS	.020	.024	3	.005	.014	2	.002	.065	1	.027	.035	3	.959/7	.949/4	.981/58	.985/6	.959/40	.739/1	.923/25	.906/7
WITHOUT CENTERPOINT																					
ALL	WITH SMALL ENGS	.008	.030	9	.004	.009	8	.040	.068	7	.019	.055	9	.974/176	.952/13	.976/188	.98/69	.907/68	.914/14	.937/186	.898/17
ALL	H/O SMALL ENGS	.008	.031	8	.004	.009	7	.015	.071	6	.020	.056	8	.973/156	.948/12	.975/167	.98/61	.903/146	.90/13	.934/165	.891/16
MIXED FLOW		.009	.027	2	.007	.002	2	.006	.065	3	.025	.045	2	.967/55	.922/5	.967/59	.976/61	.870/81	.932/11	.925/54	.850/7
H/O	WITH SMALL ENGS	.007	.027	6	.001	.010	5	.047	.065	3	.009	.048	6	.980/91	.966/8	.983/121	.98/22	.949/6	.884 /3	.950/145	.926/12
MIXED ENGS	H/O SMALL ENGS	.008	.029	5	.001	.011	4	.007	.052	2	.009	.052	5	.978/75	.960/7	.982/101	.98/18	.971/60	.867/2	.946/125	.916/10

EA = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

TABLE 18

GLOBAL PROBE FACTORS (PF) AND ($S_{\overline{pf}}$) FOR LEVEL t80 (10% RISK) AVERAGE OF THREE PROBE ANGLES TABLE XIV SMD 05/27/86

WITH CENTERPOINT

		$S_{\overline{pf}}$ CO EA	CO EI	CO DF	NOX EA	NOX EI	NOX DF	SN EA	SN EI	SN DF	THC EA	THC EI	THC DF	PF3 CO EA/DF	CO EI/DF	NOX EA/DF	NOX EI/DF	SN EA/DF	SN EI/DF	THC EA/DF	THC EI/DF
ALL	WITH SMALL ENGS	.042	.120	6	.043	.086	5	.056	.072	5	.034	.106	6	.901/21	.874/7	.894/24	.910/8	.886/19	.894/9	.909/31	.867/7
ALL	H/O SMALL ENGS	.045	.129	5	.046	.092	4	.026	.074	4	.034	.116	5	.891/17	.861/6	.881/20	.906/7	.887/71	.875/7	.901/28	.848/6
MIXED FLOW		.033	.073	1	.014	.085	1	.015	.063	2	.017	.078	1	.829/19	1.03/3	.820/41	.959/3	.858/62	.912/6	.878/27	.881/2
H/O	WITH SMALL ENGS	.027	.055	4	.006	.008	3	.057	.084	2	.027	.065	4	.951/9	.901/5	.981/76	.973/42	.921/4	.823 /2	.932/32	.868/6
MIXED FLOW	H/O SMALL ENGS	.031	.063	3	.004	.010	2	.002	.065	1	.029	.072	3	.942/7	.879/3	.980/62	.969/26	.959/40	.739/1	.922/24	.846/4

WITHOUT CENTERPOINT

ALL	WITH SMALL ENGS	.023	.119	9	.024	.093	8	.040	.068	7	.020	.099	9	.907/190	.884/12	.924/117	.89/11	.907/68	.914/14	.931/161	.896/12
ALL	H/O SMALL ENGS	.024	.124	8	.025	.096	7	.015	.071	6	.021	.105	8	.902/170	.883/11	.919/104	.90/10	.903/146	.90/13	.928/143	.892/11
MIXED FLOW		.019	.144	2	.021	.124	2	.006	.065	3	.007	.122	2	.824/62	.915/4	.860/60	.894/3	.870/81	.932/11	.899/61	.888/3
H/O	WITH SMALL ENGS	.018	.046	6	.006	.022	5	.047	.065	3	.018	.057	6	.970/30	.935/7	.982/118	.95/12	.949/6	.884 /3	.949/107	.910/10
8D	H/O SMALL ENGS	.020	.050	5	.006	.023	4	.007	.052	2	.019	.063	5	.968/24	.929/6	.981/100	.95/10	.971/60	.867/2	.946/86	.900/8

EQ = EQUAL AREA SAMPLING
EI = EQUAL INTERVAL SAMPLING

TABLE 19 - Verification of Computed Penalty Factors

Conditions/Risk	PF Computer Calculations 10%	PF Computer Calculations 2.5%	PF Hand Calculations 10%	PF Hand Calculations 2.5%
Mixed flow engines only With centerpoint level - CO EI	1.03	0.911	1.03	0.913
All except mixed flow and small engines without centerpoint level - NOX EA	0.962	0.937	0.962	0.936
All engines except mixed flow without centerpoint level - THC EA	0.913	0.862	0.916	0.868
All engines with centerpoint index - THC EA	0.912	0.865	0.911	0.865
All except small engines without centerpoint index - NOX EI	0.970	0.950	0.965	0.945

TABLE 20 - PF3 Options

Option Oescription	Alternate Option	Chosen Option	Probe Factors if Each Option Choice is Reversed CO	Probe Factors if Each Option Choice is Reversed NOx	Probe Factors if Each Option Choice is Reversed SN	Probe Factors if Each Option Choice is Reversed THC
Confidence (risk)	10%	2.5%	0.974	0.976	0.907	0.937
Probe angles averaged	1	3	0.931	0.935	0.769	0.824
Emission meas. calculations	Level	Index	0.858	0.886	0.854	0.895
Probe center port	With	Without	0.951	0.960	0.825	0.911
Inclusion of small eng's.	Without	With	0.957	0.960	0.855	0.893
Inclusion of mixed flow	Without	With	0.968	0.974	0.892	0.922
Probe port locations	Eq. Int.	Eq. Area	0.925	0.970	0.849	0.848
PF3 for all chosen options			0.959	0.963	0.854	0.898

TABLE 21 - Percent Change With Alternate PF3 Options

Option Description	Alternate Option	Chosen Option	% Change in PF3 if Each Alternate Option is Chosen CD	% Change in PF3 if Each Alternate Option is Chosen NDx	% Change in PF3 if Each Alternate Option is Chosen SN	% Change in PF3 if Each Alternate Option is Chosen THC
Confidence (risk)	10%	2.5%	1.56	1.35	6.21	4.34
Probe angles averaged	1	3	-2.92	-2.91	-9.95	-8.24
Emission meas. calculations	Level	Index	-10.53	-8.00	0.00	-0.33
Probe center port	With/CP	WD/CP	-0.83	-D.31	-3.40	1.45
Inclusion of small eng's.	WD/AG	W/AG	-0.21	-0.31	0.12	-0.56
Inclusion of mixed flow	WD/8D	W/8D	0.94	1.14	4.45	2.67
Probe port locations	Eq. Int.	Eq. Area	-3.55	0.73	-0.59	-5.57

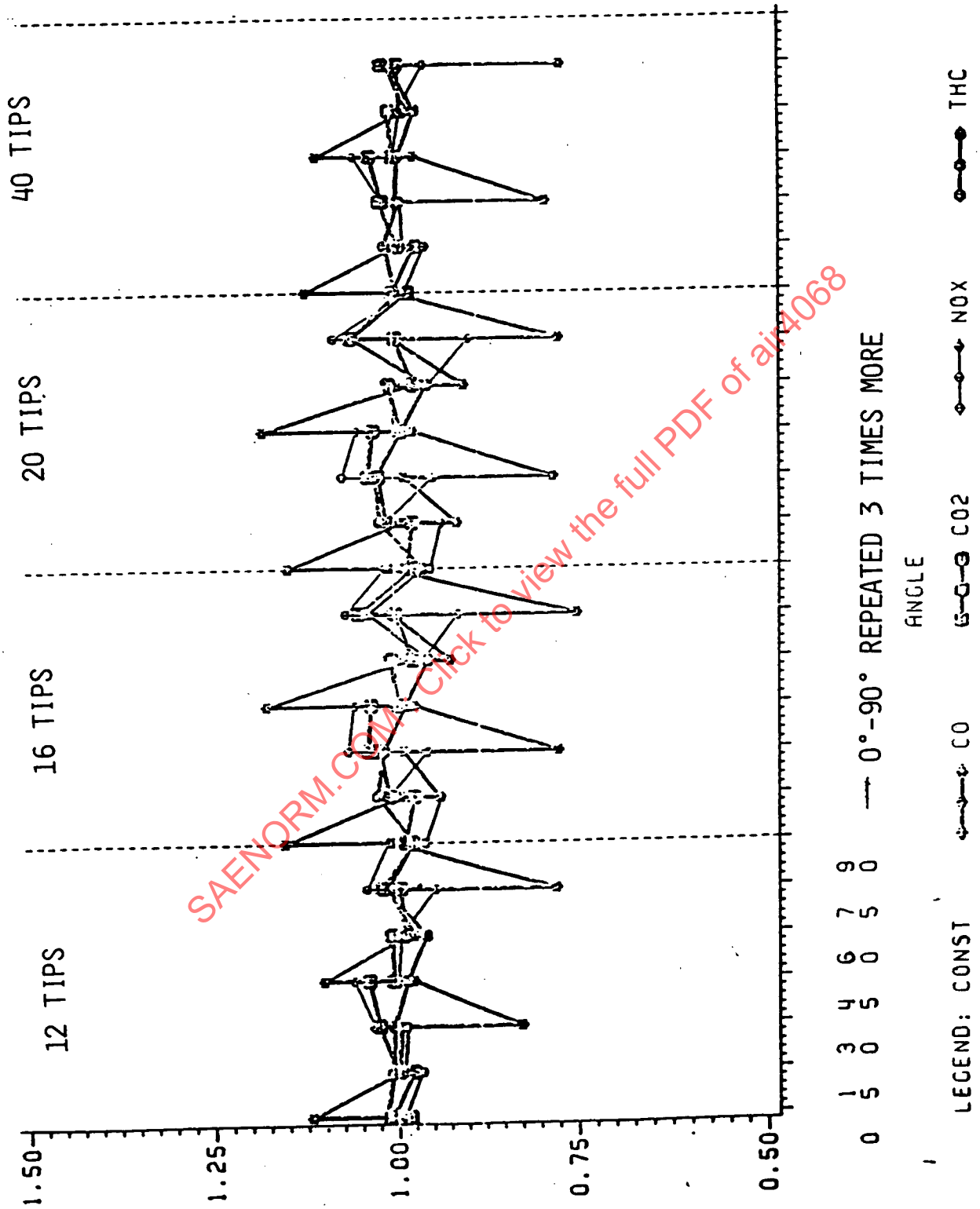


FIGURE 11 - PF Versus # Sampling Tips and Probe Angle

APPENDIX A
VERIFICATION OF ASSUMPTIONS

A.1 GENERAL:

The assumptions of this analysis were initially considered reasonable engineering judgements and not requiring extensive verification analysis. However, the credibility of the results would be enhanced by some detail work intended to verify the assumptions hence, this "Verification of Assumptions" Appendix. The assumptions are repeated here for reference:

a. Forty point (min) traverse data adequately represents the true emissions for each engine constituent and power level.

b. PF will be acceptable if derived across only the following data:

(1) All available engines
(2) CO at idle
(3) THC at idle
(4) NOx at high power ($\gtrsim$85%)
(5) SN at high power ($\gtrsim$85%)
(6) CO_2 at idle and at high power ($\gtrsim$85%)

c. Separate probe factors may be needed for mixed flow engines.

d. The several manufacturers' emission contour plotting and interpolating computer programs are equivalent.

e. Overlaying the contour plots with probe sampling geometries and extracting emission levels by interpolation yields averages equivalent to what would be obtained by using that probe geometry on that engine.

These assumptions are now analyzed in turn.

A.2 VERIFICATION OF ASSUMPTIONS:

a. Verification of Assumption Number 1 - Adequacy of 40 Point Traverses: The attached P&W memo addressed to N. T. Campbell (Appendix B) referred to as "SAE/E-31 Discussion Paper #DP84/S34" details the differences in numerical and area weighted averages of 20, 40, and 80 point traverse data. For the area weighted comparison of 40 and 80 point traverse averages, the emission differences observed are less than 1.6%. With that small a change between the very detailed 80 point traverse and the more economical 40 point traverse, it is concluded that a 40 point (min) traverse is adequate.

In addition, note that DP84/S34 deals with mixed flow data. With agreement that good in the extreme emission gradients of mixed flow engine tailpipes, it is certain that nonmixed flow engines would be adequately sampled with 40 point traverses.

A.2 (Continued):

b. Verification of Assumption Number 2 - Use of Idle and High Power Emissions Data Only: The first implication of this assumption is that analyzing only CO and THC data taken at idle is sufficient for all engine power levels. Since well over 95% of all CO and THC is produced at the idle power in an engine's landing/takeoff (LTO) cycle, little or no error is incurred with this assumption as it relates to CO and THC.

The second implication is that analyzing SN data taken only at one high power level yields pf suitable for all power levels. In the case of smoke, it is usually at its maximum at high power, hence little or no error is incurred with this assumption as it relates to SN.

The third implication of the assumption is that analyzing NOx data taken at only one high power point yields pf adequate for use across all engine power levels. In the case of NOx, this is an important consideration since the NOx contribution is spread out across the whole LTD cycle (unlike CO and THC which only contribute significantly at idle).

In order to verify assumption two as it relates to NOx, a comparison was made of total carbon (TC) pf at the idle and high power level. At idle, TC included CO, THC, and CO_2. At high power, TC was only CO_2. TC pf were chosen because:

(1) The data was readily available.

(2) TC is mostly CO_2 which usually correlates well with rich, high NOx regions of the exhaust.

If the TC pf at idle and high power are in rough agreement, it can be concluded that:

(1) The power levels have equivalent pf for NOx.

(2) The available power levels adequately bracket and represent normal engine operating levels.

(3) Assumption 2 is verified.

Tables A1 and A2 present the TC pf at idle and high power along with the appropriate degrees of freedom. These numbers were obtained with a computer program. The first value of Table A1, 0.786/208, was confirmed by hand calculation to verify the programming.

Table A3, presents the percent difference between the TC pf at idle and high power that were shown in Tables A1 and A2.

TABLE A1 - Total Carbon Probe Factors
t 95 (2.5% RISK)
at Idle (PF/d.f.)

Engines	Equal Area	Equal Interval
All engines	0.786/208	0.728/15
All except small engines	0.775/187	0.721/14
Mixed flow engines only	0.607/60	0.639/5
All engines except mixed flow	0.943/97	0.909/9
All except mixed flow and small engines	0.940/84	0.900/7

TABLE A2 - Total Carbon Probe Factors
t 95 (2.5% RISK)
at High Power (PF/d.f.)

Engines	Equal Area	Equal Interval
All engines	0.802/207	0.784/26
All except small engines	0.791/186	0.782/24
Mixed flow engines only	0.680/82	0.788/18
All engines except mixed flow	0.966/117	0.934/23
All except mixed flow and small engines	0.964/99	0.933/21

TABLE A3 - Percent Δ in TC Probe Factors

$$\Delta\% = \frac{(\text{IDLE TC PF}) - (\text{HI PWR TC PF})}{(\text{HI PWR TC PF})} \times 100$$

Engines	EQ Area	EQ Interval
All engines	-2.00%	-7.14%
All except small engines	-2.02%	-7.80%
Mixed flow engines only	-10.74%	-18.91%
All engines except mixed flow	-2.38%	-2.68%
All except mixed flow and small engines	-2.49%	-3.54%

A.2 (Continued):

Note that for the equal area sampling, including all engines, the difference in TC PF from idle to high power is only 2%. The agreement is not as good for equal interval sampling and gets still worse when only utilizing mixed flow engines. The important point is that for the entire engine mix, all engines, and equal area sampling, the assumption permitting analyzing only two power levels of data is verified. A 2% difference is considered negligible. (There is no significant TC PF difference between 0.802 and 0.786.)

c. Verification/Refutation of Assumption Number 3 - Need for Separate PF's for Mixed Flow Engines: The PF3 presented in Table 20 along with the rationale for the options chosen refute the validity of this assumption. For the reasons stated in Section 6, no separate pf should be computed for mixed flow engines; they should be left within the larger group of data.

d. Verification of Assumption Number 4 - Equivalency of Contour Plotting Programs: To verify this assumption, a simulated profile test case was sent to each manufacturer to analyze as if it were an emission profile. The test case was documented in a letter to E-31 and is attached as Appendix C.

A.2 (Continued):

The test case is an equation. Each manufacturer was to solve the equation for simulated emissions at each of their standard tailpipe traverse locations. Those data were then to be fed to their contour plotting programs, interrogated by interpolation for equal area and equal interval probe designs as was done for emission traverse results, and a probe factor computed as compared to the "true" value their simulated traverse yielded, i.e., the area weighted traverse average.

The simulated emission traverse area weighted averages agrees excellently with the official, analytical average as shown in Table A4:

TABLE A4 - Test Case Traverse Average Comparison

Participant	No. Traverse Points	Traverse Area Wtd. Average	Analytical Average	% Error
RR Eng. "A"	110	85.9	86.3	-0.5%
RR Eng. "B"	121	86.4	86.3	0.1%
PW	40	86.7	86.3	0.5%
PW	80	86.8	86.3	0.6%
PW	120	86.5	86.3	0.2%
GE	40	86.1	86.5[1]	-0.5%
GAR	57	86.3	86.3	0.0%
AVCO	49	85.7	86.3	-0.7%
RAE[2]	121	86.4	86.3	0.1%
RAE[2]	721	86.2	86.3	-0.1%

NOTES:

[1] GE engine has centerbody in exhaust.

[2] The RAE data was left in as additional verification of the efficacy of the plotting programs although RAF emissions data was not in this analysis.

A.2 (Continued):

Note that the low Δ% error levels in Table A4 indicate that each manufacturer's traverse average did a good job of assessing the actual analytical average. In addition, the manufacturers' computed $\overline{pf}$ should have all been very similar if the contour plots were equivalent. They were similar as shown below in Table A5 where the SAPOOL values are shown along with the final PF.

TABLE A5 - Test Case Probe Factors

Manufacturer	Equal Area SAPOOL	Equal Area $\overline{pf}$	Equal Interval SAPOOL	Equal Interval $\overline{pf}$
RR Eng. "A"	0.0094	1.009	0.0043	1.018
RR Eng. "B"	0.0086	1.006	0.0067	1.017
PW (40 pt)	0.0224	1.020	0.0237	1.008
PW (80 pt)	0.0069	1.016	0.0150	1.006
PW (120 pt)	0.0113	1.015	0.0090	1.006
GE	0.0037	1.009	0.0038	1.009
GAR	0.0411	0.999	0.0529	0.982
AVCO	0.0259	1.003	0.0113	1.021
	PF = 0.967	PF = 0.967	PF = 0.958	PF = 0.958

A.2 (Continued):

Note that RAE, formerly NGTE, was not included in the above $\overline{pf}$ or PF calculations as they did not submit emissions data for this report's analysis.

The agreement in $\overline{pf}$ is excellent. The PF calculated in both equal area and equal interval calculations is only 3 to 4% different from the perfect analytical solution of the equation in Appendix C. This is encouraging since the computation of PF includes the effects of manufacturers' differences in:

a. Traverse locations
b. Plotting programs
c. Interpolation algorithms
d. Computational software, etc.

It is concluded that the manufacturers' contour plotting and interpolation programs are equivalent.

A.2 (Continued):

e. Verification of Assumption Number 5 - Equivalency of Overlay Emission Predictions and Actual Data: It is felt that the best way to verify that overlaying contour plots with probe geometries, predicting emissions, and calculating probe factors really works, is to proceed with a comparison of actual engine probe factors with the PF3 where such data are available.

A test of assumption 5, and indeed a good portion of the entire analytical approach, would be to calculate real engine probe factors (pfr) for as much data as is available and observe whether or not more than 2.5% of them are below the PF's recommended in this document. If assumption 5 is reasonable, and the analysis method appropriate, the predicted risk of passing 2.5% of the engines when they should have failed will be borne out in real data.

The real probe factors (pfr) were calculated as follows:

$$pfr = \frac{(\text{Real rake sample})}{(\text{Trav. Area Wt. Avg.})} \qquad \text{(Eq.A1)}$$

The pfr's were calculated for as many engines as possible and are listed in Table A6. Only emission index pfr's were used in this comparison as index was the basis of the recommended PF's in this document.

TABLE A6 - Index Real Engine Probe Factor/Probe Concentration (ppm or SN)

Type	Test Date	Constituent CO	Constituent NOx	Constituent SN	Constituent THC
Mixed Flow "A"	11/9/83	1.237/62.61	--	--	1.154/40.92
"	11/16/83	0.877/35.5	--	--	0.614/13.38
"	11/17/83	1.162/27.2	--	--	0.752/8.6
"	11/18/83	0.991/47/8	--	--	0.833/24.9
"	11/19/83	--	0.954/89.4	1.417/13.4	--
"	11/21/83	1.004/51.2	--	--	0.856/22.88
"	11/21/83	0.978/38.2	--	--	0.675/14.88
"	11/22/83	1.013/28.1	--	--	0.364/5.0
"	11/23/83	1.206/41.7	--	--	1.081/16.98
"	11/23/83	1.159/33.9	--	--	0.874/11.68

TABLE A6 (Continued)

Type	Test Date	Constituent CO	Constituent NOx	Constituent SN	Constituent THC
"	11/28/83	1.115/22.2	--	--	0.543/2.6
"	11/29/83	--	1.146/82.0	1.405/13.7	--
Mixed Flow "B"	3/17/80	0.907/18.1	--	--	1.328/5.6
Mixed Flow "C"	6/13/80	0.875/102.0	--	--	0.885/67.3
"	11/11/76	0.995/148.6	--	--	0.778/93.6
"	11/15/76	--	0.934/50.3	--	--
"	11/3/76	--	0.958/59.7	--	--
"	11/19/83	--	0.992/91.1	--	--
"	11/22/83	--	1.015/89.9	--	--
Nonmixed Flow "A"	9/22/72	1.001/444.4	--	--	1.019/196.4
"	9/28/72	--	0.983/190.0	--	--
Mixed Flow "D"	3/15/77	--	--	1.097/30.8	--
"	2/21/77	--	--	1.066/33.9	--
"	2/23/77	--	--	1.103/33.6	--
"	4/19/77	--	--	1.122/28.1	--
"	4/26/77	--	--	1.205/32.6	--
"	4/27/77	--	--	1.219/32.0	--
"	11/19/83	--	--	1.179/26.7	--
"	9/25/72	--	1.018/369.1	--	--
Nonmixed Flow "B"	8/18/80	--	0.982/275.8	--	--
"	8/15/80	1.021/784.4	--	--	1.031/927.9

[3] [4] [5] [6] [7] [8]

TABLE A6 (Continued)

Type	Test Date	Constituent CO	Constituent NOx	Constituent SN	Constituent THC
Small "A"	1/31/86 Rec'd	--	--	1.13/39.0	--
Small "B"	1/31/86 Rec'd	--	--	1.05/45.7	--
Nonmixed Flow "C"*	--	1.02/(NA)	0.979/(NA)	--	1.00/(NA)
Nonmixed Flow "D" Low +*	--	0.994/(NA)	0.995/(NA)	0.940/(NA)	0.945/(NA)
" HI +*	--	1.04/(NA)	1.07/(NA)	1.04/(NA)	1.08/(NA)

NOTES:

+ = LOW or HI pfr of 6 pfr's tested (for 6 angles)

$$\text{INDEX PROBE FACTOR} = \frac{\text{Probe emission level}}{\text{Trav. emission level}} \times \frac{\text{F/A (trav)}}{\text{F/A (probe)}}$$

NA = Not Available

A.2 (Continued):

NOTES: These noted data were considered in error and were not considered in this analysis for the following reasons:

1. 30+ ppm CO background
2. 15+ ppm THC background
3. Unstable engine test, traverse point location documentation poor
4. - 7. Identified sampling leaks
8. Data below THC cut-off of 15 ppm

Note that in Table A6 the emission levels are also reported for reference. Note too that for the nonmixed flow "C" and "D" data, emission index results were obtained by the approximation formula shown at the bottom of the table. That formula makes use of the approximation that index equals level divided by CO_2. CO_2 may be approximated by a constant times fuel-to-air ratio or that constant divided by air-to-fuel ratio. The constants then cancel out when the real pf is calculated.

Some of the data were edited out of these results for the reasons noted at the bottom of Table A6.